Use of the municipal dump site on Masirah island, Oman by Egyptian Vultures *Neophron percnopterus*, 2013–2018

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Masirah island, Oman holds one of the densest populations of breeding endangered Egyptian Vultures *Neophron percnopterus* in the world. Counts of Egyptian Vultures were made at the Masirah island municipal dump site during January 2013–March 2018. The average mean monthly number of vultures counted was 39.87 ± 2.22 (N=61, range: 13–82); the ratio of non-adult to adult vultures was 0.7 ± 0.08. Counts of vultures at the dump were highly variable, and no annual patterns of dumpsite use by adults, non-adults or vultures of all ages were found. Data suggest that numbers of vultures using the dump peaked in 2015–2016, and that numbers in 2018 were similar to those in 2013. This apparent recent decline in vulture use of the dump could be the result of a declining resident population or the changes in vulture foraging, reflecting the fact that vultures are highly adapted to cope with changes in food availability. Repeating past surveys for breeding vultures and other ecological field research could shed light on the current status and ecology of Egyptian Vultures on Masirah island, help develop counts at the dump site as a means for monitoring the population, and help understand the potential effects of the ongoing national upgrade of waste management in Oman on vultures and other avian scavengers.

INTRODUCTION

Monitoring populations of endangered species is important so that changes in abundance can be detected and timely conservation activities undertaken, if necessary (Yoccoz *et al* 2001, Buckland *et al* 2005, Nichols & Williams 2007). Monitoring can also provide information regarding the relative importance of the monitored population at regional and global scales.

The Egyptian Vulture *Neophron percnopterus* is a globally endangered (BirdLife International 2018) obligate scavenger that feeds on small food items, including anthropogenic waste (Botha *et al* 2017). Indeed, in much of its wide distribution, Egyptian Vultures are commensal/mutualistic with humans (Gangoso *et al* 2013, Henriqes *et al* 2018), and are often found at rubbish dumps, abattoirs, and temporary settlements of nomadic and semi-nomadic human communities. While Egyptian Vultures can benefit from anthropogenic waste, toxic waste can be harmful. For this reason modern waste management can be beneficial to vultures, even if it reduces the overall amount of available food. Egyptian Vultures, like other avian scavengers, provide important ecological services that benefit humans. By consuming biological waste, vultures hinder the spread of diseases that might afflict humans and livestock.

There is evidence that the published estimate of 100 pairs of resident Egyptian Vultures in Oman (Jennings 2010) may be out of date due to population growth (Meyburg *et al* In press). The breeding population on Masirah island, Oman had been estimated at 12 pairs (Griffiths & Rogers 1975, Rogers 1988). However, results of a single-year survey estimated there to be 65–80 breeding pairs, making it the second densest population in the world after Socotra island, Yemen (Al Bulushi *et al* 2013, Angelov *et al* 2013). Further, all 12 adult Egyptian Vultures caught in winter 2017–2018 at a landfill in Oman did not migrate (Meyburg *et al* In press; https://egyptianvultureoman.blogspot.com/), suggesting that a large proportion of vultures seen at waste disposal sites in Oman during the winter (Eriksen & Victor 2013, Al Fazari & McGrady 2016) is resident.

In recognition of the importance of the population of Egyptian Vultures on the island, the Environment Society of Oman (ESO) initiated regular counts of scavenging birds at

the main rubbish dump. Because the population is relatively unstudied, these counts can provide important baseline data, and establish a simple, repeatable process for monitoring that population. Here, we provide a detailed analysis of the Egyptian Vulture counts obtained during 2013–2018. While not all Egyptian Vultures on the island visit the dump site on a daily or maybe even an annual basis, counts there can serve as an index of Egyptian Vulture abundance and age composition. The effort also helped develop bird identification and survey skills in ESO field assistants, whose main tasks focus on marine turtles.

STUDY AREA AND METHODS

Study area

Masirah island is located *c*15 km offshore of mainland Oman in the Arabian sea at *c*20.4° N, 58.8° E. The Masirah island municipal dump site (MMDS) is in the northern part of the island at 20.57° N, 58.88° E (Figure 1), and is attractive to Egyptian Vultures and other scavengers (*eg* gulls). The fenced area of the MMDS covers *c*16 ha, but most dumping of organic matter occurred in a rather ad hoc fashion within *c*2–3 ha.

Field methods

We counted and aged all Egyptian Vultures scavenging at the dump site every month during January 2013–March 2018, except August and November 2014. Vultures were

Figure 1. Map showing location of Masirah municipal dump site, which was 'closed' June 2018. Since then, most waste that might be consumed by vultures has been gathered at a nearby transfer station and trucked to Tahwa, the site of the modern engineered landfill some 200 km to the north on the mainland.

classified as either 'adult' (≥4 yrs old) or 'non-adult' (subadult/juvenile, <4 yrs old) based on plumage (Clark & Schmitt 1998).

Counts were made by 1–3 observers, mostly from two vantage points (20.576° N 58.890° E; 20.569° N 58.880° E), which together gave a view of the entire dump site. Although close enough to make counts and determine the age of birds, our presence did not disturb birds at the site. A few birds were sometimes observed while observers moved between vantage points, and these were added to the total.

We attempted to count all Egyptian Vultures that were present at the dump site during our visits, even Egyptian Vultures that were very distant. At least two counts (*ie* 'daily counts') occurred each month (at least one in the morning and one afternoon), but if time allowed more counts were made. Because some morning and afternoon counts occurred on a single day, and were therefore not independent, we used the maximum count made on any given day, for our analyses ('Statistical analysis' below).

Although the active dumping area being used by vultures was small, birds moved around the site during our counts, and piles of rubbish could obscure our views. Despite our attempts to avoid it, some low level of double counting individuals probably occurred, and some individuals went uncounted. Because of this, the numbers we report should be interpreted as an index (and not an estimate) of Egyptian Vultures using the site.

During counts, birds were perching, walking through the rubbish and flying at different distances from the observer(s). To improve count accuracy, multiple (typically 2–3) counts were made at each vantage point until consistency in count values was achieved. When multiple observers made counts, they counted independently, then conferred to ensure that the maximum number of birds was recorded. The duration of observation bouts at individual vantage points was *c*10–20 minutes, but varied depending upon the number of birds. This meant that it took about 1–1.5 h to complete the count, including travel time between vantage points.

We recorded the total number of birds observed per age class, and classified the months of August–September as 'non-breeding' or 'winter', and January–July as 'breeding' or 'summer'. From limited data from Masirah island it seems that most breeding by Egyptian Vultures occurs in the spring (many start incubating in February), but that some lay eggs as early as October (Angelov & Yotsova 2012).

Statistical analysis

Using maximum daily counts when >1 counts were made per day, we calculated the mean number of vultures counted each month of the study. These mean monthly counts (hereafter, monthly counts) were assumed to be independent, and were used for statistical analyses. Analyses aimed at examining annual variation in vulture use of the site excluded data from 2018, when data were collected January–March only. We used linear models (Agresti 2015) to test for (1) linear and quadratic trend; (2) monthly variation, and (3) annual variation in mean monthly counts of Egyptian Vultures. All statistical analyses were performed in the R computing environment (R Core Team 2017).

RESULTS

A total of 204 counts were made during the study period, 98 in the morning and 106 in the afternoon. Eighty-eight daily maximum counts (23 morning, 65 afternoon) were used in our analyses.

Overall the average monthly count of Egyptian Vultures at the rubbish dump was 39.87 ± 2.22 (N=61, Median=36, Min=13, Max=82; Table 1). Tests for linear and quadratic trends in average monthly counts were highly significant (Table 2A). There was no evidence that

Table 1. Average mean monthly counts of Egyptian Vultures at the Masirah Municipal Dump Site January 2013–March 2018.

Month	N	Mean	Median	SE	Min	Max
Jan	6	30.7	28.2	4.7	20	51
Feb	6	36.3	39.5	3.81	23	46
Mar	6	38.9	39.5	5.68	17	55.5
Apr	5	36.6	24.5	11.3	15	79
May	5	39.1	32	10.8	23	81.5
Jun	5	44.9	37	9.23	24	70.5
Jul	5	47.8	51	11.9	13	82
Aug	4	45.9	48.8	9.13	21	65
Sep	5	41.6	41	7.24	22	66
Oct	5	35.8	36	5.24	21	50
Nov	4	47.8	46.8	10.4	29.5	68
Dec	5	38.5	28	7.58	24	62

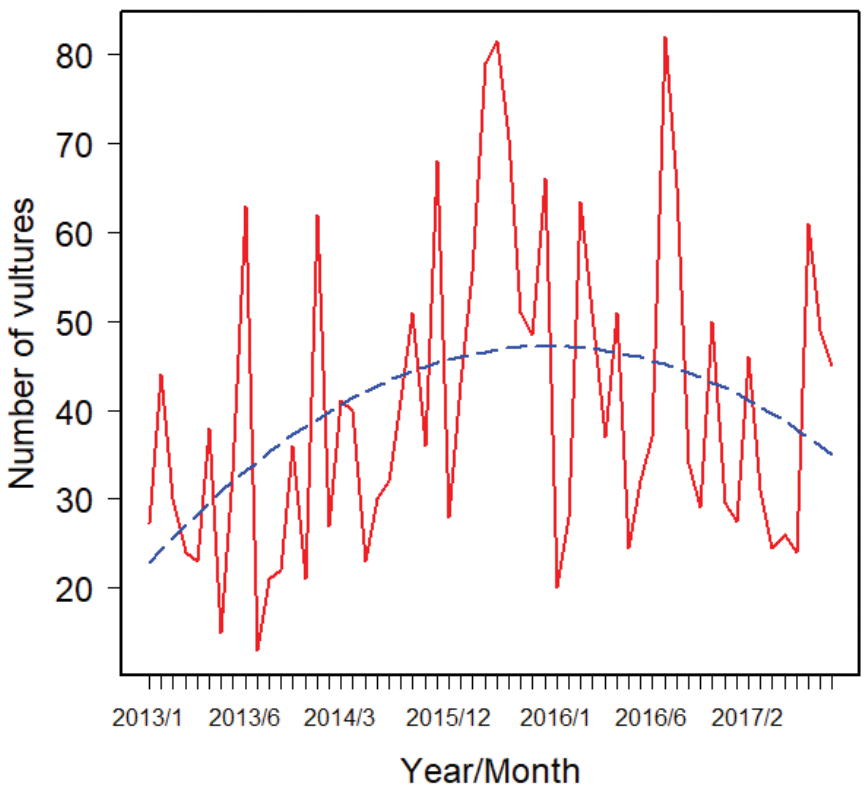

Figure 2. Plot of mean counts of Egyptian Vultures per month at the Masirah municipal dump site January 2013–December 2017 (red solid line). The dashed line is the quadratic trend line using estimates of regression parameters presented in Table 2A.

Table 2. Results of general linear model testing for effect on monthly counts of Egyptian Vultures of (A) linear and quadratic temporal trends *(ie* effect of time); (B) month of the study; and (C) year of the study.

A

	Estimate	SE	t	Value	Pr(>|t|)
(Intercept)	21.350920	6.671734	3.200	0.00228	**
Linear	1.505398	0.521752	2.885	0.00558	**
Quadratic	-0.021913	0.008572	-2.556	0.01337	*

B

	Estimate	SE	t	Value	Pr(>|t|)
(Intercept)	30.722	7.498	4.098	0.000156	***
month2	5.611	10.603	0.529	0.599062	
month3	8.194	10.603	0.773	0.443336	
month4	5.878	11.121	0.529	0.599508	
month5	8.378	11.121	0.753	0.454845	
month6	14.178	11.121	1.275	0.208358	
month7	17.078	11.121	1.536	0.131051	
month8	15.153	11.855	1.278	0.207199	
month9	10.878	11.121	0.978	0.332803	
month10	5.078	11.121	0.457	0.649973	
month11	17.028	11.855	1.436	0.157251	
month12	7.778	11.121	0.699	0.487612	

C

		Estimate	SE	t	value	Pr(>|t|)
(Intercept)		29.444	4.362	6.750	1.14E-08	***
2014		5.856	6.470	0.905	0.3696	
2015		27.056	6.169	4.386	5.52E-05	***
2016		14.306	6.169	2.319	0.0243	*
2017		7.431	6.169	1.204	0.2338	

mean monthly counts varied across months of the year (Table 2B); however, the average annual count was significantly lower in 2013 and higher 2015 and 2016 (Table 2C). Mean counts per year are summarized in Table 3; a significant effect of year occurred in 2015 and 2016 (Tables 3 and 2B). Figure 2 plots mean monthly vulture counts overlaying a quadratic trend line. There was no significant effect of month of the year on the data.

The age composition of the vultures observed at the dump was highly variable, and showed no obvious seasonal pattern or trend across the study period (Figure 3). On average the ratio of non-adults to adults was 0.70 (Median=0.51, SE=0.08; N=61).

DISCUSSION

The rubbish dump on Masirah island MMDS is regularly used by Egyptian Vultures. On average a maximum of *c*40 vultures were observed there in any given month, similar to maximum numbers at rubbish dumps in the stronghold country of Turkey (E Buechley, S Oppel unpublished data), which are considered to be globally high counts. Although

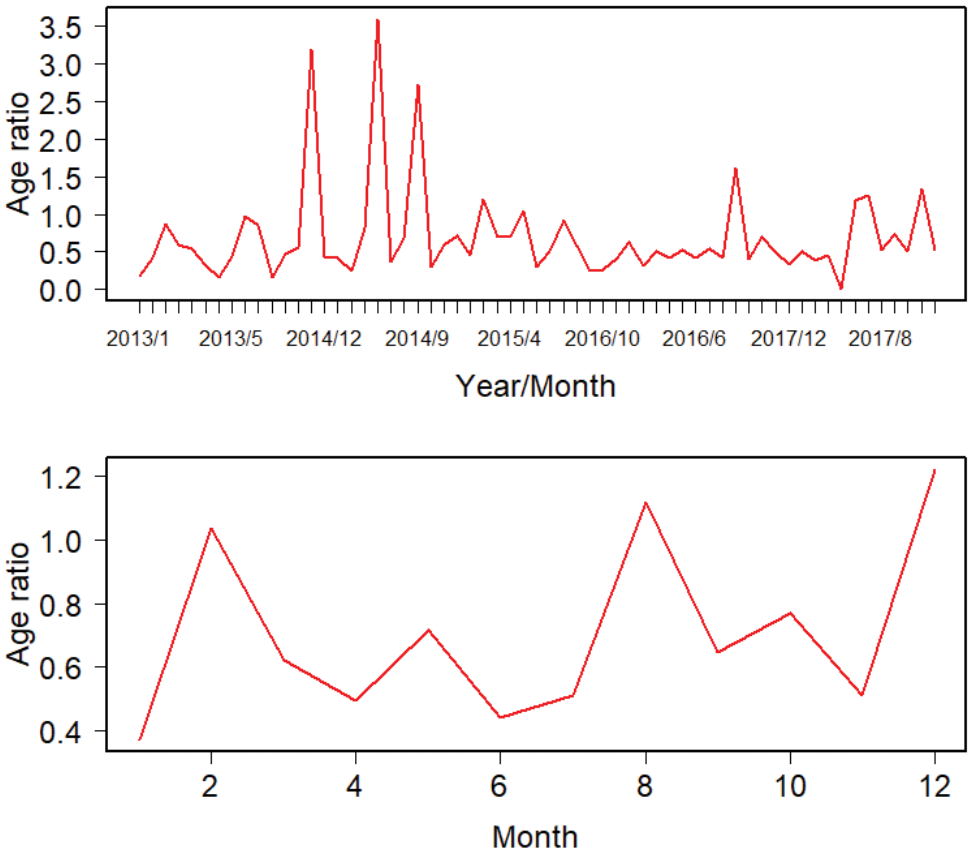

Figure 3. (A) Mean age ratio (non-adult/adult) of Egyptian Vulture counts at the Masirah island municipal rubbish dump January 2013–March 2018. (B) Mean age ratio for each month of the year (1=January, 2=February, *etc*).

Table 3. Summary of Egyptian Vulture counts at the Masirah municipal dump site per year January 2013–March 2018. Data from 2018 were January–March only, and so were not used in analyses of annual variance (Table 2, Figure 2).

Year	N	Mean	Median	SE	Min	Max
2013	12	29.4	25.7	3.99	13	63
2014	10	35.3	34	3.75	21	62
2015	12	56.5	53.2	4.84	28	81.5
2016	12	43.8	37	5.45	20	82
2017	12	36.9	30.2	3.62	24	61
2018	3	26.7	21	7.75	17	42

relatively high in global terms, the numbers counted at any given time at MMDS represent only about 10–15% of the estimated population of Egyptian Vultures on the island (Angelov *et al* 2013), which probably does not include a large number of migrants (Meyburg *et al* In press).

Although the birds that use the rubbish dump could be mostly from nearby territories, radio tracking studies in northern Oman (McGrady *et al* 2018, Meyburg *et al* In press) and what is known of typical Egyptian Vulture foraging (*ie* they forage opportunistically over large areas) suggest that MMDS is used by vultures from across the island. Tracked non-breeding Egyptian Vultures in northern Oman ranged over areas much larger than Masirah (> 800 km^2), despite having food that is persistently super-abundant at discreet locations (*ie* landfills and dumps), and territorial vultures regularly travelled distances in a single day (Meyburg & McGrady unpubl. data) greater than the distance between MMDS and the most distant known territory on Masirah island (Angelov & Yotsova 2012).

Taken together, our results suggest that mean counts peaked during 2015–2016, and declined thereafter leading to a significant quadratic trend in mean monthly counts. We do not know if that recent apparent decline is a result of resident vultures making more use of food sources other than the dump, or a decline in the size of the island's vulture population. Although we had no data on the amount of available food or details of its distribution on the island, it seems unlikely that changes in food supply at the rubbish dump or at other locations was the cause for the declines in numbers at the rubbish dump after 2015–2016. Apparent declines notwithstanding, it should be noted that in June 2018 the national upgrading of waste management resulted in MMDS being closed, and waste is now assembled at a nearby transfer station and transported to the Tahwa engineered landfill, over 200 km to the north on the mainland (22.36° N, 59.35° E, Figure 1). It will be interesting to see whether this change will result in a decline in the vulture breeding population on the island. Data from tracked birds on the mainland show that they continue to visit dumps that have been closed, perhaps driven by adaptations useful when food is scarce (McGrady *et al* 2018).

It was somewhat surprising that no differences were seen in the total number of vultures between months of the year (*ie* no seasonal pattern), nor was there an obvious pattern across months of changing numbers of non-adults. Masirah island has a high density of breeding Egyptian Vultures, which seem to be moderately productive (Angelov *et al* 2013). Thus, we expected a pulse of non-adult vultures coming to the rubbish dump as juveniles fledged, and perhaps using the rubbish dump for some months or longer. The lack of such a pulse could be explained by the apparently long annual breeding period (October–May at least, Angelov *et al* 2013) that would buffer the pulse effect or the availability of other food sources (*eg* at the shore line) coupled with the characteristic wide-ranging foraging behaviour of vultures.

Important goals of the research were to develop a workable scheme for making counts and monitoring the vulture population on Masirah island, and to develop new research skills amongst the ESO field assistants. The methods proved to be such that the field assistants could fit vulture counts into their monthly work schedule, and were able to reliably collect and record data on numbers and ages of vultures, suggesting that citizen scientists might be used for such work (McGrady 2016) on Masirah and elsewhere. Because Egyptian Vulture plumages can be used to age them more precisely during the first four years, it is likely that improvements to the methods can be achieved, given the positive aptitude of the field assistants. Given that waste management changed on the island in June 2018, these results provide a good basis for a before-and-after study of the effects of that change on vultures. As such, counts should be continued so as to make best use of the data already collected, and to provide insight into possible national-scale effects of waste management changes on vultures and other scavenging birds. Using dump site counts as a means of monitoring the population of Egyptian Vultures on the island requires further development and field work, including multi-year breeding surveys that will enable linking count data to breeding population size and productivity. Radio tracking of birds

would help determine the extent to which vultures move away from the island, and if there is any pattern in the use of the dump by island-bound birds. Individually marking birds could help in estimating abundance and detecting trend, as well as understanding movements and survival.

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