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Forbidden islands. The absence of endemics among the insular non-volant terrestrial mammalian fauna of the Red Sea

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Abstract - The Red Sea is a land-locked sea that is globally significant in terms of the unique biodiversity and endemism of its marine species. In contrast, the terrestrial biodiversity on its islands is poor and mainly composed of species present also on the mainland. To profile the non-volant terrestrial mammalian fauna, we reviewed all available records in the literature and report some recent captures; in particular, we point out two additional species from the Dahlak archipelago: the Northeast African spiny mouse (*Acomys cahirinus*) and a still undetermined shrew (*Crocidura* sp.). As far as we know, the only endemic vertebrates are three species of snake (Squamata, Serpentes) and perhaps one gazelle (*Gazella arabica*). The composition of the insular mammalian fauna of the Red Sea is olygotypic, consisting of only a few taxa, mostly anthropochorous, that are shared with the mainland of eastern Africa and/or western Arabia, and which are repeated monotonously on the few islands inhabited by mammals. A lack of endemic mammals can be explained as the result of the only recent connection of almost all the islands with the mainland during the Last Glacial Maximum and by the harsh climatic conditions that allow the survival of only a few xeric specialists.

Key words: Commensal rodents, *Crocidura*, *Gazella*, *Ichneumia albicauda*, insular mammals, *Nanger soemmerringii*, Red Sea.

Riassunto - Isole proibite. L'assenza di endemismi tra i mammiferi terrestri insulari non volatori del Mar Rosso.

Racchiuso da terre, il Mar Rosso è un mare d'importanza globale per la sua biodiversità marina e per il numero di endemismi. Al contrario, la biodiversità terrestre insulare è scarsa e prevalentemente costituita da specie presenti anche sulla terraferma. Per descrivere la composizione della fauna terrestre a mammiferi abbiamo esaminato tutte le osservazioni rintracciabili in letteratura e riportato alcune recenti catture. In particolare, segnaliamo due ulteriori specie dall'arcipelago delle Dahlak: il topo spinoso egiziano (*Acomys cahirinus*) e un toporagno ancora indeterminato (*Crocidura* sp.). Sulle isole del Mar Rosso non vivono mammiferi terrestri endemici e alla luce delle conoscenze attuali, gli unici vertebrati endemici non volatori includono tre specie di serpenti (Squamata, Serpentes) e, forse, una gazzella (*Gazella arabica*). La composizione della fauna di mammiferi insulari del Mar Rosso è oligotipica, costituita da pochi taxa, per lo più antropocori, che sono condivisi con le faune continentali in Africa orientale e/o in Arabia occidentale, e che si ripetono con monotonia sulle poche isole abitate da mammiferi. La mancanza di mammiferi endemici può essere spiegata come conseguenza del recente collegamento di quasi tutte le isole con la terraferma durante l'ultimo massimo glaciale e come effetto delle condizioni climatiche severe che permettono solo la sopravvivenza di pochi specialisti xerofili.

Parole chiave: *Crocidura*, *Gazella, Ichneumia albicauda*, mammiferi insulari, Mar Rosso, *Nanger soemmerringii*, roditori commensali.

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INTRODUCTION

The Red Sea is a branch of the Indian Ocean and is regarded by oceanographers as an ocean in formation. It has the shape of a large and narrow gulf, extending north-south and separating the eastern coast of North Africa from the western Arabian Peninsula (Fig. 1). This almost land-locked sea is connected artificially to the north with the Mediterranean, via the Suez Canal, and to the south with the Gulf of Aden (Indian Ocean), via the Bab el Mandeb, a narrow strait just 30 km wide and only 130 metres deep at the Hanish Sill. Thus, the major currents of these connecting seas fail to enter the Red Sea, exception made for a small inward current at the northern extremity and a more complex bidirectional two- or three-layered current at the Bab el Mandeb (Sheppard *et al*., 1992). The tidal range changes from north to south, with greatest values at the two ends and decreasing towards the central part of the Red Sea, at about 20° N, where tides are virtually absent (Sheppard *et al*., 1992). The Red Sea occupies a large part of the submerged Afro-Syrian Great Rift Valley with long, straight shorelines and narrow coastal plains (Pritchard, 1979) (Fig. 2). It has a maximum width of 355 km, and originated from the gradual separation of the Arabian tectonic plate from Africa, which is still rotating northeastwards with an anticlockwise shift of about 5 cm/year. The Red Sea is the world's northernmost tropical sea and has the best-developed coral reefs in the western Indian Ocean region. It is home to more than 250 species of hard (scleractinian) corals, which is the highest diversity presently recorded in the Indian Ocean (Pilcher, 2002).

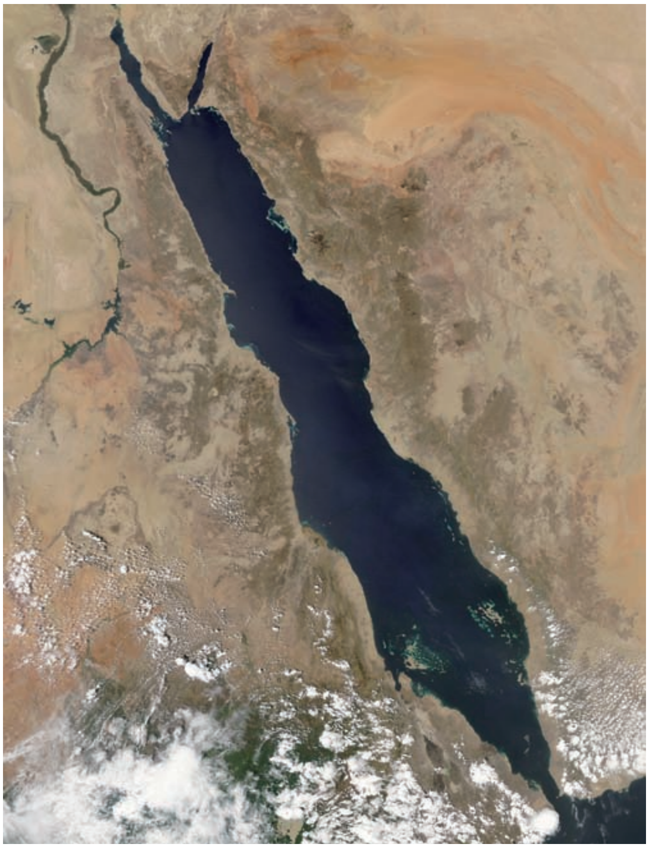

Fig. 1 - The Red Sea, as seen from space (NASA/courtesy of visibleearth.nasa.gov.)

Warm water and the lack of significant fresh water runoff from the Red Sea coasts and islands provide ideal conditions for the formation of the world's least impacted coral reefs (Pilcher, 2002).

Like stars in a clear night sky, the islands of the Red Sea seem countless. Indeed, there are more than 350 islands in the territorial waters of Eritrea alone, and over 100 in those of Yemen. The islands have different geological origins. Some new islands were formed by underwater eruptions (cf. Gass *et al*., 1973), as in the case of a new lava islet formed in December 2011 in the Zubayr volcanic archipelago of Yemen (Klemetti, 2011). However, only a few are volcanic in origin, such as those of the Zubayr and Hanish archipelagoes and some islands in the Howakil Bay (Eritrea) and in southern Eritrea (Coleman, 1993; De Marchi *et al*., 2009). Located about 50 km west of the Red Sea axis, between 23º and 24º N, the Egyptian Zabargad is not a volcanic island but probably an uplifted block of upper mantle and crustal rocks (Bonatti *et al*., 1983; Coleman, 1993). In contrast, other islands are low, flat and sandy, and consist of fossilised coral (cf. Felemban, 1995). Others are of continental origin, for example the Eritrean Dissei, which is close to the Buri Peninsula (De Marchi *et al*., 2009). Although the majority of the Dahlak (Eritrea) and the Farasan (Saudi Arabia) islands are coral in origin, the fact that they are quite close to mainland coasts make them appear like continental archipelagoes, too.

At the end of Pleistocene, the majority of the Red Sea islands were joined to the nearest African and Arabian mainland (cf. Macfadyen, 1930). In that epoch, the sea level dropped 130 m below the present level, allowing con-

Fig. 2 - Marsá al Marākh, located 9 km south-west of Taba, near the Israeli–Egyptian border, is a small inlet of the northern Red Sea – also known as the "fjord" – regarded as the geographical point at which the Afro-Syrian Great Rift Valley enters the Eurasian mainland (photo by Marco Masseti).

tinental fauna to colonise the islands. The exceptions are a few islands surrounded by deep sea: The Brothers islands, small coral outcrops; the medium-sized Zabargad island, which originated from a tectonical upthrust of upper mantle material; and the Zubayr archipelago, a group of ten islands formed by the top of a shield volcano on the axial zone, at the spreading margin between the African and Arabian plates. Today, the Bab el Mandeb strait is about 30 km wide, but at the peak of the last glacial it was much narrower. Though the strait was never completely closed, there may have been islands in-between which could have been reached with rudimentary rafts (Bailey *et al.,* 2007). The fact that many of these islands are relatively remote, with no freshwater sources, has largely prevented human settlement; thus, the terrestrial and underwater habitats remain largely undisturbed by human activity, providing a rare opportunity for faunistic and zoogeographical studies. Moreover, the opening of the Suez Canal has connected the Indian Ocean with the Mediterranean Sea since 1869. As the current flows in only one direction – from the Red Sea to the Mediterranean – it has enabled the colonisation of the Mediterranean by a large number of species from the Red Sea (Lessepsian migration), many of which have become invasive (Por, 2009; Pancucci-Papadopoulou *et al*., 2012). Apparently, very few species have taken the opposite route (Sheppard *et al*., 1992).

The complete absence of permanent fresh water on many of the Red Sea islands makes them quite difficult to colonise (Fig. 3). Some – *i.e.,* the Egyptian Tiran (Su-Aretz, 1979) and Zabargad (Gübelin, 1981), or the Seven Brothers islands off Djibouti (Bark Jones, 1946) – can be rightly defined as “desert islands”. Many of them are fringed with mangroves (cf. Gladstone, 2000), which are at the world’s northernmost limit of their geographical range along the southern Sinai coast (Lipkin, 1987; Pilcher, 2002). Rainfall is higher in the southern Red Sea, although it rarely exceeds 100 mm/year, allowing a more varied and extensive vegetation cover (Edwards, 1987).

The present study intends to provide a comprehensive review of the mammals living on the Red Sea islands. Knowledge of this subject is scattered over dozens of publications, and no attempt has ever been made before to summarise it, apart from a recent paper on the mammals of the Farasan archipelago (Masseti, 2010a). The present study is based on information in the literature and on direct observations of recent collections.

MATERIALS AND METHODS

The composition of the non-volant mammalian fauna of the Red Sea was based on the collections of European and North American natural history museums. We particularly focused on those kept in the countries that once colonised the regions bordering the Red Sea or that are known to keep collections of explorers and naturalists that had visited those areas. Today, most of the region is politically unstable and unsafe for scientific researchers to visit.

Fig. 3 - Domestic goat of the *Galla* Somali race climbing an *Acacia* tree in search of food on the island of Dahlak Kebir (Eritrea). The paucity of food and water on the Red Sea islands makes life hard for mammals (photo by Giuseppe De Marchi).

Unfortunately, not many mammalian specimens from this area are preserved in natural history museums. Therefore, our information was completed on the basis of the scientific literature and trip reports from the end of the 16th century (see Ramusio, 1563) to the present (Tab. 1). Further additions include a few mammal specimens collected by one of us (GDM) in the Dahlak archipelago, and now kept at the Museo di Storia Naturale di Milano (Italy), as well as field records collected during ornithological expeditions carried out in 2002-2004 by GDM and GC in the southern Eritrean Red Sea.

RESULTS

During the course of the present study, data on the non-volant terrestrial mammals of the Red Sea archipelagoes could be obtained from only a few islands (Fig. 4). These included the Egyptian Shadwan; the Sudanese Sawākin and Debir (Er Rih); the Eritrean Massawa, Sheik Said, Dissei, Dahlak archipelago (Dahlak Kebir, Dohul Bahut, Sheik Said, NN086, Sayin, Harat, Dahret, Dur Ghella, Isratu, Entedebir, and Museri) (Fig. 5), and Fatmah; the Saudi Arabian al Hasani and Farasan archipelago (Farasan Al-Kebir, Segid, Zifaf, Dumsuq, and Qummah); and the Yemenite Sumayr and al-Hanish al-Kabir.

Tab. 1 - References dated from 1790 to 2014 reporting the occurrence of non-volant terrestrial mammal species on Red Sea islands and archipelagoes.

Island or archipelago	**Country**	**References**
Shadwan	Egypt	Osborn & Helmy, 1980
Sawākin	Sudan	Heuglin, 1877; Anderson & De Winton, 1902; Kock, 1980; Evans, 1987; Shobrak *et al*., 2003; Gladstone *et al*., 2006
Debir (Er Rih)	Sudan	Heuglin, 1861
Massawa	Eritrea	Cretzschmar, 1830; Rüppell, 1835; Heuglin, 1861; Brehm, 1863; Heuglin & Fitzinger, 1866; Heuglin, 1877; Anderson & De Winton, 1902; Del Prato, 1891; Sordelli, 1902; Parisi, 1917; De Beaux, 1923; Mertens, 1925; Largen *et al*., 1974; Yalden *et al.,* 1976; Kock, 1980
Sheik Said	Eritrea	Heuglin & Fitzinger, 1866
Dissei	Eritrea	De Marchi *et al*., 2006; De Marchi *et al*.,2009
Dahlak archipelago (Dahlak Kebir, Dohul Bahut, Sheik Said, NN086, Sayin, Harat, Dahret, Dur Ghella, Isratu, Entedebir, and Museri)	Eritrea	Bruce of Kinnaird, 1790; Annesley Mountnorris, 1811; Ehrenberg, 1827; Rüppell, 1838 and 1840; Heuglin, 1861 and 1877; Heuglin & Fitzinger, 1866; Del Prato, 1891; Sclater & Thomas, 1897-1898; Sordelli, 1902; Parisi, 1917; De Beaux, 1923; Baschieri, 1954; Baschieri Salvadori, 1954; Roghi & Baschieri, 1954; Clapham, 1964; Lewinsohn & Fishelson, 1967; Largen *et al*., 1974; Harrison, 1965 and 1972; Hayman & Hill, 1971; Bolton, 1973; Yalden *et al.,* 1976; Kock, 1980; Kingdon, 1982; Yalden *et al*., 1984; Hillman, 1993; Yalden *et al*., 1996; De Marchi, 2002; Oriani & Castiglioni, 2003; Shobrak *et al*., 2003; Benardelli, 2004; De Marchi, 2004; Grubb, 2005; Torunsky *et al*., 2007; De Marchi *et al*., 2009; Anderson *et al*. 2013; Gippoliti, 2010 and 2013; Chiozzi *et al.,* 2014a
Fatmah	Eritrea	De Beaux, 1930-31
al Hasani island and the Farasan archipelago (Farasan Al-Kebir, Segid, Zifaf, Dumsuq, and Qummah)	Saudi Arabia	Dollman, 1927; Harrison, 1968; Kingdon, 1982; Groves, 1983, 1985; Flamand *et al.,* 1988; Jennings, 1988; Grubb, 2005; Kingdon, 1990; Harrison & Bates, 1991; Thouless, 1991; Thouless & Al Bassri, 1991; Evans, 1994; Newton, 1995; Gladstone, 2000; NCWCD, 2000; Fisher 2001; Mallon and Kingswood 2001; Mallon & Hoffmann, 2008; Grubb, 2005; Torunsky *et al*., 2007; Masseti & Bruner, 2009; Masseti, 2010a; Torunsky *et al*., 2010; Bärmann *et al*., 2013; Lerp *et al.,*2013; Wronski, 2013
Sumayr (Zimmer)	Yemen	Bruce of Kinnaird, 1790
al-Hanish al-Kabir	Yemen	Dollman, 1927; Haltenorth & Diller, 1977; Nader, 1990; Harrison & Bates, 1991; Al-Jumaily, 1998

The species collected during recent surveys are the following:

1) A shrew of the genus *Crocidura* Wagler, 1832, characterised by a very flat braincase: one partial skull (Fig. 6) collected among food remains found in a small cave inhabited by a barn owl, *Tyto alba* (Scopoli, 1769), on Isratu Island, Dahlak archipelago, in November 1999. Although this specimen is not very well preserved, we estimated a condylobasal length of 16.5 mm and a zygomatic breadth of 7.8 mm. The presence of 8 teeth in the upper dentition and the absence of the fourth small upper unicuspid suggest a representative of the genus *Crocidura* rather than *Suncus*. Based on our preliminary morphological analysis, the specimen could not be identified at the species level.

2) Northeast African spiny mouse, *Acomys* (*Acomys*) *cahirinus* (É. Geoffroy, 1803): several specimens trapped on 21 February 2010 and 7 March 2010 on Dur Ghella island (Dahlak archipelago).

3) House mouse, *Mus* (*Mus*) *musculus* L., 1758: a single specimen found dead on Dahret Island, Dahlak archipelago, on 8 July 2008.

The complete non-volant terrestrial mammal list recorded so far on the Red Sea islands (including the abovementioned species) is given in Tab. 2.

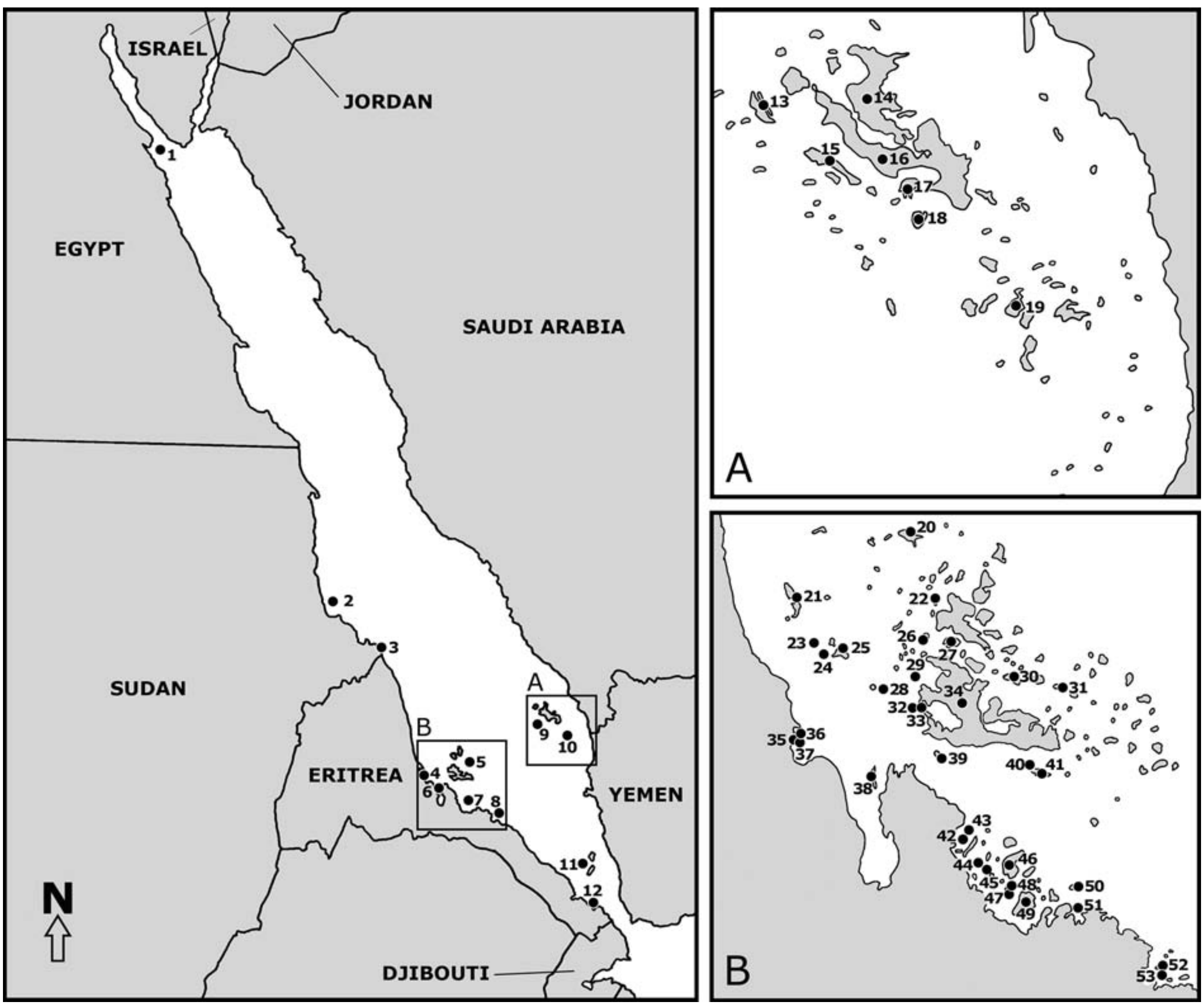

Fig. 4 - Location of the Red Sea areas and islands with reports of the presence of non-volant mammals (see Tab. 2 for recorded species and Appendix for geographical information). The map to the right shows the Red Sea in the context of its bordering countries. Maps A and B (left side) are enlargements of corresponding areas on the main map. The maps are not drawn to the same scale.
Red Sea island areas (numbers 1 to 12): 1=Shadwan island; 2=Sawākin island; 3=Debir island; 4=Massawa (Massawa, Taulud and Sheik Said islands); 5=Dahlak archipelago; 6=Dissei island; 7=Howakil bay; 8=Anfile bay; 9=Farasan archipelago; 10=Sumayr island; 11=Hanish archipelago (al-Hanish al-Kabir island); 12=Assab bay (Fatmah island).
Map A: Saudi and Yemeni islands (numbers 13 to 19): 13=Sarso; 14=Segid; 15=Zifaf; 16=Farasan Al-Kebir; 17=Qummah; 18=Dumsuq; 19=Sumayr.
Map B: Eritrean islands (numbers 20 to 53): 20= Isratu; 21= Harat; 22=Kad Norah; 23=Dohul Bahut; 24=Dahret; 25=Dohul; 26=Dar Solum; 27=Dhu-ladhyia; 28=Dur Ghella; 29=Sarad; 30=Sayin; 31=Gharib; 32=Entedebir; 33=Nocra; 34=Dahlak Kebir; 35=Taulud; 36=Massawa; 37=Sheik Said; 38=Dissei; 39=Shumma; 40=NN086; 41=Museri; 42=Dasetto; 43=Dase; 44=Dahaila Kebir; 45=Dahaila Seghir; 46=Howakil; 47=Umm es Seil; 48=Debel Ali; 49=Baka; 50=Umm es Sahrig; 51=NN045; 52=Handa; 53=Hant.

Fig. 5 - A population of Soemmerring's gazelle, *Nanger soemmerringii* (Cretzschmar, 1828), on the island of Dahlak Kebir (photo by Giuseppe De Marchi).

Tab. 2 – List of all known non-volant mammals of the Red Sea islands.
* ZMB 2115 (skull and skin, labelled "Type" of *Gazella arabica* Hemprich and Ehrenberg);
**BMNH 97.12.21.1, 14 April 1897 ♂. Original label: *Gazella littoralis* partial skull with horns (trophy) + skin coll. Capt. C. Fleming.); [2]MSNG 1458 (♂ ad.) and 1463 (♂ iuv.) *Gazella isabella isabella*. It may be interesting to note that several authors have argued that Dahlak Kebir island was formerly inhabited by gazelles of a species different from that now present: *Gazella gazella* according to Ehrenberg (1827), or *Gazella isabella* Gray, 1846, according to Baschieri (1954) and Baschieri Salvadori (1954). *G. isabella* is a synonym of *G. dorcas* (Grubb, 2005), formerly also indicated at the subspecific level as *G. dorcas isabella* (Groves, 1997). According to Sclater & Thomas (1898), the habitat of *Gazella isabella isabella* extended along the Red Sea coast from Sawākin southwards to Massawa and territories inland up to Bogos, Barka and the region of Taka (De Beaux, 1930-31).
(† = extinct; BMNH = British Museum Natural History; MSNG = Museo Civico di Storia Naturale di Genova; MSNM = Museo di Storia Naturale di Milano; MZUF = Museo di Zoologia dell'Università di Firenze; SFM = Senckenberg Museum Frankfurt; ZMB = Zoologischen Museum in Berlin). Systematic treatment and common names after Wilson & Reeder (2005).

#	Common name	Scientific name	Islands	References and museum specimens
1	Ethiopian hedgehog	*Paraechinus aethiopicus* Ehrenberg, 1832	Massawa	Leche, 1902; Laurent & Laurent, 2002
2	Undetermined shrew	*Crocidura* sp.	Isratu	present work; MSNM Ma7901
3	Sahelian tiny shrew	*Crocidura pasha* Dollman, 1915	Sawākin	Kock, 1980

#	Common name	Scientific name	Islands	References and museum specimens
4	Asian house shrew	*Suncus murinus* (L., 1766)	Dahlak Isls[1]; Sawākin[2]; Dahlak Kebir[3,4,5,7]; Massawa[1,2,3,4,5,6,7]	[1]Heuglin, 1861; [2]Heuglin, 1877; [2]Anderson & De Winton, 1902; [3]Del Prato, 1891; [3]Sordelli, 1902; [3]Parisi, 1917; [4]Yalden *et al.,* 1976; [5] Kock, 1980; [6]SFM 1334, 12516; [7]Rüppell, 1840
5	Hamadryas baboon	*Papio hamadryas* (L., 1758)	Massawa[1]; Farasan Al-Kebir[2]	[1] Rüppell, 1835; [1] Yalden *et al*., 1977; [2]MZUF 11329; [2]Masseti & Bruner, 2009; [2]Masseti, 2010a
6	Caracal	*Caracal caracal* (Schreber, 1776)	Sawākin	Setzer, 1956
7	Wildcat	*Felis silvestris* Schreber, 1777	Sawākin	Setzer, 1956
8	Pale fox	*Vulpes pallida* (Cretzschmar, 1826)	Sawākin	Setzer, 1956
9	? Rüppell's fox ?	? *Vulpes rueppellii* (Schinz, 1825) ?	Massawa[1]; Debir (Er Rih)[2]	[1]Heuglin, 1877; [1]De Beaux, 1928, 1930-1931; Heuglin, 1861; Heuglin & Fitzinger, 1866
10	White-tailed Mongoose	*Ichneumia albicauda* (G. [Baron] Cuvier, 1829)	Farasan Al-Kebir[1]; Dissei[2];	[1]Jennings, 1988; [1]NCWCD, 2000; [1]Fisher, 2001; [1]Masseti, 2010a;[2] De Marchi *et al*., 2006; [2]De Marchi *et al*., 2009
11	Striped hyaena	*Hyaena hyaena* (L., 1758)	Sumayr	Bruce of Kinnaird, 1790; cf. Tuchscherer, 2004
12	Aardwolf	*Proteles cristata* (Sparrman, 1783)	Sawākin	Setzer, 1956
13	Honey badger	*Mellivora capensis* (Schreber, 1776)	Sawākin	Setzer, 1956
14	Arabian (Farasan) gazelle	*Gazella arabica* (Lichtenstein, 1827)*	†Farasan Al-Kebir	ZMB 2115; Dollman, 1927; Groves, 1983, 1985; Nader, 1990; Grubb, 2005
15	Dorcas gazelle	*Gazella dorcas* (L., 1758)	Sawākin[1]; Massawa[2]	[1]BMNH 97.12.21.1**; [1]Lydekker, 1914; [1]Setzer, 1956; [2]MSNG 1458 and 1463
16	Mountain gazelle	*Gazella gazella* (Pallas, 1766)	Segid[1,2,3,5], Farasan Al-Kebir[1,2,3,4,5,8], Zifaf[1,2,3,5], Dumsuq[1,2,3,5], and Qummah[1,2,3,5], al-Hanish al-Kabir[6]; Sumayr[7]	[1]Kingdon, 1990; [2]Thouless & Al Bassri, 1991; [3]Masseti, 2010a; [4]MZUF 11330, 11331, 11332; [5]Cunningham & Wronski, 2011; [6]Dollman, 1927; [6]Haltenorth & Diller, 1977; [6]Nader, 1990; [6]Harrison & Bates, 1991; [6]Al-Jumaily, 1998; [7]Bruce of Kinnaird, 1790; [8]Flamand *et al.,* 1988;
17	Soemmerring's gazelle	*Nanger soemmerringii* (Cretzschmar, 1828)	Sawākin[1]; Dahlak Kebir[2]	[1]Lydekker, 1914; [1]Haltenorth & Diller, 1977; [2]Bruce of Kinnaird, 1790; [2]Annesley Mountnorris, 1811; [2]Rüppell 1838; [2]Heuglin, 1861; [2]Bolton, 1973; Kingdon, 1982; [2]Yalden *et al*., 1984; [2]Hillman, 1993; [2]Yalden *et al.*, 1996; [2]De Marchi, 2004; [2]BMNH 69.783, ZD 1993.56- ZD 1993.59; [2]MSNM Ma7634-Ma7663
18	Lesser Egyptian gerbil	*Gerbillus* (*Gerbillus*) *gerbillus* (Olivier, 1801)	Massawa	Laurent & Laurent, 2002

#	Common name	Scientific name	Islands	References and museum specimens
19	Brown rat	*Rattus norvegicus* (Berkenhout, 1769)	Massawa[1]; Fatmah[2], Assab bay isls (Eritrea)	[1]Rüppell, 1842; [1]Laurent & Laurent, 2002; [2]De Beaux, 1930-1931; [2]Laurent & Laurent, 2002
20	Black rat	*Rattus rattus* (L., 1758)	Sawākin[1]; Dahlak Kebir[2]; Sheik Said (near Massawa)[3]; NN086[4], Dohul Bahut[4,9], Sayin[4], Dhu-ladhiya[4], Gharib[4], Kad Norah[4], Sarad[4], Dahalia Kebir[4], Dase[4], Dur Ghella[5], Isratu[6,7], Entedebir[6]; Museri[4,8]	[1]Evans, 1987; [1]Shobrak *et al*., 2003; [1]Gladstone *et al*., 2006; [2]Rüppell, 1838; [2]Harrison, 1972; [2]Yalden *et al.,* 1976; Heuglin, 1861; [3]Heuglin & Fitzinger, 1866; [3]present work (De Marchi, January 2010); [4]De Marchi *et al*., 2006; [5]Heuglin & Fitzinger, 1866; [6]Clapham, 1964; [7]present work (De Marchi, December 2009); [8]The Second Israel South Red Sea Expedition to the Dahlak Archipelago, 1965; [9]Anderson *et al*., 2013
21	House mouse	*Mus* (*Mus*) *musculus* L., 1758	Shadwan island[1]; Sawākin[2]; Massawa[2,3], Dahlak Kebir[3], Dur Ghella[3], Dahret[4]	[1]Osborn & Helmy, 1980; [2]Anderson & de Winton (1902); Cretzschmar, 1830; [3]Heuglin, 1861; [3]Brehm, 1863; [3]Heuglin & Fitzinger, 1866; [3]Mertens, 1925; [3]Laurent & Laurent, 2002; [4]Baschieri, 1954; [4]Baschieri Salvadori, 1954
22	Northeast African spiny mouse	*Acomys* (*Acomys*) *cahirinus* (É. Geoffroy, 1803)	Dur Ghella	De Marchi *et al*., 2013; present work
23	Eastern spiny mouse	*Acomys* (*Acomys*) *dimidiatus* (Cretzschmar, 1826)	Farasan Al-Kebir	Masseti, 2010a

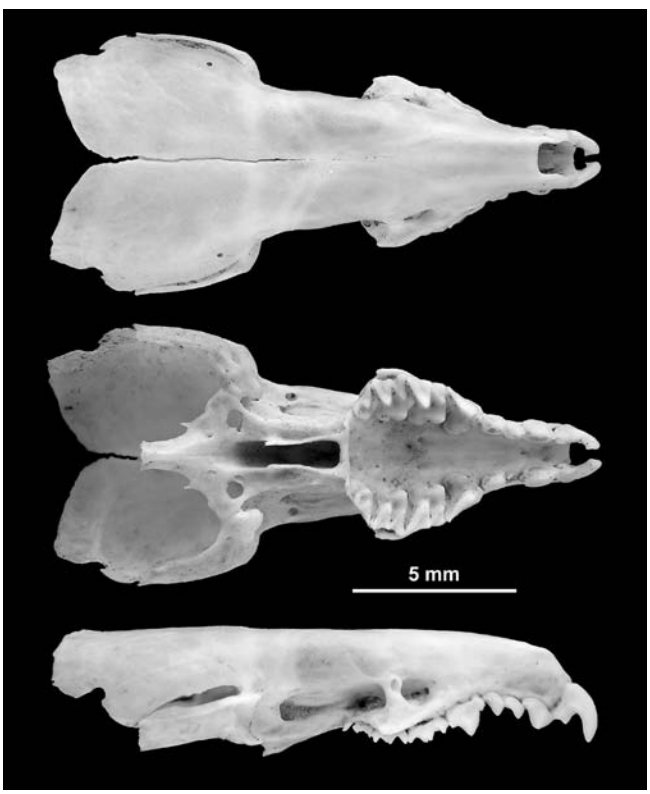

Fig. 6 - The skull of a small soricid (*Crocidura* sp.), characterised by a flat braincase, found in a pellet from a barn owl, *Tyto alba* (Scopoli, 1769), in a cave on Isratu island, Dahlak archipelago, in 2009 (photo by Michele Zilioli; Museo di Storia Naturale di Milano).

DISCUSSION

The extant fauna

Whereas several islands located very close to the mainland coast feature the occurrence of species such as the brown rat, *Rattus norvegicus* (Berkenhout, 1769), and the Asian house shrew, *Suncus murinus* (L., 1766), unexpected additional species have been reported in Sawākin (Sudan) and Massawa (Eritrea). On Massawa, the dorcas gazelle, *Gazella dorcas* (L., 1758), and the hamadryas baboon, *Papio hamadryas* (L., 1758), have been reported (Tab. 2). The aardwolf, *Proteles cristata* (Sparrman, 1783), the caracal, *Caracal caracal* (Schreber, 1776), the wildcat, *Felis silvestris* Schreber, 1777, the honey badger, *Mellivora capensis* (Schreber, 1776), the pale fox, *Vulpes pallida* (Cretzschmar, 1826), as well as Soemmerring's gazelle, *Nanger soemmerringii* (Cretzschmar, 1828), have been reported from Sawākin (Setzer, 1956). The subspecies *Proteles cristatus pallidior* (Cabrera, 1910) was described based on one specimen from Sawākin (Cabrera, 1910). However, both towns are connected to the coast by "artificial land bridges". Sawākin, a round island at the end of a long inlet, is linked to the mainland by a causeway (90 m) built in 1877. Mammals likely reached Massawa islands (Taulud and Massawa) by walking along the causeways that link the mainland to Taulud (1030 m), and Taulud to Massawa (200 m), both built in the 1870s. Even more likely, the findings were inaccurately geolocalised, being referred to the nearby mainland rather than to Massawa and Sawākin islands. It appears rather unlikely that these species settled on such densely inhabited islands. As for other mammals that are officially said to have been collected from Sawākin, we are more inclined to believe that they had been brought to Henry W. Setzer from the mainland during his stay on the Sudanese island.

The hamadryas baboon was recorded for the first time on the Red Sea island of Massawa by Rüppell (1835). However, Rüppell's text '*Ungemein häufig in ganz Abyssinien, von der Meeresküste bei Massaua bis zu ...*' [= 'Very frequent throughout Abyssinia, by the seashore at Massawa up to…'] is unclear about the location of the finding and might well refer to the mainland of Massawa rather than to the island itself. Many decades later, in April 1984, a complete skull with mandible of a subadult female was discovered in a temporary burial on Farasan Al-Kebir, and since then has been kept in the collections of the Zoological Section "La Specola" of the Museum of Natural History of the University of Florence, under the catalogue number MZUF 11329 (Masseti & Bruner, 2009; Masseti, 2010a) (Fig. 7). This species is not to be regarded a true Red Sea island mammal, since it has been recorded only twice based on remains of single specimens (Masseti, 2010a). They were most likely pets, introduced by humans to Farasan Al-Kebir (Masseti & Bruner, 2009) and Massawa: indeed, live baboons are regularly kept as pets by Eritreans, mainly children. Moreover, hamadryas are often commensals with humans in their Saudi Arabian and East African continental ranges (Lackman-Acrenaz, 1998).

Worth noting is the almost complete absence of records of Erinaceidae. So far, only one species, the desert hedgehog, *Paraechinus aethiopicus* Ehrenberg, 1832, has been reported from Massawa (Leche, 1902; Laurent & Laurent, 2002): it might have arrived at the island via the causeways or might have been actually observed on the mainland, as has occurred for other species. In contrast, erinaceids are widespread on the islands of the Persian Gulf: the long-eared hedgehog, *Hemiechinus auritus* (Gmelin, 1770), is reported on Bahrein (Hill & Webb, 1984), together with the desert hedgehog (Harrison, 1972), which has also been recorded from Tanb island (Harrison, 1981; Nader, 1990).

Fig. 7 - Skull of a subadult female of Arabian hamadryas baboon, *Papio hamadryas arabicus* Thomas, 1900, found on the island of Farasan Kebir in April 1984 (photo by Saulo Bambi; courtesy of the Museo di Storia Naturale dell'Universita di Firenze, Sezione di Zoologia "La Specola").

Carnivores

The carnivore record includes three species: the white-tailed mongoose, *Ichneumia albicauda* (G. [Baron] Cuvier, 1829), a not better-identified fox, and possibly the striped hyena, *Hyaena hyaena* (L., 1758). The occurrence of the hyena was noted by Bruce of Kinnaird (1790) on the island of Zimmer (Jazirat Sumayr), which is located south of the Farasan archipelago, but already in Yemenite territorial waters: '*Although Zimmer is said to be without water, yet there are antelopes upon it, as also hyaenas in number, and it is therefore probable that there is water in some subterraneous caves or clefts of the rocks, unknown to the Arabs or fishermen, without which these animals could not subsist. It is probable the antelopes were brought over from Arabia for the Sherriffe's pleasure, or those of his friends, if they did not swim from the main, and an enemy afterwards brought the hyaena to disappoint that amusement. Be that as it will, though I did not myself see the animals, yet I observed the dung of each of them upon the sand, and in the cisterns; so the fact does not rest wholly upon the veracity of the boatman*' (Bruce of Kinnaird, 1790: I, p. 351). Tuchscherer (2004) also mentioned these carnivores on the Red Sea islands: '*La faune sauvage, gazelles et hyènes surtout, est assez limitée*' [= 'Wild fauna, gazelles and hyenas above all, is fairly limited'].

According to the National Commission for Wildlife Conservation and Development (2000), on the Farasan islands '*Foxes* [unspecified at the species level] *used to occur but no longer do so* [...]. *Feral cats and rats competing for the same food may be driving them back*'. Indeed, a variety of fox has been reported by Heuglin (1861, 1877), and Heuglin & Fitzinger (1866), from the island of Debir, which is located off the Sudanese coast, south of Sawākin. On that island, formerly also known as Eiro, are the ruins of the Ptolemaic city of Epitheras, or Theros, cited in the *Periplus of the Erythraean Sea* (*Periplus Maris Erythraei*), which dates to 70 A.D. (cf. Schoff, 1912; Casson, 1989). Heuglin (1861) referred the Debir fox to the taxon *Canis niloticus* (É. Geoffroy Saint Hilaire, 1803). The scientific name of this canid, reminiscent of a jackal, is actually an old synonym for *Vulpes vulpes aegyptiaca* (Sonnini, 1816), the Egyptian red fox or Nile red fox, which is distributed in the Sinai peninsula, Egypt, as well as to the western Mediterranean coastal desert (Waterhouse, 1838; Osborn & Helmy, 1980). Since Heuglin (1861) noted that the fox species he reported from Debir was also present in Arabia, this would effectively rule out the above-mentioned *V. vulpes aegyptiaca*, but also the pale fox, *Vulpes pallida* (Cretzschmar, 1826), which are both unknown in the Arabian Peninsula. The distribution of the red fox does not extend to sub-Saharan Africa: it is actually limited to the north of this continent and the Arabian Peninsula, as well as the remaining Palaearctic region (cf. Wozencraft, 2005). *V. pallida*, on the other hand, is dispersed in the semi-arid Sahelian region of Africa bordering the Sahara, from Mauritania and Senegal through Nigeria, Cameroon and Chad to the Red Sea (Sillero-Zubiri, 2004). Hence Heuglin (1861) likely reported another species, perhaps Rüppell's fox, *Vulpes rueppelli* (Schinz, 1825), whose range encompasses a large part of the Saharo-Sindian deserts, as well as semi-desert areas, from western North Africa to Saudi Arabia and the Middle East, including Afghanistan and Pakistan (Corbet, 1978; Gasperetti *et al.,* 1985; Mendelssohn & Yom-Tov, 1999; cf. Wozencraft, 2005). In Africa, this carnivore is found from the northern deserts down south to Sudan and Somalia. The confusion between the different taxa may have stemmed from the fact that, as observed by Cuzin & Lenain (2004), following Osborne (1992), Rüppell's fox '… *may be confused with the red fox* […] *which has dark markings to the back of the ears, especially by European observers who may be unfamiliar with the sleekness, pallor and long ears of local red foxes*'. Sillero-Zubiri (2004: p. 202) observes that the taxon *Canis pallidus* Cretzschmar, 1827, has indeed been used to indicate the Rüppell's fox, quoting Rüppell's *Atlas zu der Reise im nördlichen Afrika* (Rüppell, 1826: p. 34, pl 11), in which the type locality was referred to as "Kordofan", Sudan (see also Merriam, 1898). Thomas (1918) associated *V. pallida* with Rüppell's fox and also with the fennec fox, *Vulpes zerda* (Zimmermann, 1780). Also Clutton-Brock *et al*. (1976) support this grouping, suggesting that these desert foxes are closely related to the Indian fox, *V. bengalensis* (Shaw, 1800), and to the Cape fox, *V. chama* (A. Smith, 1833). In any case, it would appear that Heuglin (1861) was well aware of the difference between his "*Canis niloticus*" and the African *Vulpes pallida*. In his *Reise in Nordost-Afrika*, Heuglin (1877) refers to this fox, which he found amidst *Avicennia* bushes along the coast and on some of the islands of the Red Sea; he tried to compare it with a small, sand-coloured jackal with long legs and ears, described by Blanford (1870) as *Canis pallidus* Ruepp. The identification of Heuglin's *Canis niloticus* with another representative of the Canidae family, namely Blanford's fox, *Vulpes cana* Blanford, 1877, appears more unlikely. This species inhabits the cliffs of the Near Eastern deserts, where it is recorded from the Iranian plateau to the Levant and the southern Arabian Peninsula (Ilani, 1983; Ginsberg & Macdonald, 1990; Harrison & Bates, 1991; Abu Baker *et al*., 2004; Shalmon, 2004; Masseti, 2009b). Peters & Rödel (1994) first recorded this fox from the western Red Sea shore of Egypt, expanding the canid's known distributional range even into Africa. However, it seems that neither *Canis niloticus* nor *C. pallidus* have ever been used as synonyms of *Vulpes cana*. The canid observed on Debir island by Heuglin (1861) may also be attributed to the Arabian red fox, *V. vulpes arabica* Thomas, 1902, which, according to Gasperetti *et al*. (1985), is ubiquitous in Arabia, being present in large numbers even in the western part of the peninsula. Nor can it be ruled out that individuals of this subspecies may have been introduced by man from Arabia onto the islands off the Red Sea coast of Africa: they may have been pets or used to prevent damage produced by small rodents, such as mice and rats, to human larders (cf. Masseti, 2012). Indeed, in most of the Mediterranean area, *V. vulpes* was the object of particular human attention throughout prehistory since the early Neolithic period, when the canid might have been important symbolically and as food (Masseti, 2012). Alternatively, the fox could have simply walked to Eiro: images from Google Earth (2014) show the presence of mud flats joining the south-eastern corner of the island to the mainland, which suggests that the water there is very shallow and could be crossed during low tide by people, camels, and possibly also foxes.

As far as is presently known, apart from cats and dogs the only carnivore which certainly occurs nowadays on some of the Red Sea islands is the white-tailed mongoose. It has been reported from Dissei, an island off the Buri Peninsula in central Eritrea (De Marchi *et al*., 2006), and from Farasan Al-Kebir (Jennings, 1988; NCWCD, 2000; Fisher, 2001; Masseti, 2010a). This medium-sized carnivore is the only species of the genus *Ichneumia* I. Geoffroy Saint-Hilaire, 1837 (Taylor, 1972). It is widespread in sub-Saharan Africa, from Senegal to Sudan and South Africa, and, beyond the Red Sea, to Saudi Arabia (Wozencraft, 2005) (Fig. 8). Scattered records have also been obtained from the Nile valley in Sudan (Cloudsley-Thompson, 1968) and the southern Arabian Peninsula (Harrison, 1968). It is a very adaptable species of carnivore, which occurs in different habitats, from woodlands to semi-desert, but is not found in swamps, tropical rain forest (Coetze, 1967), nor on mountains above 4000 m (Taylor, 1972). Man is probably the major predator of white-tailed mongooses, though the young may be subjected to limited predation by large birds of prey (Taylor, 1972). The species could have been imported to the two Red Sea islands by humans, considering that man has often deliberately introduced several species of mongoose onto a number of islands off the coasts of Africa. Populations believed to be originated by introductions are those of the slender mongoose, *Galerella sanguinea* (Rüppell, 1835), of Zanzibar (Lydekker, 1896; Madon & Gundevia, 1952; Haltenorth & Diller, 1977); the small Asian mongoose, *Herpestes javanicus* (É. Geoffroy Saint-Hilaire, 1818), of the not distant island of Mafia (British Museum Natural History [BMNH] No. 8.6.19.2; Corbet, 1978; Corbet & Hill, 1992; Wozencraft, 2005; Kock & Stanley, 2009), and Mauritius (Lever, 1985); and the marsh mongoose, *Atilax paludinosus* (G. [Baron] Cuvier, 1829), of Pemba (Haltenorth & Diller, 1977). The Egyptian mongoose, *Herpestes ichneumon* (L., 1758), has been reported from Madagascar (Corbet, 1978; Lever, 1985; Long, 2003), whereas the Indian grey mongoose, *H. edwardsi* (É. Geoffroy Saint-Hilaire, 1818), occurs on Mauritius (Hinton & Dunn, 1967; Corbet, 1978; Wozencraft, 2005). These carnivores are often regarded as efficient predators of poisonous snakes (cf. Masseti, 2009b), but ethnozoological enquiry also documents that they have been utilised to combat the wild and commensal rodents that constitute a serious threat in agricultural and urban areas (cf. Kauhala, 1996; see also Hinton & Dunn, 1967). They are generally considered to be among the worst invasive species at world level. The white-tailed mongoose is probably the principal factor preventing ground-nesting seabirds from using certain Red Sea islands (Shobrak *et al.*, 2003). On

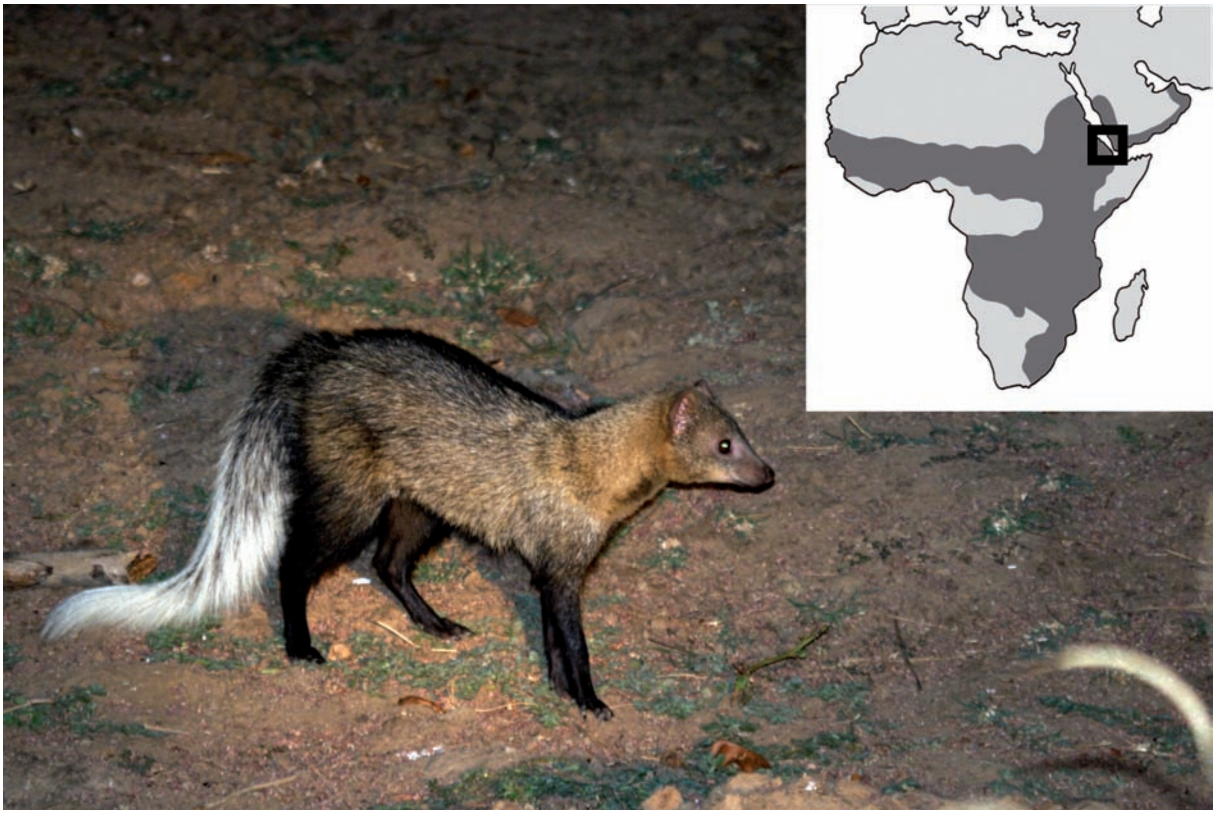

Fig. 8 - A white-tailed mongoose, *Ichneumia albicauda*, G. [Baron] Cuvier, 1829 (photo by MCSchaeffer, https://creativecommons.org/licenses/by-sa/3.0/, modified) and map showing the geographical location of the Dahlak and Farasan archipelagoes in the context of the general distribution of the species (from Taylor, 2013, modified).

the Farasan archipelago, for example, it has been shown to have a severe adverse effect on the breeding success of the osprey (Fisher, 2001). Furthermore, De Marchi *et al*. (2006) and De Marchi *et al*. (2009) suggested a possible relation between the occurrence of this carnivore and the absence of colonies of the crab plover, *Dromas ardeola* Paykull, 1805, on the Eritrean island of Dissei. The presence of the white-tailed mongoose on the latter island, as well as on Farasan Kebir, can be probably explained as the result of human-mediated introduction. Similarly, the introduction of the small Indian civet, *Viverricula indica* (É. Geoffroy Saint-Ilaire, 1803) and feral cats to the island of Socotra, off the Horn of Africa, caused the disappearance of all ground-nesting seabird species except for a small number of Saunder's tern, *Sterna saundersi* Hume, 1877 (Al-Saghier 2000; PERSGA/GEF 2004).

Rodents

Rodents are exclusively represented by four species commensal with man. The black rat, *Rattus rattus* (L., 1758), is the most widespread mammal, being reported from at least 19 islands (Rüppell, 1838; Heuglin, 1861; Fitzinger, 1866; Clapham, 1964; The Second Israel South Red Sea Expedition to the Dahlak Archipelago, 1965; Harrison, 1972; Yalden *et al.,* 1976; Evans, 1987; Shobrak *et al*., 2003; De Marchi *et al*., 2006; Gladstone *et al*., 2006; Anderson *et al*., 2013; present work), and perhaps also from another 8 (the Eritrean islands of Handa, Hant, Dar Solum, Dahaila Seghir, Dasetto, Debel Ali, NN045, Umm es Sahrig and Umm es Seil: De Marchi *et al*., 2006; present work) (see: Tab. 2). Reports quote generically the presence of rats on the Farasan archipelago (Gladstone, 2000; NCWCD, 2000; Syed Rafatullah, pers. comm.). The black rat is one of the most adaptable species of rodent and one of the most destructive predators that has ever existed. Today, it is distributed throughout most of the world thanks to human mediation (Atkinson 1985; Cuthbert & Hilton, 2004; Towns *et al*., 2006; Howald *et al*., 2007). It is the most successful island colonist (Martin *et al*., 2000; Masseti, 2009a), also invading mangrove areas (Mendelssohn & Yom-Tov, 1999). On the Red Sea islands, the black rat is known to prey upon the eggs and chicks of marine birds (Evans, 1987; De Marchi *et al*., 2006; Clapham, 1964). It is a water-dependent, omnivorous species (Wranik, 2003), and is also an excellent swimmer that can feed on fish and snails (Bath-Sheba, 1932; Harrison, 1972). Consequently, it cannot be excluded that black rats avoid territories without a permanent fresh water supply. However, reduced availability of fresh water does not appear to prevent the diffusion of the rodent. The uninhabited island of Darsah (5.412 km^2), for example, in the Yemenite archipelago of Socotra, about 300 km off the Horn of Africa in the Indian Ocean, is a dry rock, apparently without any permanent fresh water supply (Eike Neubert, pers. comm.). It is known, however, to be inhabited by an enormous population of black rats (Massa'a al Jumaily and Abdul Karim Nasher, pers. comm.). The intense infestation of these rodents has caused serious mortality of sooty gulls, *Ichthyaetus hemprichii* (Bruch, 1853), and desertion of the breeding colony (Gladstone *et al*., 2006).

House mice appear to be less dispersed than black rats, having been recorded from a distinctly smaller number of islands (Cretzschmar, 1830; Heuglin, 1861; Brehm, 1863; Heuglin & Fitzinger, 1866**;** Osborn & Helmy, 1980; present work). In the Dahlak archipelago, the species was recently recorded by one of the authors (GDM), who found only a recently dead specimen on the tiny island of Dahret in 2010 (Fig. 9). Extensive research carried out on Dahret did not find any other specimen of this rodent, not even prints on the largely dusty surface of the island, suggesting that the species possibly went extinct. The house mouse is evidently a commensal of man which has considerably extended its distribution through human agency, but on semi-desert islands it can hardly survive outside anthropogenic settlements. Its extinction on Dahret island might be an example of this.

Fig. 9 - A dead house mouse, *Mus musculus* L., 1758, photographed on the island of Dahret, in the Dalhak archipelago, in 2010 (photo by Giuseppe De Marchi).

Eastern spiny mice, *Acomys dimidiatus* (Cretzschmar, 1826), were trapped by Iyad A. Nader for the first time on the Red Sea island of Farasan Kebir, on 18 November 1983 (Masseti, 2010a). About 30 years later, in February and March 2010, several representatives of another spiny mouse species, the Northeast African spiny mouse, *Acomys cahirinus* (É. Geoffroy, 1803), were collected by one of the authors (GDM) on the island of Dur Ghella in the Dahlak archipelago (Fig. 10).

The brown rat has been recorded only once, by De Beaux (1930-31) from the island of Fatmah, which is located in the bay of Assab, in southern Eritrea. According to Al-Jumaily (1998), this species does not occur within the Yemenite political borders either, from where only *R. rattus* has been recorded to date. The brown rat is much more dependent on freshwater than the black rat, and the extreme dryness of the Red Sea islands may be among the main causes of the absence of this species from the majority of these. Yalden *et al*. (1976) observed that the species is restricted in Ethiopia '… *to coastal areas and probably dependent upon shipping for its continued occurrence in this country*'.

Fig. 10 - Northeast African spiny mouse, *Acomys cahirinus* (É. Geoffroy, 1803), photographed on Dur Ghella island (Dahlak archipelago, Eritrea). The range of this species is basically west of the distribution of the morphologically similar Eastern spiny mouse, *A. dimidiatus* (Cretzschmar, 1826), which is distributed from the Sinai peninsula and the Levant to the Middle East (photo by Giuseppe De Marchi).

Jesse C. Hillman reported the occurrence of an unidentified '*very pale rodent*' on Dohul, in the same Eritrean group of islands (unpublished report: 12 February 1993)

Shrews

To date, known representatives of the Soricidae family are very few in number on the Red Sea islands. The tiny Sahelian shrew, *Crocidura pasha* Dollman, 1915, was reported by Kock (1980) from Sawākin. This shrew is distributed to Sudan and the Sahelian savannah of Sudan and Mali, with a single record from Ethiopia (Hutterer, 2005). The Asian house shrew, *Suncus murinus* (L., 1766), has been recorded on Sawākin (Heuglin, 1877; Anderson & De Winton, 1902; and Kock, 1980), on the Dahlak islands (Heuglin, 1861), where it was observed to be quite common, on Massawa and Dahlak Kebir (Rüppell, 1840; Del Prato, 1891; Sordelli, 1902; Parisi, 1917; Yalden *et al*., 1976; Kock, 1980), and on Massawa (Heuglin, 1861; Parisi, 1917), where both authors identified the soricid with the former taxonomic name of *Crocidura* (*Pachyura*) *crassicaudata* (Lichtenstein, 1834).

A last addition, the skull of a small soricid (*Crocidura* sp.), now kept at the Museo di Storia Naturale di Milano (MSNM Ma 7901), was found by GDM in 1999 in a barn owl pellet in a cave on Isratu island, Dahlak archipelago.

Gazelles

Gazelles are the only wild ungulates occurring on the Red Sea islands. These gazelles essentially belong to two taxonomic groups: *Gazella* de Blainville, 1816, and *Nanger* Lataste, 1885. Three species of the genus *Gazella* have been recorded to date: the dorcas gazelle, *G. dorcas* (L., 1758), on Sawākin (BMNH 97.12.21.1) and Massawa (MSNG 1458 and 1463); the mountain gazelle, *G. gazella* (Pallas, 1766), in the Farasan archipelago (Thouless, & Al Bassri, 1991; Masseti, 2010a; Lerp *et al.,* 2013; Wronski, 2013) as well as on al-Hanish al-Kabir (Dollman, 1927; Al-Jumaily, 1998), and possibly Sumayr (cf. Bruce of Kinnaird, 1790) (Fig. 11); and the enigmatic *G. arabica*, once seemingly found in the Farasan archipelago, but also on the nearby Arabian coast (ZMB_MAM_2115).

In contrast, Soemmerring's gazelle (genus *Nanger*) occurs only on Dahlak Kebir (Fig. 12). The earliest record of gazelles from the Dahlak archipelago was by Bruce of Kinnaird (1790) during his visit to Dahlak Kebir in September 1769 (cf. Benardelli, 2004). Later, Henry Salt (in Annesley Mountnorris, 1811) reported the killing of a gazelle on Dahlak Kebir at the beginning of the 19th century (sometime between 1804 and 1806): '*It was eleven o'clock before we got away we saw many deer* [sic!] *on the road and by accident caught a doe big with young that*

Fig. 11 - Populations of mountain gazelle, *Gazella gazella* (Pallas, 1766), still occur on several islands of the Farasan archipelago (Farasan Al-Kebir, Segid, Zifaf or Sarso, Qummah, and perhaps Dumsuq), as well as al-Hanish al-Kabir and, possibly, Sumayr (photo by Marco Masseti).

Fig. 12 - In the Dahlak archipelago, Soemmering's gazelle, *Nanger soemmerringii* (Cretzschmar, 1828), is found only on the larger island, Dahlak Kebir (photo by Giuseppe De Marchi).

had been previously wounded. She was large of a light dun colour white on the belly and rump with small black horns which were circled with rings'. Ehrenberg (1827) reported that the hunters who accompanied him in 1825 thought the ungulates that occurred there were mountain gazelles. The occurrence of Soemmerring's gazelle on Dahlak Kebir was first recorded by Rüppell (1838) and then by Heuglin (1861) (cf. Chiozzi *et al.* 2014b). However, Baschieri Salvadori, the zoologist of the 1953 *Spedizione Subacquea Italiana nel Mar Rosso* (Baschieri 1954; Baschieri Salvadori, 1954), considered them to be *Gazella isabella* Gray, 1846, a synonym of *G. dorcas* (see Grubb, 2005). It was formerly also classified at the subspecific level of the latter species: *G. dorcas isabella* (Groves, 1997). The dorcas gazelle extended from North Africa to the Levant. However, he did not collect a specimen to support his claim (Yalden *et al.*, 1996). We cannot exclude that the species in the gazelle population changed between 1861 and 1953, or that Baschieri Salvadori's report is inaccurate. Torunsky *et al*. (2007) initially suggested that the gazelles of Dahlak Kebir may also be more closely related to the Saudi gazelle, *Gazella saudiya* Carruthers and Schwarz, 1935, a species originally endemic to the western parts of the Arabian Peninsula, but recently (2008) declared extinct. However, the same authors later rejected the assumption, confirming the occurrence of *N. soemmerringii* on Dahlak Kebir (Torunsky *et al*., 2010).

More recently, reports on the island of Dahlak Kebir refer the local gazelles to *N. soemmerringii*, albeit to a dwarf variety very likely arising from the "island rule" effect (Bolton, 1973; Chiozzi *et al.,* 2014a; Kingdon, 1982; Yalden *et al*., 1984; Yalden *et al.*, 1996; De Marchi, 2004) (Fig. 13). The unsettled issues concerning the specific identification of the extant gazelles of Dahlak Kebir com-

Fig. 13 - Soemmerring's gazelle, *Nanger soemmerringii* (Cretzschmar, 1828), is present on the island of Dahlak Kebir with a variety of reduced dimensions, very likely caused by the "island rule" effect. The size difference between a continental subspecies (*N. s. berberana* Matschie, 1893) and the insular population is clearly shown here by the skulls of two adult males of comparable age (photo by Giorgio Bardelli; Museo di Storia Naturale di Milano).

pared with those that may have inhabited the island in the past could be partly solved based on historical grounds. In a recent interview conducted by one of the authors (GDM, 6 July 2010), the last governor of the Dahlak archipelago, Taha Siraj – who was in office for some years until 1991 and was the son of the previous governor – asserted that Dahlak Kebir's population of gazelles had faced serious problems of survival during the years of his service. Furthermore, at the time of his father's tenure, the ungulates seemed to have become extinct, or had become extremely rare on the island, so much so that the governor decided to import other gazelles from the mainland coast. Taha Siraj recalls that some stocks were also introduced to other islands, perhaps Shumma and Dur Ghella, but unsuccessfully, as they failed to survive. He does not remember, however, when the introductions actually occurred. Consequently, it cannot be ruled out – as suggested by Kingdon (1990) for the ambiguous origin of the extant Farasan gazelles – that the original population of Dahlak Kebir has also been replaced by new stocks and new species from the mainland, or that crossings took place with the new introductions even over recent historical times. Indeed, the nearby Farasan islands, off the southern Saudi Arabian coast, are today characterised by an endemic subspecies of gazelle, the Farasan mountain gazelle, *G. g. farasani* Thouless & Al Bassri, 1991 (Flamand *et al.,* 1988; Thouless & Al Bassri, 1991; Masseti, 2010a), but with phenotypical patterns somewhat different from the ungulate originally reported from the archipelago and previously designated as the Farasan gazelle, *Gazella arabica* (Lichtenstein, 1827). The latter, enigmatic ungulate was in fact indicated as a separate species restricted to the Farasan insular range (Dollman, 1927; Groves, 1983). According to Kingdon (1990), it cannot be excluded that the original population has been replaced by new stocks from the mainland, or that crossings occurred with new introductions over the last 160 years. The taxonomic status of the gazelles now present on Dahlak Kebir has raised an extensive debate within the international scientific community, which has been summarised in Yalden *et al*. (1996). A dwarf subspecies of *N. soemmerringii* had been already identified by A.W. Gentry, based on a single specimen from Dahlak Kebir (Bolton, 1973; Yalden *et al*. 1996). This insular population may likely form a yet undescribed subspecies (Gippoliti, 2013). Based on photographs (De Marchi, 2002, 2004) and careful morphometric comparisons (Chiozzi *et al.,* 2014a), it is quite small sized, and with horns in the male similar to those of the already mentioned Somali subspecies, *N. s. berberana* (Matschie, 1893) (Fig. 14), but with the tips only slightly curved inwards and without the characteristic hook (Oriani & Castiglioni, 2003). Sequences of cytochrome b mitochondrial DNA also confirmed that these gazelles are a dwarf variant of the larger mainland Soemmerring's gazelle, suggesting that this island population may have been established not long ago from a small subset of

Fig. 14 - In the foreground, two sub-adult domestic Somali goats, once widely known also as *Galla* (male, black; female, spotted). Both seem not to exceed 70 cm at the withers. This is approximately the height also of the Soemmerring's gazelle, *Nanger soemmerringii* (Cretzschmar, 1828), in the background, which is in contrast with the range of the species (between 81 cm and 98 cm) (see: Dorst & Dandelot, 1969; Funaioli, 1971; Haltenorth & Diller, 1977; and Kingdon, 2004) (photo by Giuseppe De Marchi).

mainland animals (Torunsky *et al*., 2007; Torunsky *et al*., 2010; Kamal M. Ibrahim, 2010; pers. comm.). On Dahlak Kebir, this arid-adapted gazelle has practically no predator. Ospreys occasionally use the ungulate bones for the construction of their nests where, according to Roghi & Baschieri (1954), osteological remains of the gazelles have sporadically been found (Fig. 15). The local abundance of gazelles and the presence of villages also allows local persistence of a population of winged scavengers, such as the Egyptian vulture, *Neophron percnopterus* (L., 1758) and the hooded vulture, *Necrosyrtes monachus* (Temminck, 1823) (De Marchi *et al*., 2009).

Another enigma is the past presence of the above-mentioned gazelle on the Farasan archipelago. So far, the only endemic mammal known on the Red Sea islands is the Arabian gazelle, *G. arabica* (Lichtenstein, 1827), which was originally reported from the Farasan islands (Masseti, 2010a). This intriguing ungulate is known only from a single male specimen preserved in the Berlin Museum (ZMB MAM 2115, skull and skin labelled: "Type" of *Gazella arabica* Hemprich and Ehrenberg) (Lydekker, 1914; Masseti, 2010a) (Fig. 16). It was apparently collected by Hemprich and Ehrenberg in 1825 (Neumann, 1906; Harrison, 1968; Groves, 1983, 1985), but the specimen may not actually come from the Farasan. Therefore, its former distribution and status may never be known (Groves, 1983; Mallon & Kingswood, 2001; Mallon & Hoffman, 2008). Originally described as *Antilope arabica* by Lichtenstein (1827-1834), it was later indicated as the type of *G. arabica* by Neumann (1906), who in stating that the specimen was from Farasan may have had information now unavailable to us (Groves, 1983). This male was indicated as the type of a distinct species restricted to the Farasan insular range (Dollman, 1927). In fact, the skull dimensions and horn shape of the male lectotype of *G. arabica* are very different from all other known gazelle species (Groves, 1983; cf. Grubb, 2005). It was even suggested that its unique skull morphology was the result of pathological deformation (Groves, 1983). On the other hand, some suggest a possible analytical error in the origin of the Berlin gazelle. On 30 April, 1825, C.G. Ehrenberg wrote to H. Lichtenstein from Massawa that, together with F.G. Hemprich, he had collected a gazelle on Farasan Kebir, but he failed to indicate the sex or any other data (Groves, 1983). Later, Hemprich & Ehrenberg (1828) included this Arabian specimen with two others from the Sinai, but without distinguishing the specimens from the two localities. Neumann (1906) was the first to query the inclusion of the Hemprich and Ehrenberg specimens in the same taxon. He identified the type of *Gazella arabica* as '*an old buck*

Fig. 15 - Soemmerring's gazelles, *Nanger soemmerringii* (Cretzschmar, 1828), have practically no predator on the island of Dahlak Kebir. However, because ospreys, *Pandion haliaetus* (L., 1758), sometimes use their bones as building material for their nests, some authors have hypothesised that these birds, which are notoriously piscivorous, can occasionally prey upon the gazelles (see Roghi & Baschieri, 1954) (photo by Giuseppe De Marchi).

from Farasan Island, no. 2115, in the Berlin Museum'. Surprisingly, in a recent study of the skull and skin of the lectotype – which had so far been considered belonging to a single individual – the two items were found to come from different specimens (Bärmann *et al*., 2013). The skull sequence is nested within the clade of northern *G. gazella*, and likely comes from Israel (Bärmann *et al.* 2013) or Syria (Bärmann *et al.,* 2014), while the skin sequence is nested within the southern (or Arabian) *G. gazella*; the latter matches the genetics of the gazelles now inhabiting the Farasan archipelago, which are regarded as a distinct subspecies, *G. g. farasani* Thouless & Al Bassri, 1991, of the mountain gazelle (Wronski *et al*., 2010) (Fig. 17). Therefore, we have no evidence supporting that other gazelle species inhabited the Farasan archipelago except the present *G. g. farasani*. In fact, if we exclude the lectotype, no other specimens were ever confidently assigned to *G. arabica*. Therefore, the taxonomic status, distribution and phylogenetic relationships of this enigmatic species is likely to remain unknown (Bärmann *et al*., 2013). On the other hand, as might have happened on Dahlak Kebir, we cannot rule out that the Farasan gazelle population may have been restocked by humans with different species over time.

Fig. 16 - The type of the misterious Arabian gazelle, *Gazella arabica* (Lichtenstein, 1827), includes this skull and a skin, both designated with catalogue number ZMB_MAM_2115 (Museum für Naturkunde, Berlin). The German explorers Hemprich and Ehrenberg seemingly collected the specimen in the Farasan islands in 1825. However, recent genetic evidence suggests that while the skin comes from a Farasan gazelle, the skull is that of an Israeli or Syrian mountain gazelle. Probably, there was a mistake in the past in assigning skull and skin to the same individual. This combination of specimens from different sources originated the type now preserved in Berlin. Recently, Bärmann *et al.* (2014) proposed to consider only the skin of ZMB_MAM_2115 as the lectotype of *Antilope arabica* Lichtenstein, 1827 (courtesy of Museum für Naturkunde Leibniz Institut for Research on Evolution and Biodiversity at the Humboldt University, Berlin).

Insular dwarfism

Interestingly, the gazelles presently found on Dahlak Kebir and on the Farasan archipelago are dwarf compared with their mainland counterparts (Thouless & Al-Bassri, 1991; Wronski & Cunningham, 2010; Chiozzi *et al.*, 2014a, 2014b). Insular dwarfism is a very common phenomenon in large mammals, possibly due to genetic isolation from continental populations, quantitative and qualitative reduction in food supply, alteration of intraspecific competition, and absence of large carnivores (cf. Masseti & Mazza 1996; Masseti, 2009a). Dwarfism appears to be the only evolutionary option available to large-sized animals to lower selective pressure when they move into insular settings (Mazza, 2007 and references therein). In ungulates, reduction of size and simplified horn development have often been interpreted as the consequence of prolonged isolation in restricted areas of low trophic production, combined with the effects of genetic bottlenecks and of continuous consanguinity (Lister, 1989; cf. Masseti & Zava, 2002).

On islands, body size reduces quite rapidly. According to Azzaroli (1977), size can drop in just a few millennia, but it can occur in an even shorter time. For example, when the small red deer, *Cervus elaphus hispanicus* Hilzmeier, 1909, of the *Marismas* of the river Guadalquivir, in southern Spain, was transferred to areas with higher food availability – such as the Asturias, the Sierra of Cadiz, or the Sierra Morena – individuals of definitively larger dimensions and a more complex antler architecture developed in just a few years (cf. Delibes de Castro *et al*., 1990).

Fig. 17 - Skull of an adult female of the extant Farasan gazelle, *Gazella gazella farasani* Thouless & Al Bassri, 1991 (catalogue number: MZUF 11330, Zoological Museum, University of Florence) (photo Saulo Bambi; courtesy of the Museo di Storia Naturale dell'Universita di Firenze, Sezione di Zoologia "La Specola", Florence).

The fossil record from the Island of Jersey suggests that the populations of red deer that had been newly introduced from the mainland became adapted shortly after isolation (Lister, 1989, 1996). Research on the European mouflon *Ovis orientalis* Gmelin, 1774, from the Kerguelen Islands (Bousses & Reale, 1996) and on the feral domesticated sheep from Santa Cruz Island, California, (Van Vuren & Bakker, 2009) also indicated that some morphological traits (body mass and wool traits) may have changed in just 25-90 years, which correspond to an extraordinarily low number of generations in these large animals (cf. Chiozzi *et al*., 2014a). The woolly mammoth, *Mammuthus primigenius* (Blumenbach, 1799), turned dwarf between 7000 and 4000 yr BP on Wrangel islands, in the Arctic Ocean (Lister, 1993, Vartanyan *et al.,* 1993).

The geological history and the geographical location of many of the islands considered in the present study suggest that gazelles may have been already present on the Farasan islands and on Dahlak Kebir when the Holocene eustatic rise in sea level detached these islands from the mainland. However, in the absence of a fossil record, we consider more likely that the extant insular populations are the result of human introduction. Gazelles were very likely introduced to most of these islands for hunting and to provide a source of fresh meat (Masseti, 2009b, 2010b). Examples of this type of game management are known in the Arabian area since prehistoric times (cf. Karami & Groves, 1993; Tomé, 2003). Indeed, animals the size of a deer can be shipped long distances quite easily, even on small, primitive boats (cf. Clutton-Brock, 1981). Once released into the new territories, the continental Soemmerring's gazelles originated a free-ranging population, the descendants of which still live there today. Once back in the wild, the phenotypical patterns of their continental ancestors were modified and they became dwarf. The gazelles have survived only on Dahlak Kebir, perhaps because it is large enough to maintain sufficiently numerous herds and, thus, avoid the effect of fluctuations induced by human exploitation (cf. Rüppell, 1838), recurrent droughts (cf. Chiozzi *et al*., 2014b), genetic drifts, as well as the unpredictable spread of epidemics.

Biogeography of the Red Sea islands

Altogether, very few endemic terrestrial vertebrate taxa are known to date on the Red Sea islands. For example, no endemic species is present on these archipelagoes, based on the checklist of the additional data on the insular mammalian species of the world proposed by Alcover *et al.* (1998). The same can be said for local sea birds. The only near-endemic avian species is the white-eyed gull, *Larus leucophthalmus* Temminck, 1825, which, however, is also found in the Gulf of Aden, and could have colonised the Red Sea from there after the Last Glacial Maximum, when the Red Sea was unsuitable for marine life because of its increased salinity (Braithwaite, 1987; De Marchi *et al*., 2009).

The relative paucity of endemic terrestrial vertebrates from the Red Sea archipelagoes is quite surprising indeed. As far as is presently known, there are only three endemic species of snake, and, perhaps – as we have seen above – one gazelle, the already mentioned *Gazella arabica*. The Sarso island racer, *Platyceps insulanus* Mertens, 1965, is known only from a single specimen captured by W. Kost along the coast of the island of Sarso, a low-lying coral atoll of the Farasan archipelago, in November 1964 during the "Meteor" Expedition launched by the Senckenberg-Museum in the Indian Ocean (Mertens, 1965) (Fig. 18). The holotype specimen is now preserved at the Senckenberg Museum in Frankfurt (SMF 60027: 1 male adult, W. Kost, Saudi Arabia, 26/11/1964) (Fig. 19). Based on Kost's report, but also on the subsequent taxonomic description by Mertens (1965), the snake has never been seen again since, either on Sarso or on other nearby islands (Masseti, 2014). Hence, the endemic Sarso island racer is known only from the holotype and a sloughed skin. Its unclear status, however, has led several authors, such as Leviton *et al*. (1992) and Egan (2007), to omit it from their checklists of Arabian herpetofauna. Some doubts

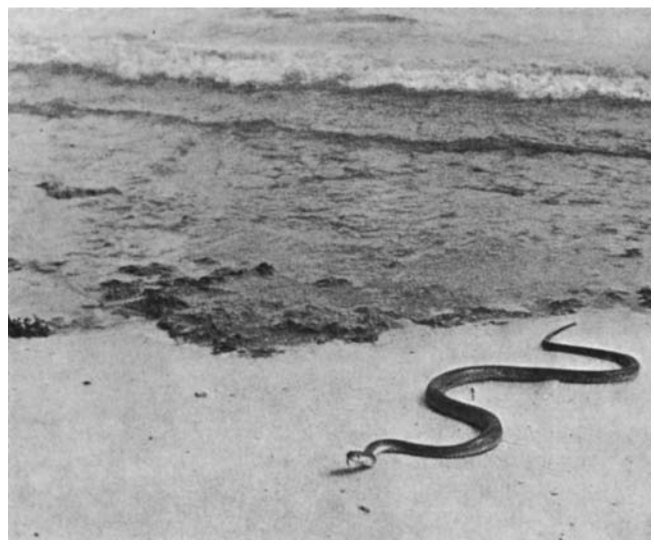

Fig. 18 - The Sarso island racer, *Platyceps insulanus* (Mertens, 1965), photographed in November 1964 on the namesake island of the Farasan archipelago during the "Meteor" Expedition in the Indian Ocean launched by the Senckenberg-Museum (from Mertens, 1965).

Fig. 19 - The holotype of *Platyceps insulanus* (Mertens, 1965) (catalogue number: SMF 60027, Senkenberg Museum, Frankfurt) (photo by Michael Franzen; courtesy of Senkenberg Museum, Frankfurt).

have also been raised on where the Sarso island racer had actually been collected. For example, Gasperetti (1988) observed that Mertens (1965) reported *P. insulanus* from what he believed to be Sarso, *i.e.,* an island of the Dahlak archipelago, whereas in fact it is part of the Farasan islands. Moreover, the fact that a specimen of the same species was captured during an expedition in the Indian Ocean raises further doubt upon the real locality of its provenance. Alternatively, *P. insulanus* really does inhabit Sarso island, and the lack of additional findings is just due to the difficulty in catching this snake.

Another endemic [?] representative of the genus *Platyceps*, the Dahlak racer, *Platyceps largeni* (Schätti, 2001), has been described from the small islands of Andeber, Nocra, and Sarad in the Dahlak archipelago (Schätti, 2001; Largen & Spawls, 2010). According to Schätti (2001), however, the species is probably more widespread in the archipelago than is presently known. The recent identification of a sixth specimen among the material collected on Museri Island in 1965 during the Second Israel South Red Sea Expedition and kept at the Natural History Collections of Tel-Aviv University (labelled TAU-R.16164), confirms Schätti's prediction (Maza *et al*., 2015). The holotype of the species, a female (collected by M. J. Largen on January 7, 1970), is kept at the Natural History Museum of London (labelled BMNH 1973.3211). Yet another endemic species from the southern Red Sea is a variety of viper, the big-headed carpet viper, or Cherlin's saw-scaled viper, *Echis megalocephalus* Cherlin, 1990 (Cherlin, 1990; McDiarmid *et al*., 1999; Schätti, 2001; Largen & Spawls, 2010). This snake is known only from four specimens collected in its type locality, originally indicated by Cherlin (1990) as '*an island in the southern Red Sea*'. It is supposedly the island of Nocra (Joger, 2010) or, perhaps, Dissei (Largen, 1997). Its type series was obtained by a Soviet Navy surgeon (Schätti, 2001). Most probably, the type locality of *E. megalocephalus* is just Nocra, a former Soviet naval base (Borkin & Cherlin, 1995). Remarkably, no endemic lizard is known from this region (Schätti, 2001).

The Red Sea islands have undoubtedly homogeneous continental mammalian faunas. This suggests a common origin of the communities from the mainland of eastern Africa and/or the western Arabian Peninsula, apparently depending on the distance of the islands from the two shores. *Acomys dimidiatus* and *Gazella gazella* colonised the islands close to the Arabian coast, whereas *Acomys cahirinus* and *Nanger soemmerringii* colonised the islands close to the African coast. Other widespread species are present on the islands on both sides of the Red Sea. This is the case, for example, of the white-tailed mongoose, the black rat and the house mice. The biodiversity is low; in fact, the communities include very few species. Whereas the absence of some groups can be easily explained by the lack of a suitably large habitat (*e.g.,* ungulates) or by human interference (*e.g*., medium-sized carnivores), the complete absence of smaller species well represented in the nearest coastal areas, such as hedgehogs (Erinaceidae), hares (Leporidae), gerbils (Muridae, Gerbillinae), jerboas (Dipodidae), gundis (Ctenodactylidae), and ground squirrels (Sciuridae, Xerini), remains inexplicable. The extant non-flying terrestrial mammalian fauna on the Red Sea islands appears to be essentially characterised by species that are somehow connected with human subsistence (*e.g.,* gazelles) or with voluntary (*e.g.,* the mongoose) or involuntary (*e.g*., shrews and murids) introduction.

Anthropochorous fauna?

Humans have exploited the natural resources of the Red Sea since prehistory; indeed. archaeological evidence indicates that this basin has attracted human settlement since very remote times. Rather than acting as a barrier, it has been an important centre of cultural and population dispersal between Africa and Arabia. In fact, during the sea level lowstand, the Bab el Mandeb strait shrunk into a narrow, shallow channel, aiding human migration even without the need for seafaring vessels (Bailey *et al*., 2007). The first use of seafood dates to the Middle Palaeolithic, followed in Neolithic times by the cultural diffusion of pre-pottery elements in the northern Arabian areas (Horton, 1987). Archaeological research has revealed approximately 1000 sites, mostly shell mounds formed during the past 6000 years, in the Farasan archipelago alone (Bailey *et al*., 2007).

The Red Sea has been a trade route from the earliest recorded history. More than 5000 years ago, rafts or simple boats ventured forth upon its waters to bring obsidian – a black volcanic glass that yields sharp blades – from the Arabian Peninsula to Egypt, where it has been found in pre-dynastic archaeological sites. Over 3500 years ago, Egypt's pharaohs sent fleets into the Red Sea to visit copper and turquoise mines in the Sinai peninsula and to sail much farther south, probably through the Bab el Mandeb, to the fabled Land of Punt (see Kitchen, 1993) (Fig. 20). Millennia later, Roman ships regularly left ports, such as Berenike, bound for India (Ingrams, 1966; see also André-Salvini *et al.*, 2010). In this sense, the most ancient and vivid historical account showing the importance of this trade route is the *Periplus of the Erythraean Sea* (*Periplus Maris Erythraei*), dating to 70 AD. Indian and Chinese seamen also took advantage of the northern monsoon in spring to cross the Gulf of Aden and then sail on to the Red Sea (Debelius, 1998). Not only was the Red Sea the preferential route for trade between India, the Near East, the Mediterranean and Europe, but its islands were also centres for the production of rare and precious goods, such as peridotites from Zabargad (Bonatti *et al*., 1983), pearls from Dungunâb, north of Sawākin, and from the Dahlak Archipelago, but also ambergris, excreted by the sperm whale, *Physeter macrocephalus* L., 1758, along the beaches of the Farasan archipelago (Tuchscherer, 2004). The Turks began sailing the western Indian Ocean in the 16th century, and the Ottoman empire was the largest market for goods imported from India and the Moluccas, spreading them throughout the Muslim world. As the global economy strengthened, Arabian merchants exchanged precious coffee for imported Chinese porcelain, fabrics and spices brought by Dutch, English and Indian ships to Mocha. By linking the Red Sea with the Mediterranean, the opening of the Suez canal in 1869 finally allowed ships to travel between Europe and Asia without circumnavigating Africa, permanently altering the times and means of world maritime trade (see Galil, 2006).

Fig. 20 - Fragment of decoration on a memorial temple to the Egyptian queen Hatshepsut (15th century BC) of the 18th Dynasty (Deir el-Bahari, Upper Egypt). It shows a baboon climbing a doum palm, *Hyphaene thebaica* (L.) Mart., 1838; a herd of long-horn cattle; and the head of a sub-adult giraffe, *Giraffa camelopardalis* L., 1758, from the mythical Land of Punt.

All this commercial trade and human movement must have had profound repercussions on the natural resources, which were already depleted by poor rainfall and an aridity that had been increasing since ancient times, especially in the southern- and western-most territories of the Red Sea. New ecological equilibria caused significant alterations in the natural distribution of several biological elements, but also the extinction of many others. Allochthonous vertebrates also began to be introduced – both deliberately and involuntarily – by man to the islands (Fig. 21). Although, for example, the earliest literary evidence of the occurrence of gazelles on the Red Sea islands goes back only to Ottoman times (Bruce of Kinnaird, 1790; Annesley Mountnorris, 1811; Rüppell, 1838; Heuglin, 1861; Benardelli, 2004; Tuchscherer, 2004), different species of these ungulates must have been introduced since very early times to the most inhospitable islets along the ancient routes across the Red Sea to ensure a supply of fresh meat. Gazelles are, in fact, the medium-sized mammalian species best adapted to the particular environmental conditions of the small and barren islands of this sea. On the islands, the ungulates, released by man in a free-ranging state, could be easily hunted for meat (Masseti, 2010). Moreover, islands are natural enclosures that allow the ungulates to derive their food supply directly from the carrying capacity of the environment, and this could have been a simple way to solve management problems (Masseti,

Fig. 21 - Skull of an adult male domestic goat collected on the island of Dumsuq (Farasan archipelago, Saudi Arabia) in 1984. It is evidence of the deliberate introduction of mammals by man to the Red Sea islands. It is another specimen of the Somali ethnic group, but in this case a primitive type, with straight, involute horns (photo by Saulo Bambi, courtesy of the Museo di Storia Naturale dell'Universita di Firenze, Sezione di Zoologia "La Specola").

1998; cf. Masseti & Zava, 2002). This was apparently the only way to exploit marginal territories that were, otherwise, generally unattractive economically for humans (cf. Masseti, 2009c, 2012). Whatever happened in the past, the gazelles of Dahlak Kebir island are not hunted today by the local people; rather, they are protected for religious reasons (Hagos Yohannes, pers. comm.). Indeed, gazelles might have had a long and prominent history in northeastern African cultures, such as Ancient Egypt, where *N. soemmerringii* was associated with Anuket, goddess of the River Nile and of water in the Nubian (Sudanese) tradition. Anuket herself was sometimes represented as a gazelle (Strandberg, 2009; Chiozzi *et al*., 2014).

Excluding Sawākin and Massawa – which have been connected to the mainland by causeways since the 19th century and have been frequented by a large human population – the non-volant mammals dispersed on the Red Sea islands include only a dozen taxa (Tab. 1). The hypothesis that all these species might have colonised the islands through human mediation is supported by the specific homogeneity of the different insular faunal communities. The exclusive dispersal on the islands of a very limited number of continental species is an undeniable fact. Noteworthy is that, of all the species that could potentially survive on the islands (*e.g*., gerbils and jerboas), only anthropocorous species (shrews, murids, mongooses and gazelles) are present today. However, the possibility that some species may have reached the islands without human intervention, possibly during sea level lowstands and/or through the so-called sweepstake routes, cannot be ruled out. The fox reported by Heuglin (1861) and Fitzinger (1866) from Debir (Er Rih) may have reached the island by walking across the mudflats during low tide or by swimming. The presence of humans with drinking water tanks and of commensal rodents may have allowed the survival of the fox, at least for a limited span of time. Natural colonisation from the mainland by a pair of golden jackals, *Canis aureus* L., 1758, occurred in 2004 on the island of Umm al-Gorm, Iran, but the local wildlife authorities soon eradicated them (Behrouzi-Rad, 2013).

CONCLUSIONS

The absence of endemic mammalian species from the Red Sea islands is so far attested by the lack of fossil and sub-fossil findings. However, very little research has been carried out on these territories compared with that conducted on the islands in the Mediterranean Sea. We suspect that islands such as Howakil and Baka in the Howakil Bay of Eritrea, which have never been explored, may disclose unexpected findings. Furthermore, a significant number of complete specimens of *Crocidura* from Isratu Island in the Dahlak archipelago should be investigated to establish the taxonomic status of this taxon.

The depth of the sea along the coast in the southern portion of the Red Sea, which has always been fairly shallow (today max. − 130 m), together with the vertical movements of the underlying salt domes of Miocene origin, created a great number of islands, mostly made of coral rocks. The youngest islands were formed 110,000-140,000 years ago, when the sea level was the same as it is today (Braithwaite, 1987). In the light of this, we cannot exclude that these territories were originally unsuitable for colonisation by non-volant vertebrates. Furthermore, during the Last Glacial Maximum, the negative water balance of the basin – caused by an elevated evaporation rate not compensated by an equivalent influx of water – increased the salinity of the Red Sea, creating conditions similar to those present nowadays in the Dead Sea (Braithwaite, 1987) that could have hampered the colonisation of the islands by non-flying terrestrial vertebrates. With the end of the last glacial period, about 15,000 years ago, the sea level gradually rose, reaching its present level around 7000-5000 years ago and shaping the Red Sea and its islands as we see them today. The recent formation of the islands perhaps explains the limited insular endemicity of non-flying terrestrial vertebrates (De Marchi *et al*., 2009). The recent origin of the islands together with their short distance from the nearest mainland, the relatively shallow depth of the surrounding seafloor, the lack of permanent fresh water bodies, and the sparse vegetation on many of them may have prevented the endemisation of mammals.

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APPENDIX

Gazeteer of the Red Sea localities cited in the text. The names in the first column (in alphabetical order) are quoted from published literature and maps and coherently reported in the text of the article. The second column gives the names approved by the National Geospatial-Intelligence Agency (NGA) (http://geonames.nga.mil/namesgaz/). The third column (Geographic Feature) includes both natural and artificial characteristics of the territory. Coordinates (fourth column) and country (fifth column) are similarly referred to the same source. The islands we list as NN plus number were named according to an unpublished list of the Eritrean Ministry of Marine Resources (see: De Marchi *et al.,* 2006).

Name as in text	Name approved	Geographic feature	Coordinates	Country
al Hasani	Al Ḩasānī	island	24° 58’ 40” N 037° 05’ 01” E	Saudi Arabia
al-Hanish al-Kabir	Jazīrat al Ḩanīsh al Kabīr	island	13° 42’ 44” N 042° 43’ 32” E	Yemen
Assab Bay	Bay of Aseb	bay	12° 54’ 26” N 042° 49’ 24” E	Eritrea
Bab el Mandeb	Bāb al Mandab, Bab el Mandeb	strait	12° 35’ 00” N 043° 21’ 00” E	Djibouti, Eritrea, Yemen
Baka	Beka’e	island	15° 00’ 53” N 040° 18’ 52” E	Eritrea
Buri Peninsula	Buri	peninsula	15° 14’ 13” N 039° 55’ 58” E	Eritrea
Dahaila Kebir	Dahaila Kebir	island	15° 09’ 30”N 040° 08’ 09”E	Eritrea
Dahaila Seghir	Dahaila Seghir	island	15° 08’ 00” N 040° 10’ 00” E	Eritrea
Dahlak Archipelago, Dahlak Islands	Dahlak Archipelago	archipelago	15° 50’ 00” N 040° 12’ 00” E	Eritrea
Dahlak Kebir	Dehalak’ Kebīr	island	15° 39’ 35” N 040° 06’ 51” E	Eritrea
Dahret	Daaret	island	15° 54’ 15” N 039° 34’ 40” E	Eritrea
Dar Solum	Dar Salūm	island	15° 59′ 00″ N 039° 56′ 45″ E	Eritrea
Dase	Dase	island	15° 14’ 25” N 040° 07’ 43” E	Eritrea
Dasetto	Dasetto	island	15° 13’ 35” N 040° 07’ 04” E	Eritrea
Debel Ali	Debel’ Ali	island	15° 05’ 09” N 040° 15’ 59” E	Eritrea
Debir, Eiro, Er Rih	Gazirat ‘Iri	island	18° 10’ 22” N 038° 26’ 23” E	Sudan
Dhu-ladhiya	Duladia	island	15° 56’ 45” N 040° 02’ 41” E	Eritrea
Dissei	Dese	island	15° 28’ 18” N 039° 44’ 52” E	Eritrea
Dohul	Dohul	island	15° 54’ 34” N 039° 38’ 32” E	Eritrea

Name as in text	Name approved	Geographic feature	Coordinates	Country
Dohul Bahut	Dul Baut	island	15° 56’ 50” N 039° 32’ 10” E	Eritrea
Dumsuq	Jazīrat Dumsuq	island	16° 32’ 27” N 042° 03’ 02” E	Saudi Arabia
Dungunâb	Dungunāb	settlement	21° 06’ 27” N 037° 07’ 02” E	Sudan
Dur Ghella	Dur Ghella	island	15° 46’ 27” N 039° 47’ 31” E	Eritrea
Entedebir	Āndēber Desēt	island	15° 42’ 11” N 039° 54’ 30” E	Eritrea
Farasan Al-Kebir	Farasān al Kabīr	island	16° 43’ 42” N 041° 54’ 39” E	Saudi Arabia
Farasan Archipelago, Farasan Islands	Jazā’ir Farasān	archipelago	16° 49’ 54” N 041° 48’ 38” E	Saudi Arabia
Fatmah	Fatuma Desēt	island	13° 01’ 31” N 042° 50’ 56” E	Eritrea
Gharib	Gharib	island	15° 47’ 00” N 040° 27’ 00” E	Eritrea
Handa	Hando	island	14° 47’ 27” N 040° 48’ 24” E	Eritrea
Hanish Archipelago	Ḩanīsh	archipelago	13° 45’ 00” N 042° 45’ 00” E	Yemen
Hant	Keda-Hando	island	14° 45’ 37” N 040° 48’ 28” E	Eritrea
Harat	Harat	island	16° 06’ 38” N 039° 27’ 53” E	Eritrea
Howakil	Hawakil	island	15° 09’ 21” N 040° 14’ 54” E	Eritrea
Howakil Bay	Bay of Hawakil	bay	15° 02’ 20” N 040° 12’ 44” E	Eritrea
Isratu	Isra-tu	island	16° 20’ 00” N 039° 53’ 00” E	Eritrea
Jeddah	Jeddah, Jiddah	settlement	21° 32’ 33” N 039° 11’ 53” E	Saudi Arabia
Kad Norah	Gad Norah	island	16° 06’ 00” N 039° 59’ 00” E	Eritrea
Marsá al Marākh	Marsá al Marākh	inlet	29° 25’ 45”N 034° 49’ 50”E	Egypt
Massawa	Mits’iwa	island	15° 37’ 00” N 039° 29’ 00” E	Eritrea
Museri	Museri	island	15° 29’ 12” N 040° 21’ 25” E	Eritrea
NN045	-	island	15° 00′ 00″ N 040° 30′ 00″ E	Eritrea
NN086	-	island	15° 30′ 00″ N 040° 20′ 00″ E	Eritrea

Name as in text	Name approved	Geographic feature	Coordinates	Country
Nocra	Nokra Desēt	island	15° 42’ 00” N 039° 56’ 00” E	Eritrea
Qummah	Qummāḩ	island	16° 38’ 00” N 042° 01’ 06” E	Saudi Arabia
Sarad	Sarad	island	15° 49’ 49” N 039° 54’ 15” E	Eritrea
Sarso	Sarad Sarso	island	16° 50’ 57” N 041° 35’ 26” E	Saudi Arabia
Sawākin	Suakin Island	island	19° 6’ 39” N 037° 20’ 13” E	Sudan
Sayin	Siem	island	15° 49’ 00” N 040° 16’ 00” E	Eritrea
Segid	Sajīd	island	16° 52’ 43” N 041° 54’ 40” E	Saudi Arabia
Seven Brothers	Sawâbi’	archipelago	12° 27’ 49” N 043° 24’ 39” E	Djibouti
Shadwan	Jazīrat Shākir	island	27° 30’ 05” N 033° 59’ 21” E	Egypt
Sheik Said	Shēk Seyd	island	15° 35’ 34” N 039° 28’ 42” E	Eritrea
Shumma	Shumma	island	15° 32’ 14” N 040° 00’ 10” E	Eritrea
Taba	Ţābā	settlement	29° 29’ 31” N 034° 53’ 45” E	Egypt
Taulud	T’walet Desēt	island	15° 36’ 13” N 039° 27’ 56” E	Eritrea
The Brothers Islands	Al Ikhwān	archipelago	26° 18’ 53” N 034° 50’ 41” E	Egypt
Tiran	Jazīrat Tīrān	island	27° 56’ 25” N 034° 33’ 40” E	Egypt
Umm es Sahrig	Um-les-Sahrig	island	15° 04’ 22” N 040° 29’ 51” E	Eritrea
Umm es Seil	Umm es Seil	island	15° 03’ 39” N 040° 14’ 25” E	Eritrea
Zabargad	Jazīrat Zabarjad	island	23° 36’ 39” N 036° 11’ 46” E	Egypt
Zifaf	Zufāf	island	16° 42’ 43” N 041° 46’ 31” E	Saudi Arabia
Zimmer, Jazirat Sumayr, Sumayr	Jazīrat Zamhar	island	16° 17’ 59” N 042° 19’ 43” E	Yemen
Zubair Archipelago	Jazā’ir az Zubayr	archipelago	15° 05’ 00” N 042° 08’ 00” E	Yemen