Creation Research Society Quarterly 2025 61:310–323

The Climate and Environment of the Exodus: Clues from the Birds of Leviticus 11:13–19

Martin Johnson

Abstract

Problems concerning the need for food and water by the flocks and herd of the Israelites are discussed, and also the need for fuel for cooking. This paper argues that the identification of the "banned birds" of Leviticus 11:13–19 points to a very different climate and environment than has been the case for the past three millennia in the territory of the "wanderings of the Israelites." This paper builds on research using onomatopoeic (OP) correlations by Johnson and Jenson (2023) which resulted in the species-level identification of seventeen of the "banned birds."

Ornithology, archaeology, and paleoclimatology all point to the Sinai Peninsula and neighbouring regions having a much higher rainfall, which would have created the conditions where grazing and water for livestock would be available, as well as firewood. The range of habitats then available provides a precise match for the requirements of that group of birds.

This has a bearing on the possible routes for the "Red Sea" crossing, as well as the date of writing Leviticus and the other Torah passages dealing with the "wanderings."

The conclusion is drawn that this specific list of birds points to the "wilderness tradition" of the Israelites being set in a landscape that would have been found in the Sinai region prior to a time around 1250 BC. Finally, consideration is given to the "*-min*" attributions found in the "banned birds" list, with its implications for Hebrew bird taxonomy.

Key Words: desertification, Leviticus authorship, Onomatopoeia, Paleoclimates, Sinai

Accepted for publication October 28, 2024

Introduction

Many popular films and representations of the journey of the Israelites after the Exodus from Egypt use illustrations of people traveling through stony and sandy deserts, typical of the region to the east of Egypt in the present times. Yet Exodus 12:28 says: "A mixed multitude went up with them also, and flocks and herds—a great deal of livestock." Weeks later they were told to keep them away from the mountain (Exodus 34:3). This raises the question of what the flocks and herds fed on, as transporting large quantities of animal feed is not mentioned. Then there is the issue of water. Only three times in the whole narrative is it stated that they were short of water—three days in the Wilderness of Shur, at Marah (Exodus 15:22–25) again at Meribah (Exodus 17:1–7), and finally, at Kadesh in the desert of Zin, some 40 years later (Numbers 20:1–11).

It is clear that the Israelites kept their flocks and herds throughout this period, and were one of several groups in the region that may be described as "Bronze Age Pastoralists." The only references to food shortages are for the people, remedied with quails and manna (Exodus 16:13, 15, et seq.), leaving open the question of where the food and water for all those flocks and herds could have come from. Then, Exodus 16:23 says "…So bake what you want to bake and boil what you want to boil…" implying the use of cooking fires, which need fuel. It is hoped the research reported here will help to answer these questions.

It will potentially shed some light on the question of the route of the Exodus and wanderings, as well as helping to fix the date of writing Leviticus to near the middle of the 2nd millennium BC.

A further issue covered is the possible taxonomic implications of the *"-min"* attributions as in "according to their kind" found in Leviticus 11 and Deuteronomy 14.

Leviticus 11:13–19 contains a list of "banned birds" and research into the identification of those birds using onomatopoeic (OP) correlations identified seventeen at species level and one more at family level (Johnson and Jenson, 2023). This paper reports research into their habitats, the geographical and environmental conditions where they might be found. These habitats range from wetlands to deserts and mountains, which indicates different environmental conditions than have prevailed in most of the southern Levant (the region to the south of present-day Israel and Jordan) for the past three millennia.

A review of paleoclimates reveals the climate changing from humid to arid in the southern Levant around 1,250 BC.

Eilat at the head of the Gulf of Aqaba is considered as a microcosm of a warm environment with wetlands containing several of the "banned birds" habitats and where the majority of them have been reported recently.

The changing climate becomes more significant when considering the territory of the wanderings of the Israelites in the post-Exodus narrative, which may include the Sinai and Negev deserts and southern Jordan, nowadays a region of arid deserts fringed with mountains. The "wilderness tradition" comprises approximately two thirds of the Torah, and has been a contentious topic in critical scholarship (Hoffmeier, 2005, pp. 3–22). Recently published opinions include that the "wilderness tradition" is a product of the 7th century BC, based on creative imagination rather than historical memories (Finkelstein and Silberman, 2002), or reflects ancient sources preserved in later writings (Soggin, 1984, pp. 19–20), and the view that the writings are a contemporary product of the 15th century BC (e.g., Petrovich, 2016, pp.186–200).

This research supports the thesis of Soggin (1984, pp. 19–20) to a limited extent. It more fully supports that of Petrovich (2016, pp. 15–35, 65–74) where he argues that texts found in the Sinai (and dating from a pre-Exodus period) evidence Hebrew script, in that the list of "banned birds" evidences conditions of the mid-2nd millennium BC in Sinai and its neighbouring territories, although the climate factors indicated by the birds means this applies to most of the Torah as noted above, rather than small segments. It also supports Hoffmeier (2005, pp. 167, 209) when he argues that references to turquoise and Acacia wood help to locate the narrative in Sinai, as it will be shown that the habitats available in the Sinai during the middle of the 2nd millennium BC similarly represent a precise match for the habitats required by the "banned birds" of Leviticus 11:13–19.

This paper presents the habitats, and diets of those birds, which are then considered against known historic distributions of these birds from the central Sahara during its last major humid period and Ancient Egypt, as well as 21st century Eilat. The conclusion is drawn that this list of "banned birds" points to the "wilderness tradition" of the Israelites being set in a landscape that would have been found in the Sinai region prior to a time around 1,250 BC and before the subsequent desertification of this region.

The 19 Birds Identified

The identifications in Johnson and Jenson (2023) were made after reviewing the translations found in the Septuagint (LXX) of the 3rd century BC and the Vulgate Bible of the late 4th century AD, together with ornithology and archaeology, including the availability of

those birds in Ancient Egypt. Possible onomatopoeic (OP) correlations were tested, and good-to-strong OP correlations were found for 17 of the 19 birds in Leviticus 11:13–19. The other two were bird 1, *nesher*, where two different eagles gave similar weak positive OP correlations, and bird 8, *tachmas*, where no positive OP correlations were obtained at all, despite several attempts.

The majority of these results support the most ancient translations (N.B. These include the flamingo and ibis!). On the basis of availability in the region throughout recorded history, and prominence within the respective genera these identifications are considered plausible. Table I summarizes those findings in generalized terms, and offers suggested translations accordingly.

The Habitats and Diets of the 19 Birds

Species-level identifications of the 19 birds are supplied below, with habitats and diets. Ornithological data is sourced from Porter and Aspinall (2010) and https://animalia.bio/.

Bird 1—*nesher*: Large brown eagles

This identification was based on weak positive OP responses against the golden eagle *Aquila aetos* (64.3%) and the tawny eagle *Aquila rapax* (68.2%). Given the similarity of eagle calls, it is likely that other large brown eagles of the family *Aquila* known in the region may produce stronger correlations. These are the greater spotted eagle *Aquila clanga*, the steppe eagle *Aquila nipalensis* and the eastern imperial eagle *Aquila heliaca,* which is currently the most numerous of these species in the region.

- **Habitats:**
  - Golden and Tawny Eagles—mountains and plains, including arid semi-desert, and wooded terrain. They may nest in trees (also rocky ledges for the golden eagle).
  - Steppe and Eastern Imperial Eagles—similar terrain, though hill country rather than mountains, and also marshes.
  - Greater Spotted Eagle—wetlands.
- **Diets:** mammals, birds, reptiles, insects, and carrion.

Table I. Proposed English translations of the 19 birds in Leviticus 11:13–19.

	Hebrew		Suggested Translation	Correlations
1	נֶשֶׁר	*nesher*	Eagle	Weak OP, LXX, Vulgate
2	פֶּרֶס	*peres*	Vulture	Strong OP, LXX, Vulgate
3	עָזְנִיָּה	*'ozniyah*	Short-toed Snake Eagle	Good OP, If Pliny's *haliaietos*, then LXX, Vulgate
4	דָּאָה	*da'ah*	Kite	Good OP, LXX, Vulgate
5	אַיָּה	*'ayah*	Falcon	Strong OP
6	עֹרֵב	*'orev*	Raven	Strong OP, LXX, Vulgate
7	בַּת יַעֲנָה	*bath ya'anah*	Desert Owl	Strong OP
8	תַּחְמָס	*tachmas*	Little Owl	*Not* OP, LXX, Vulgate
9	שַׁחַף	*shachaph*	Seagull	Strong OP, LXX, Vulgate
10	נֵץ	*nets*	Hawk	Strong OP, LXX, Vulgate
11	כּוֹס	*kos*	Long-eared Owl	Good OP, LXX
12	שָׁלָךְ	*shalak*	Cormorant	Strong OP, LXX, Vulgate
13	יַנְשׁוּף	*yanshuph*	Eagle Owl	Strong OP (LXX, Vulgate, implied from *charadrios*)
14	תִּנְשֶׁמֶת	*tinshemet*	Flamingo	Good OP, LXX, Vulgate
15	קָאַת	*qa'ath*	Pelican	Strong OP, LXX, Vulgate
16	רָחָם	*racham*	Crane	Strong OP
17	חֲסִידָה	*chasidah*	Ibis	Strong OP, LXX, Vulgate
18	אֲנָפָה	*'anaphah*	Heron	Good OP, LXX, Vulgate
19	דּוּכִיפַת	*dukiphath*	Hoopoe	Strong OP, LXX, Vulgate

Bird 2—*peres*: Griffon Vulture

The griffon vulture *Gyps fulvus* gave a strong OP correlation (77.3%). It is currently the most numerous type of vulture in the region.

- **Habitat:** all types of countryside including mountains, it nests in caves and cliff ledges.
- **Diet:** carrion.

Bird 3—*'ozniyah*: Short-Toed Snake Eagle

The short-toed snake eagle *Circaetus gallicus* gave a good OP correlation (72.7%).

- **Habitat:** open wooded plains, but also stony foothills and semi-deserts. It nests in trees or cliffs.
- **Diet:** mainly non-venomous snakes, also other reptiles and amphibians.

Bird 4—*da'ah*: Black Kite

The black kite *Milvus migrans* gave a good OP correlation (71.4%).

- **Habitat:** woodland, often near water. It nests on tree branches, cliff ledges, or buildings.
- **Diet:** fish, small mammals, birds, bats, rodents and carrion.

Bird 5—*'ayah*: Peregrine Falcon

The peregrine falcon *Falco peregrinus* gave a very strong OP correlation (89.3%).

- **Habitat**: includes mountains and forests and also marshes and wasteland.
- **Diet:** medium-sized birds, bats, small mammals, insects, and reptiles.

Bird 6—*'orev*: Fan-Tailed Raven

The fan-tailed raven *Corvus rhipidurus* gave a very strong OP correlation (84%).

- **Habitat:** a wide variety of territory between sea level and 3,000 meters, often close to human habitation. It nests on ledges or holes in rock faces.
- **Diet:** insects and other invertebrates, grain taken from animal dung, carrion, and scraps of human food. It also takes skin parasites from camels.

Bird 7—*bath ya 'anah*: Desert Owl

The desert (tawny) owl *Strix hadorami* gave a very strong OP correlation (81.5%).

- **Habitat:** rocky gorges, desert earth banks, often near palm groves, acacias, sometimes near springs and settlements. It nests in holes in rocks or cliff faces.
- **Diet:** voles, mice, and large insects.

Bird 8—*tachmas*: probably Little Owl

No OP correlation was achieved with *tachmas*, but after harmonising the LXX and Vulgate translations, the little owl *Athene noctua* was considered the most likely candidate.

- **Habitat:** open country with trees, semi-deserts, cultivated areas, often near human habitation. They both nest in holes in trees, rocks, and buildings.
- **Diet:** insects and earthworms, small amphibians, reptiles, birds, and mammals.

Bird 9—*shachaph*: Black-Headed Gull

The black-headed gull *Chroicocephalus ridibundus* gave a strong OP correlation (76%).

- **Habitat:** coastal and inland waters, farmland, and wetlands. It nests on open ground and in low trees and bushes.
- **Diet:** insects, fish, seeds, worms, carrion, and invertebrates.

Bird 10—*nets*: Hobby

The hobby *Falco subbuteo* gave a strong OP correlation (76%).

- **Habitat:** (same for all raptors of this size) scattered woodland, and cultivated areas with trees. They nest in old nests (often those of crows).
- **Diet:** large insects, such as dragonflies, also bats and small birds.

Bird 11—*kos*: Long-Eared Owl

The long-eared owl *Asio otus* gave a good OP correlation (70.4%).

- **Habitat:** deciduous woods and copses, also stands of conifers. It usually nests in trees, often in the old nest of another raptor or a crow.
- **Diet:** Its diet is mainly small rodents, especially voles, but also other small mammals, small birds, small reptiles, and insects.

Bird 12—*shalak*: Great Cormorant

The great cormorant *Phalacrocorax carbo* gave a very strong OP correlation (100%).

- **Habitat:** coastal waters and inland lakes. It nests in colonies in trees.
- **Diet:** mainly fish, but it will also eat crustaceans, amphibians, and insects.

Bird 13—*yanshuph*: Spotted Eagle Owl

The spotted eagle owl *Bubo africanus* gave a very strong OP correlation (88.9%).

- **Habitat:** open woodlands, rocky hills, ravines, sometimes near human habitation.
- **Diet:** small mammals, birds, insects, frogs, and reptiles.

Bird 14—*tinshemet*: Greater Flamingo

The greater flamingo *Phoenicopterus roseus* gave a good OP correlation (70.8%).

- **Habitat:** coastal regions, salt lakes, and mudflats. It breeds colonially on mud banks or shallow water lakes where it builds mud heap nests.
- **Diet:** crustaceans, molluscs, worms, crabs, insects, and sometimes small fish.

Bird 15—*qa'ath*: Great White Pelican

The great white pelican *Pelecanus onocrotalus* gave a very strong OP correlation (87.5%).

- **Habitat:** large inland wetlands and shallow water coastal lagoons. It nests colonially in reeds.
- **Diet:** fish, small invertebrates, also small birds, small reptiles, amphibians, and crustaceans.

Bird 16—*racham*: Common Crane

The common crane *Grus grus* gave a very strong OP correlation (90.9%).

- **Habitat:** wetlands, fields, and steppe.
- **Diet:** mainly plant matter, but also insects, snails, earthworms, crabs, spiders, millipedes, woodlice, amphibians, rodents, and small birds.

Bird 17—*chasidah*: African Sacred Ibis

The African sacred ibis *Threskiornis aethiopicus* gave a strong OP correlation (75%).

- **Habitat:** wetlands, cultivated areas, coastal marshes, parks, and large gardens. It nests colonially in trees.
- **Diet:** mainly insects, worms, crustaceans, molluscs, and other invertebrates, also fish, frogs, reptiles, small mammals, and carrion

Bird 18—*anaphah*: Grey Heron

The grey heron *Ardea cinerea* gave a good OP correlation (70.8%).

- **Habitat:** wetlands, including coastal regions. It nests colonially in trees.
- **Diet:** fish, amphibians, crustaceans, aquatic invertebrates, molluscs, snakes, small birds, and rodents.

Bird 19—*dukiphath*: Eurasian Hoopoe

The Eurasian hoopoe *Upupa epops* gave a very strong OP correlation (83.3%).

- **Habitat:** woodland, olive and palm groves, parks, gardens, oases, open and wooded areas. It nests in holes in trees or ruins.

Table II. Summary of "banned birds" habitats.

Hebrew	Proposed Identification	Mountains	Desert	Wooded Plain	Grassland Cultivated Land	Woodland	Inland Wetland	Coastal Lagoons & Marshes
nesher	Eagle (large)	√	√	√	√	√	√	
peres	Griffon Vulture	√	√	√	√			
'ozniyah	Short-toed Eagle		√	√				
da'ah	Black Kite					√	√	
'ayah	Peregrine Falcon	√		√		√	√	
'orev	Fan-tailed Raven	√	√	√	√	√	√	
bath ya'anah	Desert Owl	√	√					
tachmas	Little Owl		√	√	√			
shachaph	Black-headed Gull						√	√
nets	Eurasian Hobby			√	√			
kos	Long-eared Owl			√	√	√		
shalak	Great Cormorant						√	√
yanshuph	Spotted Eagle Owl	√		√				
tinshemet	Greater Flamingo						√	√
qa'ath	Great White Pelican						√	√
racham	Common Crane				√		√	√
chasidah	African Sacred Ibis				√		√	√
'anaphah	Grey Heron						√	√
dukiphath	Eurasian Hoopoe			√	√	√		

- **Diet:** mainly insects, but also small reptiles and frogs.

Anomalies

Two of these birds (*yanshuph* = spotted eagle owl and *chasidah* = African sacred ibis) are not now found north of the Sahara Desert. The African sacred ibis used to be a very common bird in Egypt, as evidenced by the huge number of mummified examples, including 1.75 million at Saqqara and 4 million at Tuna El-Gebel from the period around 450–250 BC (Montgomerie, 2018). The spotted eagle owl, while not recorded in Ancient Egypt, has been reported in some locations on the Arabian Peninsula.

Summary of Habitats

This list of birds covers a very wide range of habitats, mountains, desert, plains, grasslands, woodlands, and inland and coastal wetlands. Only six of the birds are likely to be found in desert areas, and all but the desert owl will also be found in other habitats. Seven of the birds are normally found only in wetland habitats, while a further four are also often found in inland wetlands (Table II). The requirement therefore is to identify territory where this specific combination of habitats can be found within a travelling distance appropriate for Bronze Age pastoralists, as described in the 'wilderness tradition.'

Territory

This list of birds (and the parallel one in Deuteronomy 14:12–18) is set in the context of the time the Israelites were reported to be wandering following the Exodus. There are four specific references to the Wilderness of Sin (Exodus 16:1, 17:1; Numbers 33:11–12) as a location. This may or may not be the same place as the desert or wilderness of Sinai (a further 13 references in Exodus, Leviticus, and Numbers) which is related to Mount Sinai (17 references in the Torah). While there continues to be debate about the location of the Wilderness of Sin, the route of travel, and the identity of most of the other locations listed in Numbers 33, (Hoffmeier, 2005, pp. 47–73) the general area is contained within the territory shown in Figure 1, which includes the Sinai and Negev deserts, southern Jordan, and northwest Saudi Arabia.

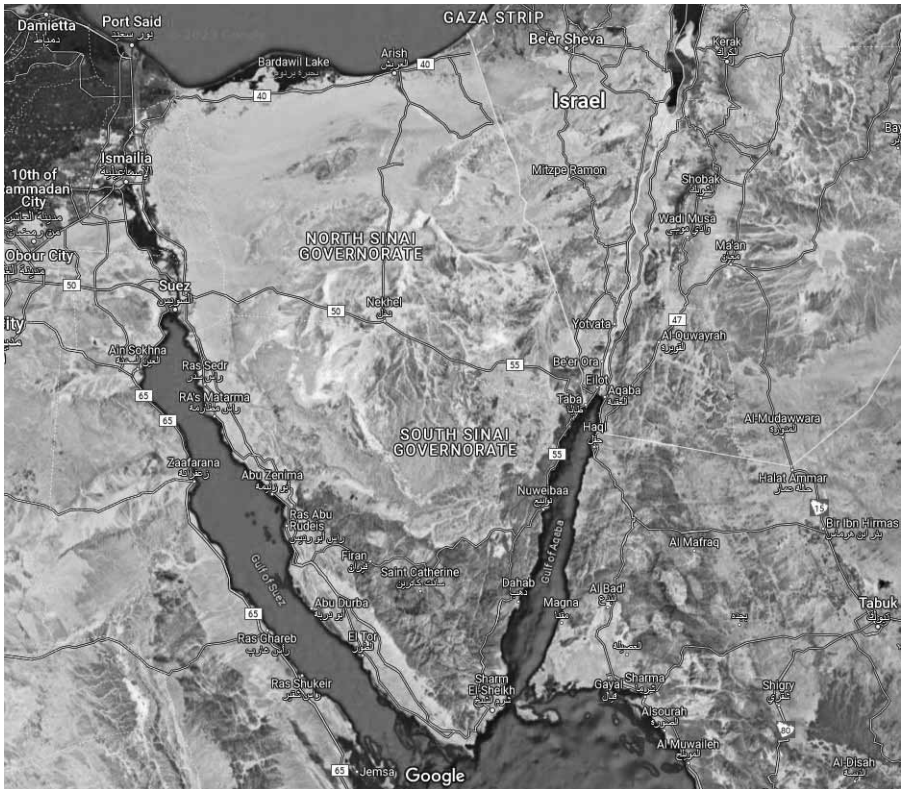

Figure 1. Satellite image showing the general territory of the wanderings of the Israelites described in Exodus and Numbers (courtesy Google Maps).

This area today is mostly arid desert. According to Numbers 33:35–36 the Israelites only reached Ezion Geber (at the head of the Gulf of Aqaba) towards the very end of the 40 years of wanderings, which if accepted at face value suggests that the main area covered before then would be in the Sinai and possibly the Negev deserts. These deserts are an eastward extension of the Sahara, and are presently considered "most extreme deserts" (Nicholson, 2011, p. 332). Rainfall varies from around 200mm per year average in the north coastal area to 3mm or less in the south (Elmenoufy et al., 2017). The majority of these birds (13 of 19) would not be found in arid desert.

However, during the second millennium BC, there was extensive grazing land in the Negev, and oaks and olives grew in the Sinai (Neev and Emery, 1995, p. 64). This correlates with a major humid period in the Sahara, which changed from savannah to arid desert around 3,000–4,000 years ago (Nicholson, 2011, p. 432). In Genesis 13:1 it says: "So Abram went up from Egypt to the Negev, with his wife and everything he had, and Lot went with him to the Negev." This implies there was grazing available in

the Negev at that time. Recent research around Al-Ula in NW Saudi Arabia has also shown that it was a greener land before 1200 BC with abundant evidence of cattle grazing and also monumental building implying a sizeable population (Royal Commission for al-Ula, 2022).

Various types of proxy records have been utilized to attempt reconstructions of paleoclimates, and for those times before written records are available, these include ocean sediment cores, pollen records, lake sediments, beach ridges, sand dunes, and evaporite deposits. The problem is, "the further back in time, the more imprecise the proxies" (Nicholson, 2011, pp. 485–486).

One paleoclimate study for Egypt suggests that, in the south, rainfall in the distant past could have been above 500mm/year, declining to around 200mm/year in the north, and that higher precipitation existed in the Red Sea mountains. The latter would have been due to orographic rainfall and the influence of Red Sea Troughs in addition to monsoonal and Mediterranean rainfall (Henselowsky et al., 2022). This study is focused on the Last Interglacial Period tentatively dated around 100,000 years ago, but reflecting rainfall and climate patterns proposed for the time period 1,000–10,000 years ago (Nicholson, 2011, p. 492). This is further supported by studies of coral reefs, pollen, land snails, and marine deposits (Klein et al., 1990). Even rainfall of 500mm/year is only enough to sustain grassland with a few trees, so the higher rainfall in the mountains becomes very important for creating the variety of habitats then possible, depending on how that rainwater is channelled.

The existence of ancient watercourses has been observed running across the Sinai Peninsula. AbuBakr et al (2013) analysed radar topography to reveal the extent of the waterway

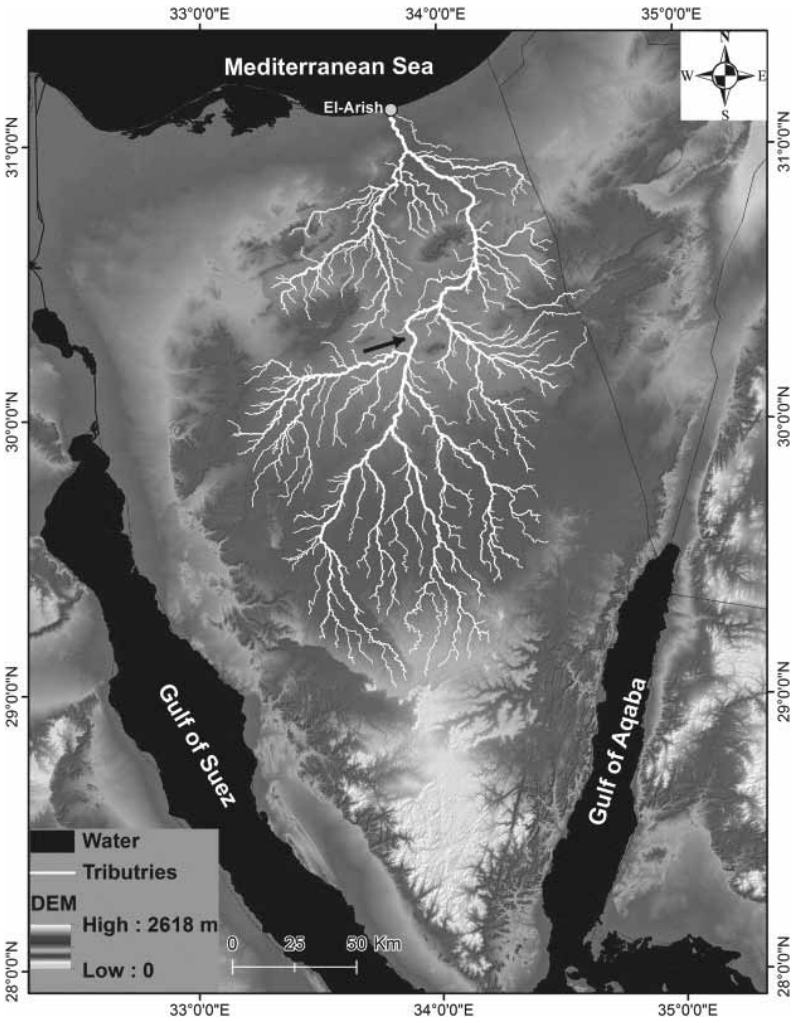

Figure 2. Topography of the Sinai Peninsula overlain with the extracted drainage network of Wadi El-Arish (channel lines within the watershed are shown in white). Credit: Radarsat-1/Shuttle Radar Topography Mission (AbuBakr, et al., 2013).

system known as Wadi El-Arish which is just visible in Figure1 but was once much more extensive and channelled water from practically all of the central area of Sinai (Figure 2) and originating in the surrounding 'Red Sea' mountains at the southern end of the peninsula. The Wadi El-Arish drainage area in particular would have been capable of supporting extensive wetlands in many places during those times of higher rainfall, surrounded by savannah desert and mountains. Similar drainage systems have been identified in NW Saudi Arabia, in Al Jow province, some 300 to 600 km east of Aqaba which could possibly have provided similar habitats to Sinai, albeit on a smaller scale, though traveling there would have involved crossing a mountainous region (Abdelkareem et al., 2020).

Desert Kites

In the Negev highlands and northeast Sinai, evidence of human activity in ancient times includes the presence of

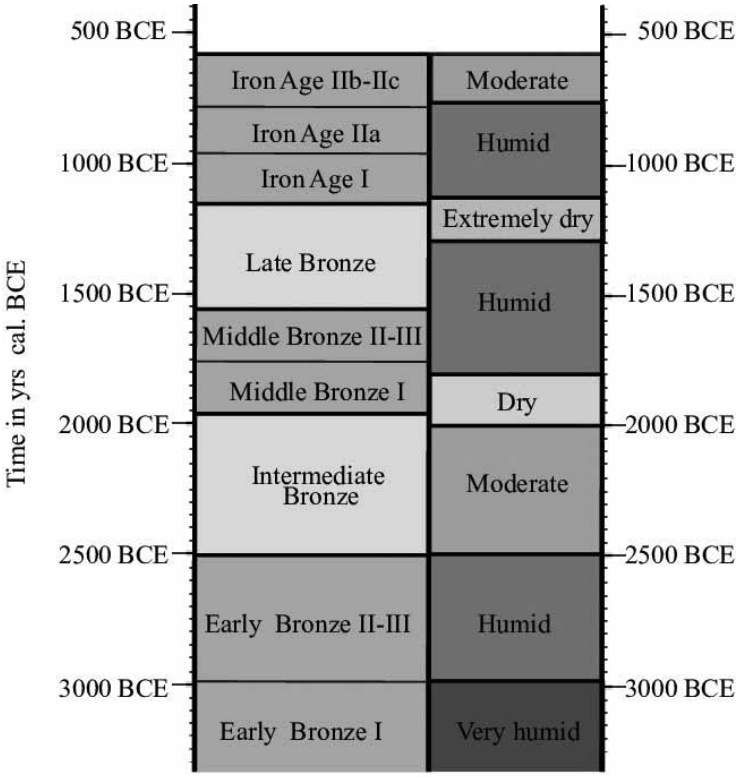

Figure 3. Summary of the climate history of the southern Levant during the Bronze and Iron Ages based on the palynological evidence (Langgut et al., 2015).

"Desert Kites," funnel-shaped installations comprising long, low walls of local field stones with two long sides converging on a stone-walled enclosure or pit at the apex. These cover an average area of one hectare (i.e., nearly 2.5 acres). Sixteen of these have been identified in the Negev to date, while hundreds more are known in eastern Jordan. These have been explained alternatively as aids to hunting, or as devices to corral and protect domestic herds. They have been found in northwest Saudi Arabia, where they are named mustatils. The use for hunting has been described with similar structures elsewhere, but the re-use of an ancient structure in such a way does not preclude other uses at earlier times, while there is ample evidence of cattle and goat remains in the Saudi Mustatils (Holzer et al., 2010; Kennedy et al., 2023). Svizzero and Tisdell (2018) have reviewed reports on over 5,000 of these structures, and conclude that although some may have been used for hunting, their main use was for mustering cattle, with a possible third function being the capture of animals such as wild goats.

Dating of these structures is tentative, and largely based on charcoal, burnt bone, or sediment which may or may not actually be associated with the original construction, and which has then been subjected to radiocarbon dating. Several of the dates of the Negev structures so derived point to the second millennium BC, around the time of the major humid period in the Sahara mentioned above. At this time, much of the central area of Sinai and the Negev highlands which are mid- and high-altitude plains was savannah and therefore well-suited to grazing by livestock. The desert kites provide corroboration of a population with livestock, though it is not currently possible to determine who those people might have been.

Palynology

Langgut et al. (2015) have attempted a paleoclimate synthesis using pollen records, covering the period from the Early Bronze Age through to the late Iron Age (Figure 3) which shows a major humid period for the southern Levant lasting 500 years across the mid-2nd millennium BC.

The "extremely dry" period beginning around 1250 BC marks the time when the Sinai, the southern Negev, southern Jordan, and northwest Saudi Arabia became arid desert. Although elsewhere in the southern Levant did experience later humid periods, these areas did not. This is because the Mediterranean climate experienced by Israel produces rainfall associated with Mediterranean depressions or cyclones, but this mostly falls to the west of the country (Nicholson, 2011, p. 333).

The Sinai region, on the other hand, is under the control of the Indian and African monsoon systems, and the special factors which drove monsoons further north up the Red Sea providing much higher rainfall during the Early and Middle Bronze Ages do not seem to have recurred since (Finkelstein and Langgut, 2014). This "extremely dry" period marks the driest conditions in the entire Bronze and Iron Age timespan, and "possibly contributed to the Late Bronze Age Collapse" (Langgut and Finkelstein, 2023).

Radiocarbon dating by itself (uncorroborated by other dateable material) is better at providing a general time frame rather than the apparent precision given in Figure 3. Keenan

(2002) lists six different Ancient Near East reports between 1991 and 2001 making this very point, that radiocarbon dating shows large disparities with archaeological dating, making them much older (in the opinion of those archaeologists) than they should be. This is mentioned just to emphasize that when considering times of climate change, we can only say that the change from humid to arid could have taken place somewhere around 1250 BC, but not with the precision that Figure 3 seems to offer.

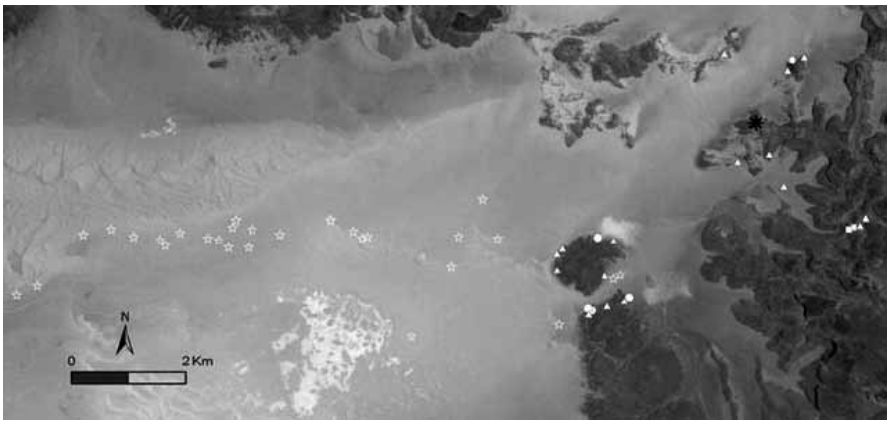

Figure 4. The Wadi Takarkori Project area. Key: asterisk Takarkori rock shelter, star Holocene open-air site, square corbeille (circular stone cairn with standing slabs), circle stone platform, triangle tumulus (adapted from Biagetti and Lernia, 2013; di Lernia and Tafuri, 2013).

Desertification

Desertification is not simply a feature of changing rainfall patterns, as it can be impacted by many factors—including changes in surface vegetation, maximum and minimum temperatures, and wind, as well as human activity including deforestation and overgrazing (Nicholson, 2011, pp. 442–443). This means that a paleoclimate date estimate based on rainfall proxy measures and pollen samples might be different to the date of full desertification. We can say with confidence that the "extreme desert" of the Sinai and Negev was once much wetter, and that during much of the second millennium BC there would have been good grazing for animals and trees for firewood. It also means that there was no need for the Israelites to travel any further afield than the Sinai and Negev areas, though they would need to keep moving on because of probable over-grazing. This suggests one of the possible westerly "Red Sea" crossing routes rather than those to the east of Sinai (see Carter, 2021, for a concise summary of current theories for "Red Sea" crossings). However, such a group—even at the smaller numbers advocated by Hoffmeier (2005, pp.153–159) would undoubtedly have accelerated desertification of the area they were passing through, in a way similar to the 1930s "Dust Bowl" in the USA.

Eilat as a Proxy Location for Bronze Age Humid Period Bird Life

At the head of the Gulf of Aqaba is the modern city of Eilat, close to the location of the ancient city of Ezion-Geber. The climate there is hot and dry, and there used to be some 12 square kilometers of saltmarsh before modern development began in the 1950s, which resulted in a lot of the saltmarshes being drained. The saltmarshes had always been used by migratory birds in the spring, but since the early 1990s, both freshwater ponds and saltwater lagoons have been constructed, which together with the small area of remaining saltmarshes provide an attractive environment for many birds all the year round (Skolnik, 2018).

Most of the birds in the Leviticus 11:13–19 list have been reported there in recent years. These include the the golden eagle, great spotted eagle, steppe eagle and eastern imperial eagle, the griffon vulture, the short-toed snake eagle, the black kite, the peregrine falcon, the fan-tailed raven, the black-headed gull, the Eurasian hobby, the great cormorant, the greater Flamingo, the Great White Pelican, the Common Crane, the Grey Heron and the Eurasian hoopoe. In addition, there is the barn owl, Pharaoh's eagle-owl and the glossy ibis. (Reports by Swann (2001), Jansen (2001), Gochfeld (2015) and IBRCE (2023)).

The little owl, desert owl, and long-eared owl are all reported regularly farther north in Israel. Overall, this is a remarkably close fit for the proposed list of birds for Leviticus 11:13–19, and illustrates what might have been commonly found in the territory of the wanderings in a wetter climate.

Testing Across Time

We have evidence of a similar range of bird species from the Takarkori rock shelter, near one of the former lakes of the Central Sahara (Van Neer et al., 2020). These have mostly been radiocarbon dated to a period between 2350–3950 BC. The dating of these items must be prior to the final deserti-

Table III. Comparison of Aves species, Takarkori (Van Neer et al., 2020), Ancient Egypt (Wyatt and Garner, 2022) and Eilat 21st Century (Jensen, 2001; Swann, 2001; Gochfeld, 2015; and the International Birding and Research Center Eilat, 2023).

Takarkori – Aves Species Finds	No. of Birds	Ancient Egypt	Eilat Reports 2001–2023
Aythya cf. *fuligula* (cf. tufted duck)	1	√	√
Podiceps cristatus (great crested grebe)	5	√	√
Pelecanus rufescens (pink-backed pelican)	2	√	x
Pelecanus onocrotalus (great white pelican)	2	√	√
Pelecanus sp. (pelican)	10	√	√
Microcarbo africanus (long-tailed cormorant)	3	√	x
Phalacrocorax cf. *carbo* (cf. great cormorant)	1	√	√
Phalacrocorax sp. (cormorant)	1	√	√
Plegadis falcinellus (glossy ibis)	1	√	√
Plectropterus gambensis (spur-winged goose)	2	√	x
Pernis apivorus (European honey-buzzard)	1	√	√
Buteo sp. (buzzard)	1	√	√
Circaetus sp. (snake-eagle)	9	√	√
Accipitridae size *Milvus* sp. (cf. kite)	4	√	√
Accipitridae size *Circus aeruginosus* (cf. western marsh-harrier)	1	√	√
Accipitridae size *Circaetus* sp. (cf. Snake-eagle)	16	√	√
Accipitridae indeterminate. (raptors)	19	√ (many)	√ (many)
Falco cf. *subbuteo* (cf. Eurasian hobby)	1	√	√
Fulica atra (common coot)	7	√	√
Gallinula chloropus (common moorhen)	1	√	√
Otididae size *Ardeotis kori* (large bustard)	4	√	√
Columbidae (pigeon or dove)	3	√	√
Corvus cf. *albus* (cf. pied crow)	1	√	√
cf. *Hirundo rustica* (cf. barn swallow)	1	√	√
Unidentifiable bird	98		

fication of the region (if only because so many are wetland birds). This area now "has a hyper-arid climate and falls within the hottest Earth temperature isoline, with precipitation nearly absent" (Cremaschi, 1998, pp. 13–48). Figure 4 shows the Takarkori wadi area where the remains were found, as it looks nowadays.

Apart from the birds, there were large number of bones from various kinds of cattle, sheep, and goats, indicating a pastoralist culture. Evidence including human burials and animal bones shows an occupation in its later phase dated from around 3000–1500 BC (Biagetti and Lernia, 2013). Isotope analysis carried out on bovine remains from this late phase indicated a grazing diet of grasses more commonly found in dry ecosystems, suggesting these animals grazed during the period of climate change from humid to arid. Ovicaprids (domestic sheep and goats) gave values consistent with a generally mixed browsing diet including shrubs and trees. The latest human burial found at Takarkori was dated about 1200 BC (Lernia and Tafuri, 2013).

Table III lists bird remains (Aves species) at Takarkori and compares them with bird identifications from Ancient Egypt across a broadly contemporary period using hieroglyphs, bone remains, mummies, and art (Nilsson et al., 2020; Wyatt and Garner,

2022). The final comparison is with the bird reports from Eilat during the 21st century. What this shows is that the same birds discovered at Takarkori were also known in Ancient Egypt and can now be seen at Eilat, giving a continuity of some 4,000 years for these species across the wider region.

This is a remarkable set of findings, and powerful evidence for an African Humid Period environment which supplied grass for grazing animals and sufficient trees for tree nesting wetland birds such as the ibis and cormorant.

Figure 5. Griffon Vulture observed over Andalusia (Spain) © Martin Johnson.

According to Their Kind

In the Leviticus list, four birds are qualified with the attribution *min* (מִין as in *laminah*, לְמִינָהּ "according to their kind"). This applied to bird 4, *ayah* = Falcon, bird 6, '*orev* = Raven, bird 10, *nets* = Hawk, and bird 19, '*anaphah* = Heron. This is accepted as a taxonomic guide, but, as Angelini and Nihan (2020, p. 48) note:

Accordingly, we should not expect that the division of animals (including birds) into species would consistently follow the divisions established in modern zoology.

The Eurasian hobby which produced a strong OP correlation with *nets* and was proposed as a "hawk" is now classified among the *Falconidae*. Also, while the ancient Egyptians clearly recognized the falcon as a distinct type of raptor, the Greeks and early Romans did not. The reports from Eilat mentioned above are helpful in showing what similar birds to these four have been reported there, indicating how ancient Hebrew taxonomic concepts might align with modern taxonomies:

1. Falcon—lead bird, peregrine falcon. Other Falconidae reported at Eilat excluding the Eurasian hobby are the red-footed falcon, Eleonora's falcon, Barbary falcon, common kestrel, and the lesser kestrel.
2. Raven—lead bird, fan-tailed raven. Other Corvidae reported at Eilat are the brown-necked raven, house crow, and hooded crow.
3. Hawk—lead bird, Eurasian hobby. Other Accipitriformes smaller than eagles but excluding falcons and kites reported at Eilat were the Eurasian sparrowhawk, Eurasian goshawk, Levant sparrowhawk, western marsh harrier, hen harrier, Montagu's harrier, pallid harrier, common buzzard, crested honey buzzard, long-legged buzzard, steppe buzzard, and the European honey buzzard.
4. Heron—lead bird, grey heron. Other Heronidae reported at Eilat were black-crowned night heron, western reef heron, squacco heron, striated heron, purple heron, western cattle egret, great white egret, little egret, and the bittern.

The chief problem with this approach is that other birds on the list not given *min* attributions have been reported together with several other related species which would suggest that they too should have been given a *min* attribution, if conformity to modern bird taxonomies lies behind the hypothetical Hebrew taxonomic concept above.

A clearly contradictory example is bird 9, *shachaph* = Black-headed Gull. This has been seen at Eilat alongside ten other species of gull, making it more abundant in terms of similar species than the Falconidae, Corvidae, or Heronidae known in the region, yet there is no *min* attribution for this bird in either the Leviticus or Deuteronomy lists.

A possible explanation could be that the gulls might have been regarded then as different varieties of the same bird, much as we nowadays classify all the scores of different varieties of domestic chicken as the same sub-species (*Gallus gallus domesticus*), just varying in size and plumage.

This explanation could easily apply also to the eagle and vulture species listed above. Both eagles and vultures are typically spotted flying at height, and against a bright sky only a silhouette can be seen with the naked eye. The silhouettes of the five eagles listed above are practically identical, but distinguishable from the silhouettes of the six vulture species found in the region (Jonsson, 1999, pp. 146–151, 124–127; Porter and Aspinall, 2010, pp. 78–83, 92–94).

The griffon vulture in Figure 5 can only be identified as such because of the known existence of large flocks of those birds at the location where the photograph was taken (north of Ronda, Andalusia, Spain). The plumage colors which distinguish it from the other vulture (the cinereous vulture) native to Spain are not visible in these conditions.

On this basis, the Hebrew taxonomy might only recognize one eagle and one vulture, with minor variations of size and plumage colors not regarded as relevant. The Heronidae on the other hand are of significantly different shapes and sizes, but have in common that they occupy the same habitats, and all fly with their heads held back, their necks in an "S" shape. This feature alone distinguishes them

from cormorants, cranes, and flamingos. These considerations simply show that a better understanding of ancient Hebrew bird taxonomies could be developed by considering a range of factors.

Conclusion

Paleoclimate evidence shows that from the Sahara across to northwest Saudi Arabia before around 1250 BC, very different climate conditions prevailed than subsequently. What is now arid desert was once savannah, with widespread tree coverage, while high rainfall in the mountain regions will have produced extensive wetlands on the lower ground, especially in the Sinai drainage area of the Wadi El-Arish. People grazed domestic animals all across this area, and certainly in the Negev highlands, until the climate changed to arid, and the land became desert.

All the "banned birds" of Leviticus 11:13–19 could have been found in the wetlands and the adjacent landscapes (savannah, woodland, desert, mountain, etc.) typical of the Middle and Late Bronze Age humid period in the central Sinai. This forms a precise fit for the habitats of the listed birds (see Table II) in a close proximity that would be difficult to match elsewhere in the territory shown in Figure 1.

This grouping of birds points directly to a set of climate and environmental conditions that can be identified over a specific period of time which includes the traditional dating of the wilderness narrative. The lack of precision of the various dating methods, coupled with the uncertainties about the speed of onset of desertification coupled with a major change in climate means we can suggest that these conditions pertained between the 18th and 13th centuries BC.

These findings are supportive of the Leviticus 11:13–19 list of "banned birds" reflecting an accurate historical and geographical account of conditions in the Sinai during the middle of the 2nd millennium BC. This supports the view of Soggin (1984, pp. 19–20) that the "wilderness tradition" contains accurate historical records, and also that of Hoffmeier (2005, pp. 167, 209), as supplementary internal evidence pointing to the wandering locations being in the Sinai.

On the other hand, it is hard to support the arguments of Finkelstein and Silberman (2002) which requires that writers in a farming community some seven to nine centuries later could have come to associate this specific set of birds with the "wilderness tradition." This is because by that time the whole of Sinai had been arid desert for several centuries, and most of these birds would be absent from that location because of the destruction of most of their habitats following climate change.

Further research using ornithological data could explore the reasons for these birds being banned, and a review of possible taxonomies.

Summary

1. The list of "banned birds" in Leviticus 11:13–19 appears to preserve an accurate reflection of a very different set of climate conditions than has prevailed in the relevant territory for the past three millennia. This list shares many birds in common with those found in the ancient Sahara and ancient Egypt when the climate in those locations was much wetter, as well as with modern Eilat which provides a microcosm of those conditions.
2. Comparisons of paleoclimate evidence shows that wetter climate conditions in the Sinai and Negev prevailed across the middle of the 2nd millennium BC, the traditional time of the Exodus.
    a. The major change in climate conditions in the late 2nd millennium BC coupled with the desertification of the Sinai Peninsula and neighbouring territories makes late authorship theories for Leviticus untenable.
    b. Both the identifications of the "banned birds" and their habitats, and the basic requirements of "flocks and herds" for food and water make the leap of supposed imagination by the hypothesised late authors hard to conceive.
    c. There is no point banning birds from being eaten by people who are most unlikely to come across such birds.
3. The Sinai and neighbouring Negev region provided adequate conditions for a large pastoralist group such as the Israelite tribes following the Exodus, making it unnecessary to propose other areas such as northwest Saudi Arabia for the territory of the wanderings.
    a. The evidence in support of a Sinai location for the wanderings of the Israelites supports arguments for the "Red Sea" crossing taking place on the west side of Sinai.
    b. The evidence of the desert kites shows that pastoralist groups once occupied the relevant areas, though the builders of them remain unknown.
    c. The Israelites themselves may have contributed to the desertification of the Sinai and Negev by grazing their animals and cutting trees for firewood.
4. The "*-min*" attributions in Leviticus 11 and Deuteronomy 14 point to a very different system of taxonomy for birds than is used at present. It seems possible that birds were

classified according to shape and size, and possibly behaviours and habitats.

Acknowledgments

With grateful thanks for advice, information, and assistance from John Wyatt and Samir Mehta.

No grant funding was received; no financial benefits or interests to declare.

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