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ORIGINAL ARTICLE

Trapping of Saker Falcon *Falco cherrug* and Peregrine Falcon *Falco peregrinus* in Saudi Arabia: Implications for biodiversity conservation

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Abstract The numbers of *Falco cherrug* and *Falco peregrinus* trapped during their migration over the Kingdom of Saudi Arabia (KSA) were investigated from published reports and through interviews with well-known trappers and dealers over several years (1989–2013). The number of trapped individuals increased for both species over a 23 year period, which is probably related to an enhanced trapping effort. Time series analysis suggests that the number of Saker Falcons being trapped is likely to be stable with annual fluctuations in the coming ten-year period, whereas the number of trapped Peregrine Falcons will probably decline with a small fluctuation initially. Using the population viability analysis suggests a high extinction rate for the Saker Falcon population migrating through KSA during the coming 10 and 20 years; whereas Peregrine Falcons probably take more than 100 years to reach the extinction threshold. However, the increase in the trapping period, especially in the spring, that has been observed during the last five years could increase the number of falcons trapped in the future. As both falcon species are migratory, implementing conservation actions across all range states is important to ensure a favourable conservation status for the Saker and Peregrine Falcons. Both species will benefit through the implementation of the Global Action Plan (GAP), developed by the Saker Falcon Task Force.

1. Introduction

The Saker Falcon *Falco cherrug* (from now on referred to as Saker) is classified as Endangered according to the IUCN Red-list of Threatened Species, due to a rapid population decline globally of 47% between 1993 and 2012 (Birdlife International, 2012; IUCN, 2013). According to Kovács et al. (2014) the Saker population trend varies between countries, for instance the population is increasing or stable in Austria, the Czech Republic, Hungary, Slovakia, and

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Ukraine, whilst it is decreasing in Bulgaria, China, Iraq, Kazakhstan, Russia, Serbia and Uzbekistan. As a result of a global population recovery, the Peregrine Falcon *Falco peregrinus* (from now on referred to as Peregrine) is now classified as Least Concern (IUCN, 2013). Both species are considered as passage migrants and winter visitors to Saudi Arabia (Shobrak and Pallaite, 1998; AlRashidi, 2004; Porter and Aspinall, 2010; Kenward et al., 2013). They arrive in Saudi Arabia during September–November on their winter migration, and return between mid-February and April on their spring migration, with a small number of birds being recorded as late as mid-May. There have been a few records of wintering in Saudi Arabia between October and March (Shobrak and Pallaite, 1998; Ferguson-Lees and Christie, 2001; Dixon, 2009; Porter and Aspinall, 2010).

The Saker and Peregrine are typically used by falconers in Arab countries, and traditionally have been trapped for falconry during the autumn migration and released after the hunting season in the spring (Allen, 1980; AlRashidi, 2004). Increasingly, instead of releasing birds trapped on migration, falcons are being retained in captivity by falconers (Erwda, 2003; AlRashidi, 2004; Kenward et al., 2013). At the same time, there has been an increasing demand for juvenile falcons for falconry, with trappers extending their activities to include the breeding grounds, especially in central and northern Asia (Dixon, 2005; Dixon et al., 2012). The dissolution of the Soviet Union in the 1990s has allowed greater access to the breeding grounds, and there has been a marked increase in the level of trapping, especially for Saker (Kenward et al., 2007; Birdlife International, 2013). Trapping in these areas has become unsustainable, which has had a negative effect on falcon populations, especially the Saker (Barton, 2002a; ERWDA, 2003; Levin, 2003; Karyakin et al., 2004; Kovács et al., 2014). Illegal trapping has been claimed as one of the main causes of decline of the Saker Falcon in Asiatic Russia (especially in the Altai-Sayan region), China, Kazakhstan, Kyrgyzstan, Mongolia, Turkmenistan and Uzbekistan (Li et al., 2000; Nikolenko, 2007; Ma and Chen, 2007; Levin, 2011; Nikolenko and Karyakin, 2013; Collar et al., 2013). This activity, along with other threats such as electrocution by medium-voltage power-lines; unsustainable trapping/harvest along the migration routes, secondary poisoning, decreased prey availability and collision with man-made structures, all appear to have contributed to the decline of the species overall (Nagy and Demeter, 2006; Cites, 2011; Kovács et al., 2014).

Following the revised population status of the Saker (IUCN, 2013), a Resolution was adopted at the 10th Conference of the Parties to the Convention of the Migratory Species (CMS) listing the species on Appendix I. Subsequently, a Saker Falcon Task Force (STF) was established under the auspices of the Coordinating Unit (CU) of the UNEP/CMS Memorandum of Understanding on the Conservation of Migratory Birds of Prey in Africa and Eurasia (Raptors MoU). The main goal of the STF is to develop a Global Action Plan for the conservation of the Saker. This Global Action Plan includes a management and monitoring system to help ensure that the trapping of wild falcons is sustainable (Williams, 2013; Kovács et al., 2014).

As for the Peregrine Falcon, the species were put on the endangered species list in 1970 because of a problem with egg shell thinning that was caused mainly by use of the pesticide DDT during the 1950s and 60s, habitat loss, hunting,

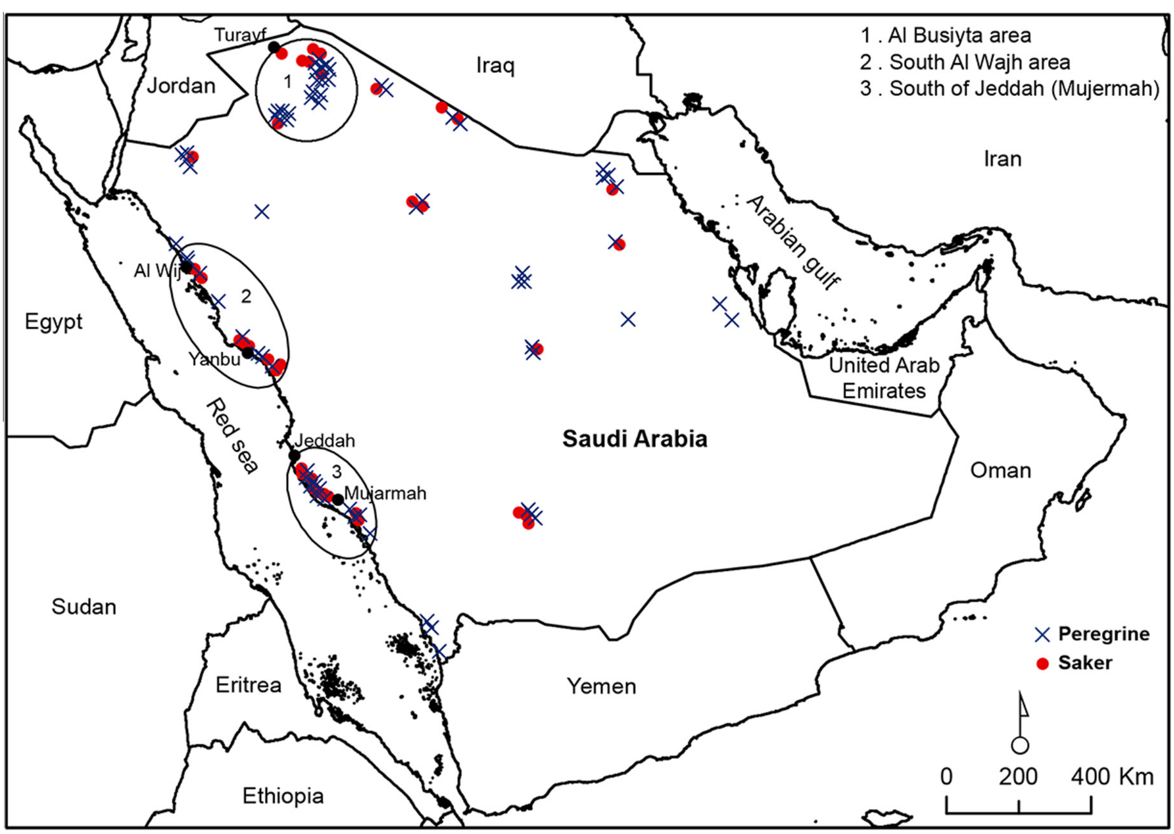

Figure 1 Locations of falcon captures in Saudi Arabia (<http://www.mekshat.com/vb/showthread.php?t=322535).

Table 1 Numbers of Saker and Peregrine Falcons trapped in Saudi Arabia from two sources: Dataset (1) presented the published report (Pallaite, 1993; Al Zanbahy, 2008) and the gap period estimated by linear regression of all; counts on years (based on linear trend exhibited by raw data "presented in red") covering the period (1989–2013). Dataset (2) is based on the data presented by a falconer and a trapper named Mohammed Al Khathlan covering the period 1996–2013.

Years	Dataset (1) published reports		Dataset (2) (Al Khathlan)	
	Saker	Peregrine	Saker	Peregrine
1989	23	94		
1990	18	55		
1991	10	64		
1992	20	54		
1993	16	85		
1994	18	82		
1995	18	85		
1996	19	88	34	143
1997	19	90	29	128
1998	20	93	13	139
1999	20	96	38	178
2000	20	99	18	105
2001	21	102	34	122
2002	24	111	24	176
2003	5	116	41	189
2004	20	132	37	156
2005	22	127	22	163
2006	21	109	36	211
2007	41	131	34	175
2008	31	86	39	181
2009	12	118	27	166
2010	18	96	39	193
2011	20	109	38	214
2012	21	99	41	217
2013	15	104	31	211
Total	492	2425	575	3067

and other factors (Tordoff and Redig, 1997; Cade, 2003). In addition to the ban on DDT, the implementation of a strategic plan including reintroduction of young stages and release of over 6000 Peregrines (Peterson, 2006) led to population recovery (Craig et al., 2004). As a result of such successful efforts, Peregrine Falcons have recently been removed from the endangered species to be listed and considered to be globally "Least Concern" (BirdLife International, 2013).

Although trapping has been identified as a major cause of the Saker population decline, there is little published information regarding the current extent of trapping and trapping effort. Lack of data is especially noticeable for countries along the migration routes, such as Saudi Arabia. This study was undertaken to quantify the numbers of Saker and Peregrine Falcons being trapped within Saudi Arabia, and make recommendations for the sustainable use of both species.

2. Methodology

The number, and timing, of Saker and Peregrine trapped were investigated through a combination of major unpublished reports (Pallaite, 1993; Al Zanbahy, 2008), information from the web-site www.mekshat.com, and through interviews with 15 falconers during a visit to a falcons camp in June 2013. One major falcon trapper (Mr. Mosad Al thalabi who's known by Ebn Al Oud) was interviewed as part of the earlier studies by Pallaite (1993) and Al Zanbahy (2008), and as he was still active, he was re-interviewed in January 2009 as part of this study. An additional major falcon trapper (Mr. Mohammed Al Khathlan) was identified through discussion with a number of falconers. These two major trappers operated in different areas, however, to avoid any overlap the data were treated separately. Dataset (1) data provided by Ebn Al Oud over the period between 1989 and 2009, which presented the published report, covering falcon trapping south of Jeddah down to the border with Yemen. The numbers of falcons trapped in the gap period (1994–2001) reported in the published reports were estimated by linear regression of all counts on years (based on linear trend exhibited by raw data) and by resampling from normal random variables based on the basic parameters dataset (1). As dataset (2) provided by Al Khathlan were covering falcons trapped in the period from 1996 to 2013, covering mostly all Saudi Arabia. To determine the status of falconry, two main questions were part of the interview with 15 of falconers and trappers using agree or disagree for answers; (a) do you think that the number of falconers increased or decreased in the last 10 years? (b) there are many falcons' trappers which decreases the number of falcons?. The methods used to trap falcons were already documented by several others (Allen, 1980; Barton, 1998; AlRashidi, 2004).

On these data, time series analysis (ARIMA model) was applied using StatSoft package (StatSoft Inc, 1995). This model was known also as Box–Jenkins methods or (p,d,g) model, where p denotes the number of autoregressive values, q denotes the number of moving averages, d the order of differencing, representing the time series required to bring the series to a kind of statistical equilibrium (Box and Jenkins, 1976). This type of statistical analysis is generally used with data which are not independent and consecutively depended on each another, like the data used in this study. The time series analysis has rapidly developed in theory and practice since 1970s to forecast and control (Frausto et al., 2003; Babazadeh and Shamsina, 2014). In addition to time series analysis the population viability parameters were applied to determine the possible future effect of the trapping according to Dennis et al. (1991). The method of these latter authors was programed in excel as best described in detail in Morris et al. (1999).

On the basis of identifying trapping areas mapping the migration routes for the Saker Falcon through Saudi Arabia was undertaken using the information available in the falconers' website. These areas or locations were marked on a map of Saudi Arabia (Fig. 1). In addition; published satellite tracking data were used to predict the route and the stopover sites that the falcons used when migrating through Saudi Arabia.

3. Results

3.1. Trapping areas

Fig. 1 shows the locations of trapped Saker and Peregrine within Saudi Arabia. Three main trapping areas are apparent, with concentrations in the north of Saudi Arabia close to the Iraq and Jordan borders at an area called Al Busiyta, and

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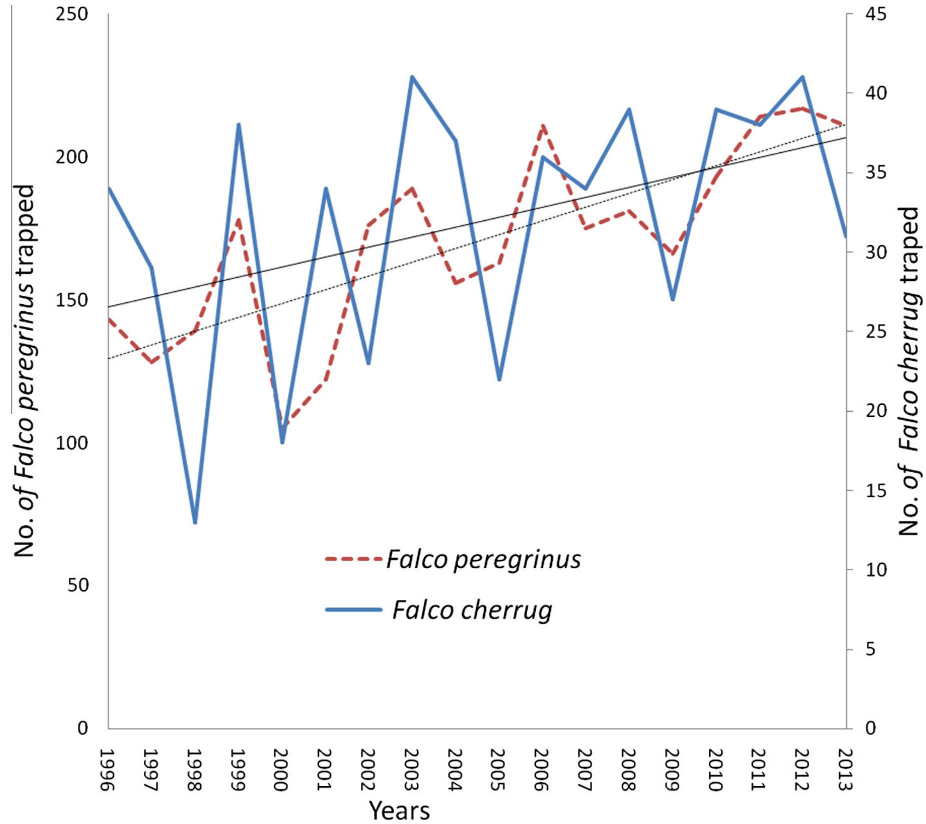

Figure 2 Number of and Saker Falcons and Peregrine Falcons trapped in Saudi Arabia during the periods of 1996–2013. (Regression line for No. of trapped Saker = 0.62 * Year – 1211.301; No of trapped Peregrine = 4.810 * Year – 9471.484).

two areas along the Red Sea coast. These trapping areas suggest the possible flyway for both species whilst crossing the Arabian Peninsula. The main habitat features of these areas are open land with almost no ground vegetation. These data also suggest that the Red Sea coast and the northern areas south of Turayf are probably the most important stopover areas for migrating falcons. Temporal variation was seen in the number of trapped falcons.

Table 1 shows the numbers of trapped Saker and Peregrine Falcons in Saudi Arabia. Both datasets showed considerable fluctuation in the number of falcons captured per year for both sets of data. The number of birds trapped fluctuated between 5 and 41 for the Saker Falcon and 86–217 for the Peregrine Falcon during 1996–2013. According to the trend lines, there is slight increase in the number of falcons trapped during the last 18 years for dataset 2 (Fig. 2). For subsequent analysis, the number of falcons trapped in the gap period (1994–2001) of the reported data, presented in the dataset (1), was estimated by regression of all the trapped falcons on all years and by resampling from normal random variables (based on mean, standard deviation, minimum and maximum of all counts). Variability in all periods was evident with a coefficient of variation of 28.0%, 49.8% and 45.1% for the Saker Falcon and 25.5%, 12.5% and 28.3% for the Peregrine Falcon in 1989–1993, 2002–2009 and the two periods, respectively (Fig. 3).

3.2. Temporal variation in the number of trapped falcons

Table 1 shows the number of trapped Saker and Peregrine in Saudi Arabia between 1989 and 2013. According to the estimated global population of the Saker Falcon the total number of trapped Saker Falcons presented 3.8–5.2% of the median population size of the species suggested by BirdLife International, 2013, whereas the total trapped Peregrine Falcon presented 0.2–0.3% of the global population for the both datasets (BirdLife International, 2013). However, both datasets showed considerable fluctuation in the number of falcons captured per year, with an annual mean for Saker of 20 for dataset (1) and 31 for dataset (2) (range 5–41 individuals), and an annual mean for Peregrine of 20 for dataset (1) and 168 for (range 86–217 individuals). According to the trend lines, there is a slight increase in the number of falcons trapped during the last 18 years for dataset 2 (Fig. 2). For subsequent analysis, the number of falcons trapped in the gap period (1994–2001) of the reported data, presented in the dataset (1), were estimated by regression of all trapped falcons on all years and by resampling from normal random variables (based on mean, standard deviation, minimum and maximum of all counts). Variability in all periods was evident with a coefficient of variation of 28.0%, 49.8% and 45.1% for Saker and 25.5%, 12.5% and 28.3% for Peregrine in 1989–1993, 2002–2009 and the two periods, respectively (Fig. 3).

3.3. Estimated numbers of trapped falcons in the future

Based on analysis of the data in the questionnaire obtained after interviewing falconers and trappers it was observed that 100% of them agreed with the increase in the number of falconers in Saudi Arabia and 91% agreed with an increase in the number of trappers. This increase in the number of

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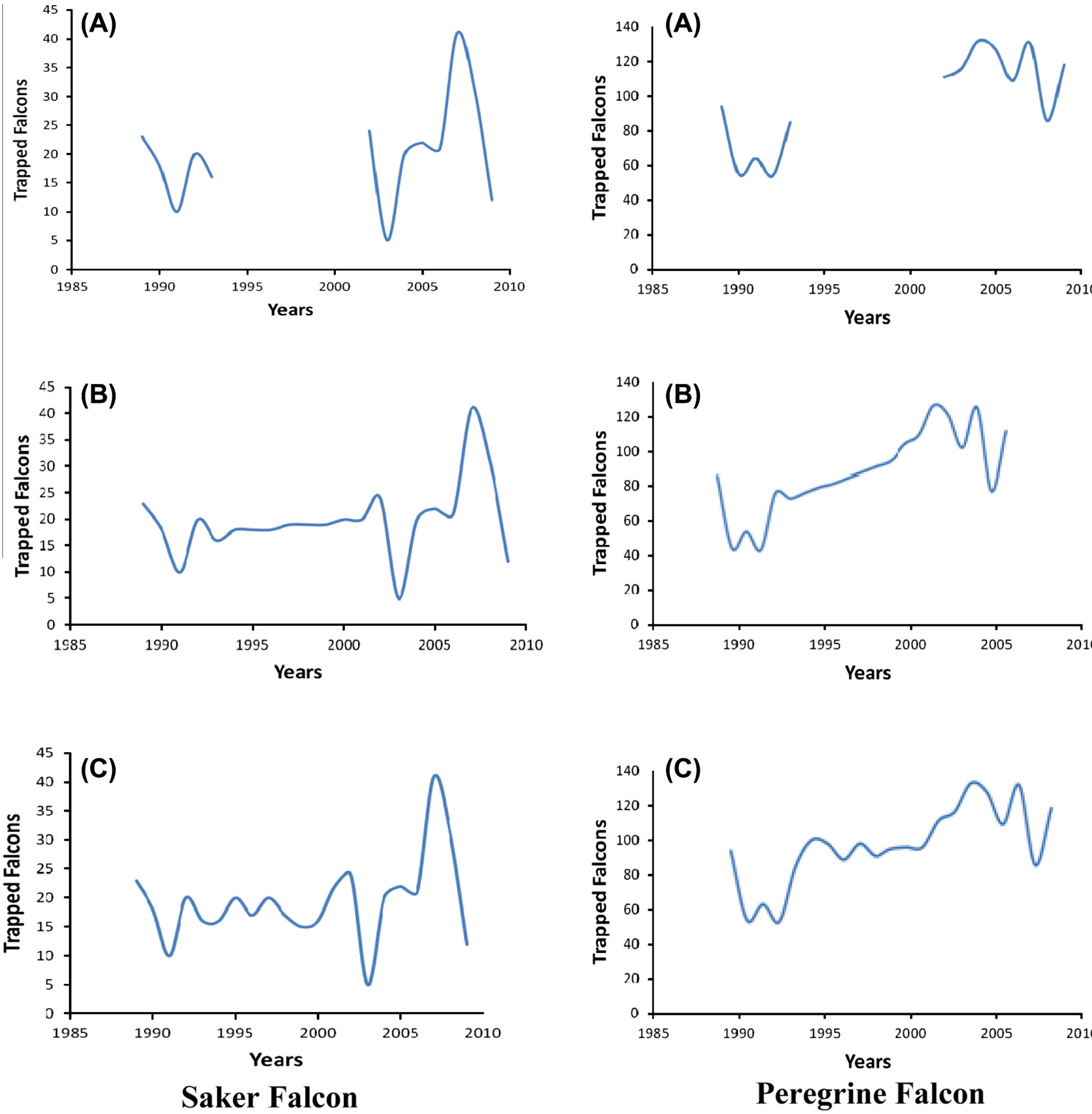

Figure 3 Trapped Saker Falcons (left panels) and Peregrine Falcons (Right panels) in Saudi Arabia (set (1) in the periods of 1989–1993 and 2002–2009 (A) and the gap in between estimated by the regression analysis (B) or derived from a normal random variables distribution based on mean, standard deviation and range of the two periods (C).

falconers and trappers could have an implication in the future conservation of the species.

3.3.1. Time series analysis

3.3.1.1. Saker Falcon. Based on data set (1), the time series data of the Saker Falcon including estimated gap years is represented by the ARIMA model (1,0,0) (1,0,0), seasonal lag 10 (each 10 years as parameter of the model); the predicted number of trapped Saker Falcons during the next ten years (2010–2019) was estimated to undertake variable fluctuations without decline (Tables 2 and 3; Fig. 4). The mean and ranges of such a period are 20.25 ± 3.34 (15–27) with a coefficient of variation (CV) of 16.5%. Whilst data set (2), which represents the overall number of falcons trapped in 1996–2013 remains relatively constant; predictive values for the Saker Falcon by the ARIMA model (1,0,0) (1,0,0), seasonal lag 6, with a mean of 32.23 + 3.2, ranged from 32 to 35 during the next ten years "2014–2023" (Fig. 4).

3.3.1.2. Peregrine Falcon. The time series analysis for the data set (1) for the Peregrine Falcon was described by the ARIMA model (2,0,0), seasonal lag 4 and the predicted number of

Table 2 Time Series Analysis Parameters (TSA) of the numbers of Saker Falcons and Peregrine Falcons trapped in dataset (1) and, which cover the periods of 1989–1993 and 2002–2009 using the ARIMA model and dataset (2) (the periods from 1996 to 2013).

	Dataset (1)				Dataset (2)			
	Param.	Asympt. Std. Err.	Asympt. T	*P*	Param.	Asympt. Std. Err.	Asympt. T	*P*
Saker Falcon								
Constant	19.753	2.428	8.134	0.000	31.989	2.135	14.983	0.000
p(1)	0.176	0.255	0.689	0.499	−0.182	0.259	−0.702	0.493
p(2)					0.256	0.269	0.951	0.357
Ps(1)	0.339	0.717	0.473	0.642				
Peregrine Falcon								
Constant	79.004	17.054	4.633	0.000	171.677	14.140	12.142	0.000
p(1)	0.313	0.219	1.432	0.169	0.5877	0.278	2.117	0.0527
p(2)	0.626	0.245	2.554	0.020	0.0480	0.322	0.149	0.884
Ps(1)					−0.3552	0.300	−1.184	0.256

Table 3 Predicted trapping of two falcons; the Saker Falcon and the Peregrine Falcon during the next ten years in Saudi Arabia. Forecasting from time series analysis based on Dataset (1), the periods of 1989–1993 and 2002–2009 and the gap in between estimated by the regression analysis, and Dataset (2) in the periods of 1996–2013.

Dataset (1)					Dataset (2)				
Years	Saker		Peregrine		Years	Saker		Peregrine	
	Forecast	Std. Err.	Forecast	Std. Err.		Forecast	Std. Err.	Forecast	Std. Err.
2010	18.552	7.365	95.584	15.791	2014	34.477	8.262	195.018	29.956
2011	19.803	7.477	108.585	16.547	2015	31.283	8.397	191.303	34.747
2012	21.150	7.481	98.632	20.107	2016	32.755	8.597	175.733	36.691
2013	14.744	7.481	103.650	21.183	2017	31.669	8.597	164.325	37.505
2014	19.835	7.481	98.995	23.108	2018	32.244	8.610	160.652	37.854
2015	20.514	7.481	100.676	24.162	2019	31.861	8.610	161.061	38.006
2016	20.176	7.481	98.291	25.447	2020	32.078	8.610	165.600	38.923
2017	26.956	7.481	98.596	26.370	2021	31.940	8.610	166.168	39.256
2018	23.566	7.481	97.199	27.324	2022	32.021	8.611	171.202	39.403
2019	17.124	7.481	96.953	28.101	2023	31.971	8.611	174.926	39.467

trapped falcons for the next ten years (2010–2019) with basic statistics of 99.7 ± 3.81 (96–109) and CV of 3.82%. The number of falcons trapped over this period show small variable fluctuations in the first years, with a very slight decline in later years (Tables 2 and 3; Fig. 5). The results for data set (2) showed a decline in the predicted values of Peregrine Falcon trapped when described by the ARIMA model (2,0,0), (1,0,0) seasonal lag 6, with a mean of 172.6 + 3.81 (Fig. 5). Model parameters of these analyses are given in Table 3.

3.3.2. Assessment of trapped population viability

Based on population parameters (Infinitesimal mean μ and Infinitesimal variable σ^2), population viability measures of the predicted number of Saker Falcon and Peregrine Falcons trapped are given in Tables 4 and 5 for data sets (1 and 2). These measures are based on numbers of trapped flacons in data sets (1 and 2) covering the period with estimation of gap by resampling of random normal variables distribution (1989–2009 "21 years") and from (1996–2013 "18 years"). The mean time to extinction threshold of trapped 4, 8 and 11 individuals for the Saker Falcon is about 33.8, 12.5 and 2.7 years respectively in all cases of dataset (1), whilst the mean time to the extinction threshold of trapped 4, 8 and 12 individuals for the dataset (2) are about 377, 249 and 175 years respectively. The confidence interval for the mean time to extinction of the trapped falcon is usually large or the dataset (2) and may be due to a skew in the population size. However, Table 4 showed that the probability of the extinction of the trapped Saker increases with the increase of the number of the extinction of threshold for both data sets (1 and 2). The cumulative distribution function of extinction time for trapped Saker Falcon from Saudi Arabia is estimated at around 3–15 years with threshold 4, 8, 12 for both datasets (Fig. 6). Such a scenario may be even worse if the extinction threshold increases above 11 individuals. However, since μ (Infinitesimal mean, muˆ) is negative, then all populations of the trapped Saker Falcon will decline eventually and the probability is that any threshold lower than the current captured population size will eventually lead to the disappearance of migratory Saker Falcons from Saudi Arabia. Such a finding indicates not only that the ultimate decline in the number of trapped migrating Saker Falcons is a certainty, but also that the extinction threshold of migratory Saker is likely to be reached quite soon if no conservation management is implemented.

As the number of trapped Peregrine was higher than Saker in both datasets, therefore I used an extinction threshold of 10, 20 and 30 of trapped individuals per year with the probability of extinction 100, 20 (Table 4). The results showed that the

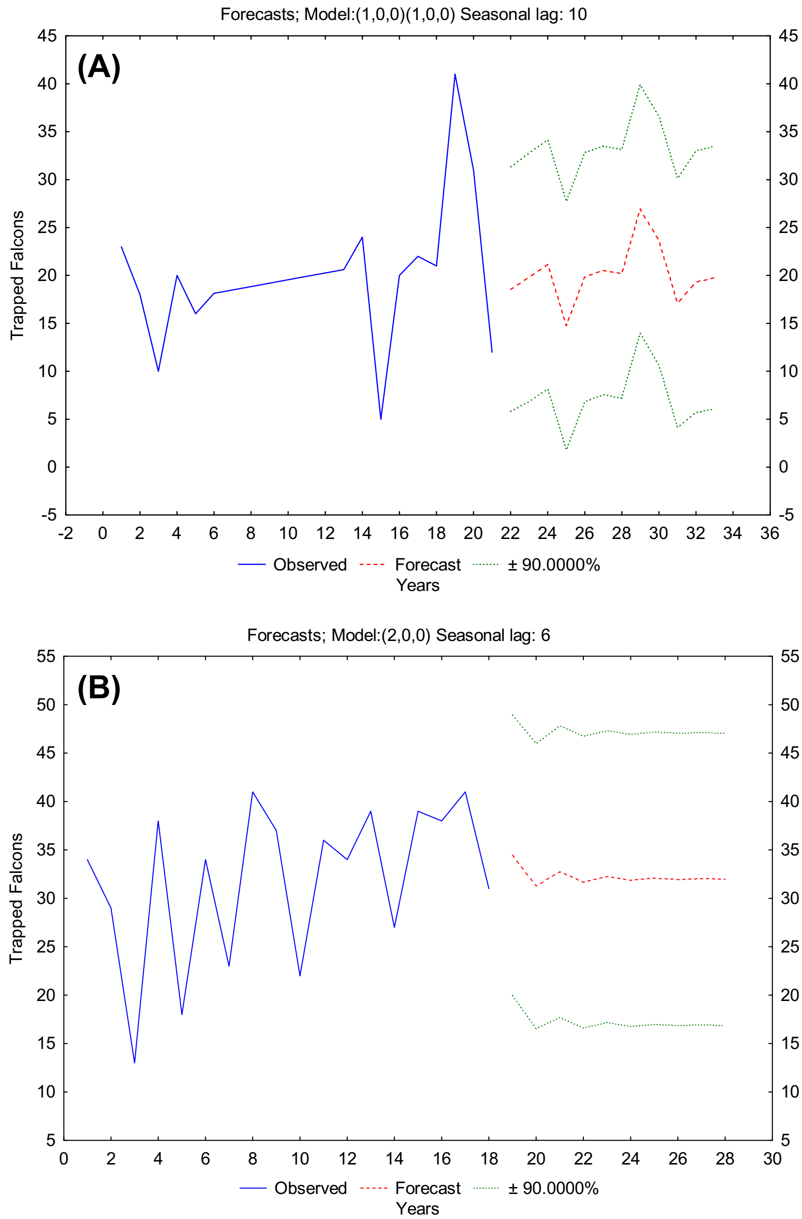

Figure 4 Predicted number of trapped Saker Falcons in Saudi Arabia during the next ten years in Saudi Arabia forecasting from time series analysis based on counts from the periods of 1989–1993 and 2002–2009 and the gap in between estimated by the regression analysis (A), and dataset (2) in the period of 1996–2013(**B**).

mean time to extinction threshold of 10, 20 and 30 individuals (i.e., to decline from 118 to 10 or 20 or 30 individuals) for the population of trapped Peregrine Falcon in dataset (1) is about 217, 156 and 120 years respectively. Whereas the mean time to extinction thresholds of 10, 20, 30 individuals for dataset (2) for the trapped population are about 133, 103 and 85 years which is lower than dataset (1). Although the probability of extinction of the trapped Peregrine is increased with the increase of the proposed extinction threshold but the possibility that extinction of the trapped Peregrine Falcon probably will occur within the next 100 years. However, since μ is positive (Table 5), then only a subset of the population of the Peregrine Falcon would eventually reach the extinction threshold with present threats to the species. The cumulative distribution function of extinction time for the Peregrine Falcon is estimated from both datasets with a threshold of 10, 20 and 30 probably more than 100 years (Fig. 7). The increase in the number of falcons trapped indicated that the average of the possible trapped population trajectories for the two species will remain the same, within confidence limits (Tables 4 and 5).

4. Discussion

4.1. Trappings areas

Information drawn out from the website suggests that the areas in the northern Saudi Arabia and the areas along the coast of the Red Sea are probably important for both species

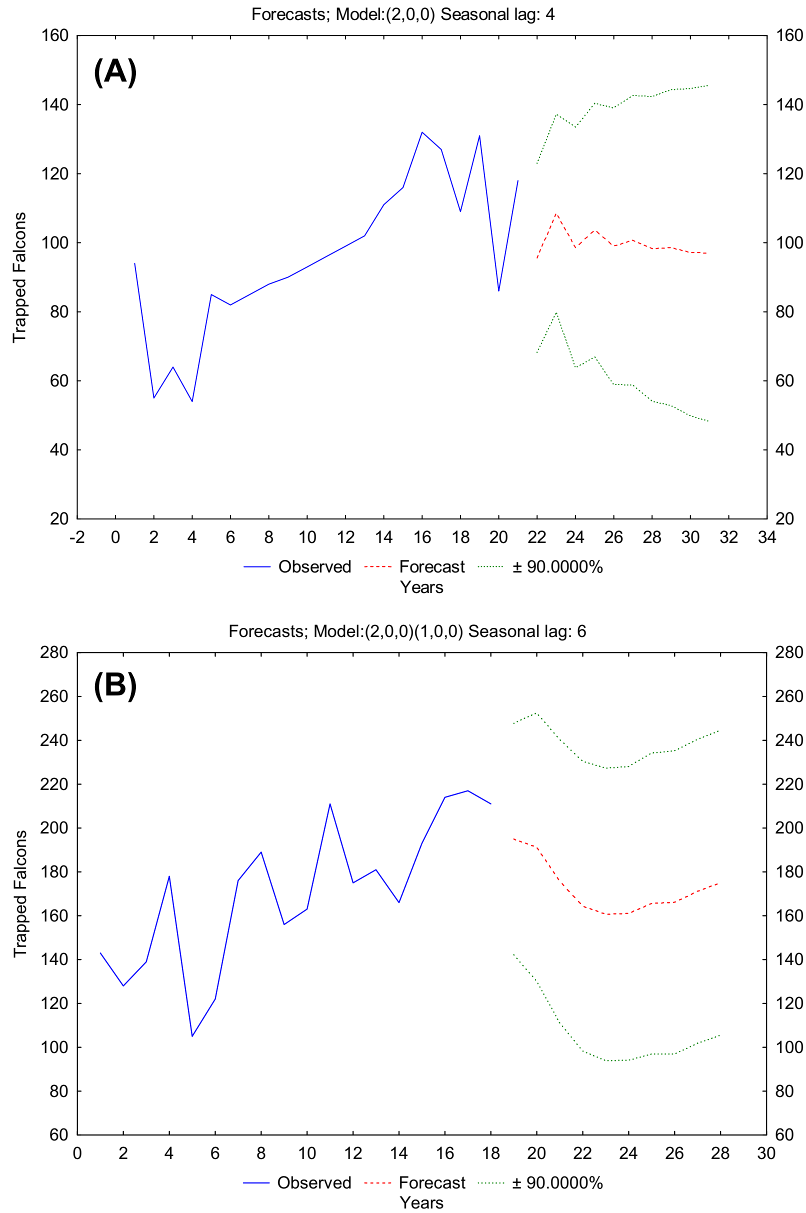

Figure 5 Predicted trapped Peregrine Falcons in the next ten years from Saudi Arabia forecasting by time series analysis based on counts from the periods of 1989–1993 and 2002–2009 and the gap in between estimated by the regression analysis (A), and dataset (2) in the period of 1996–2013 (B).

(www.mekshat.com/vb/showthread.php?t = 322535). The area in northern Saudi along the border with Iraq and Jordan is called Al Busiyta, which is an open area with scattered small patches of vegetation. This area is known as one of the traditional trapping sites used by trappers (AlRashidi, 2004). The Red Sea coast is a well-known migratory route for a range of species (Shobrak, 2011; Birdlife International, 2012) including water birds, passerines and other birds of prey. According to Newton (2004, 2008) birds during migration are under pressure to use the shortest possible route; however, the precise course taken will depend on weather patterns, *en route* resources and the geographical features they encounter. The northern site is probably an important route for central and eastern Asian migratory species crossing the Arabian Peninsula to get to their winter ground in Africa. Moreover, the concentrations of water birds and other migratory species along the Red Sea coast probably attract hunting falcons.

Satellite tracking data of the Peregrine Falcon showed that the northern site is an important route for the Eurasian tundra population crossing the Arabian Peninsula (Dixon et al., 2012). In addition nestlings fitted with microchips and observations of birds wearing Arabic jessies (sabooka) suggested that the population that migrates through the Arabian Peninsula probably originated from the Yamal Peninsula located in Yamal-Nenets autonomous district of northwest Siberia, Russia (McDonald, 1997; Eastham et al., 2000; Quinn, 2000; Barton, 2002b). For the Saker no satellite data are available, however, the recovery of four rings for nestlings ringed in Kazakhstan, and captured south of Jeddah along the Red Sea coast showed the importance of the areas along the

Table 4 Viable population parameters of the trapped Saker Falcon for Datasets 1 and 2.

Model parameters	Dataset 1			Dataset 2		
Length of time series, tq (yrs)	**20**	**20**	**20**	**17**	**17**	**17**
Number of transitions, q	**20**	**20**	**20**	**17**	**17**	**17**
Infinitesimal mean, mu^	**−0.0325**	**−0.0325**	**−0.0325**	**−0.0054**	**−0.0054**	**−0.0054**
Infinitesimal var., sigma^2∼ (unbiased)	0.3566	0.3566	0.3566	0.2557	0.2557	0.2557
MLE variance, sigma^2^ (biased)	0.3388	0.3388	0.3388	0.2406	0.2406	0.2406
Continuous rate of increase r∼	0.1458	0.1458	0.1458	0.1224	0.1224	0.1224
Finite rate of increase, lambda∼	1.1569	1.1569	1.1569	1.1302	1.1302	1.1302
"Initial" population size, nq	**12**	**12**	**12**	**31**	**31**	**31**
Extinction threshold, ne	**4**	**8**	**11**	**4**	**8**	**12**
Prob of ultimate extinction, pi^	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**
Mean time to extinct. threshold, theta^	**33.7729**	**12.4646**	**2.6749**	**376.8488**	**249.2849**	**174.6648**
Modal time to extinct. threshold, $t^{*\wedge}$	**1.1860**	**0.1617**	**0.0074**	**5.8073**	**2.5415**	**1.2478**
Prob. of extinction after 10 years	**0.6084**	**0.8563**	**0.9698**	**0.1956**	**0.3943**	**0.5522**
Prob. of extinction after 20 years	**0.7414**	**0.9077**	**0.9807**	**0.3670**	**0.5533**	**0.6795**

Table 5 Viable population parameters of trapped Peregrine Falcon for datasets 1 and 2.

Model parameters	Dataset (1)			Dataset (2)		
Length of time series, tq (yrs)	**20**	**20**	**20**	**17**	**17**	**17**
Number of transitions, q	**20**	**20**	**20**	**17**	**17**	**17**
Infinitesimal mean, mu^	**0.0114**	**0.0114**	**0.0114**	**0.0229**	**0.0229**	**0.0229**
Infinitesimal var., sigma^2∼ (unbiased)	0.0480	0.0480	0.0480	0.0434	0.0434	0.0434
MLE variance, sigma^2^ (biased)	0.0456	0.0456	0.0456	0.0409	0.0409	0.0409
Continuous rate of increase r∼	0.0354	0.0354	0.0354	0.0446	0.0446	0.0446
Finite rate of increase, lambda∼	1.0360	1.0360	1.0360	1.0456	1.0456	1.0456
"Initial" population size, nq	**118**	**118**	**118**	**211**	**211**	**211**
Extinction threshold, ne	**10**	**20**	**30**	**10**	**20**	**30**
Prob of ultimate extinction, pi^	0.2921	0.4127	0.5052	0.0330	0.0716	0.1127
Mean time to extinct. threshold, theta^	217.0809	156.1154	120.4528	133.2541	102.9634	85.2444
Modal time to extinct. threshold, $t^{*\wedge}$	42.7913	22.5456	13.5344	60.2819	38.8193	27.7339
Prob. of extinction after 20 years	**0.0052**	**0.0397**	**0.1058**	**0.0158**	**0.0456**	**0.0818**
Prob. of extinction after 100 years	**0.1236**	**0.2443**	**0.3510**	**0.0001**	**0.0022**	**0.0094**

coast for both species (Kenward et al., 2007, 2013). This probably showed that the areas along the coastal parts of the Saudi Red Sea could be considered as a narrow flyway, which channels into corridors, where falcons may encounter topographic bottlenecks. Therefore, the Red Sea coast is an important flyway for several species of water birds and passerine which falcons consume during their migration. The information available is, however, not conclusive, concerning the migration route falcon populations migrating over the Arabian Peninsula and more investigations are needed to determine the migration route over the Arabian Peninsula especially for the Saker Falcon.

4.2. Number of trapped falcons

Despite a significant number of studies of population modelling on birds of prey, no published work has investigated the impact of trapping on a species, or to predict how this may alter in future. The annual fluctuations recorded during the period of this study are most likely due to two factors. Firstly, variation in annual productivity on the breeding grounds will determine the number of falcons that migrate through the region. Large annual variations have been recorded in both the Saker and Peregrine, as well as a range of other bird species (Newton, 1989, 2004, 2013; Kenward et al., 2007; Monnert, 2009). Secondly, there could be annual fluctuations in trapping effort within Saudi Arabia in response to the demand for falcons. In addition to annual fluctuations in trapping effort, the results from interviews with falcon trappers showed an increase in trapping activities. This increase is likely to be due to an increased demand for birds caught in Saudi Arabia following stricter enforcement of CITES regulation by Saudi Wildlife Authority reducing imports from the breeding grounds implementation in Saudi Arabia. Of particular concern is the increase in the number of Saker trapped in Saudi Arabia during the period of the study, despite a decline in the overall breeding populations. Dixon (2007, 2009) showed declines in Saker populations across the breeding range, and Moshkin (2010) estimated a decrease in the Saker breeding populations in Russia, Kazakhstan, China and Mongolia by 53.6% in the last 20 years. Some of the increase in the number of Peregrine trapped could be as a consequence of the widespread recovery in breeding populations (IUCN, 2013).

Another possibility explaining the slight increase in the trapped falcons found in this study could be as a result of a shift in migration. This was suggested by Kenward et al. (2007, 2013) for the Saker Falcon as eight percent of Saker Falcons ringed in Kazakhstan were trapped in the Arabian

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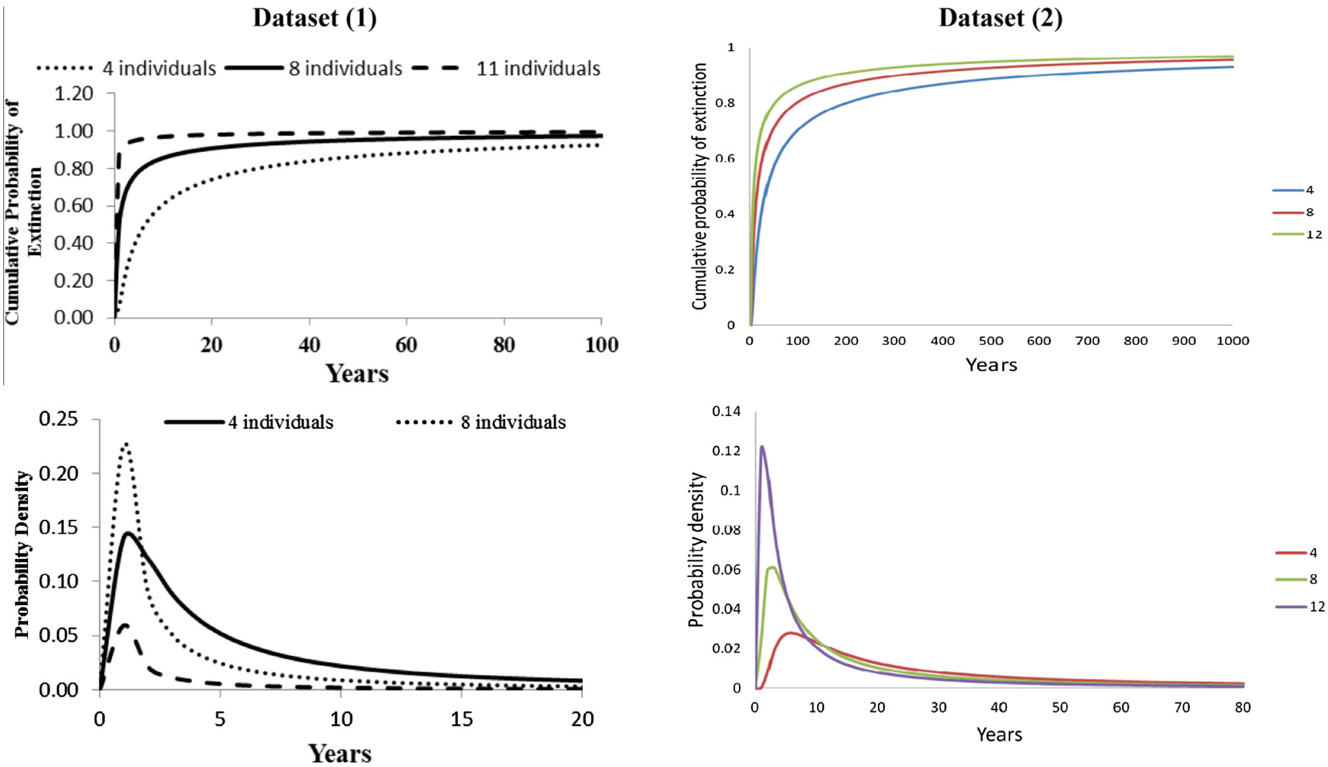

Figure 6 Cumulative probability of extinction (above) and probability density (below) of the Saker Falcon in the next 20 and 100 years respectively based on dataset (1) of the trapped falcon on a threshold of 4,8 and 11 individuals (left) and a threshold of 4, 8 and 12 individuals for dataset (2).

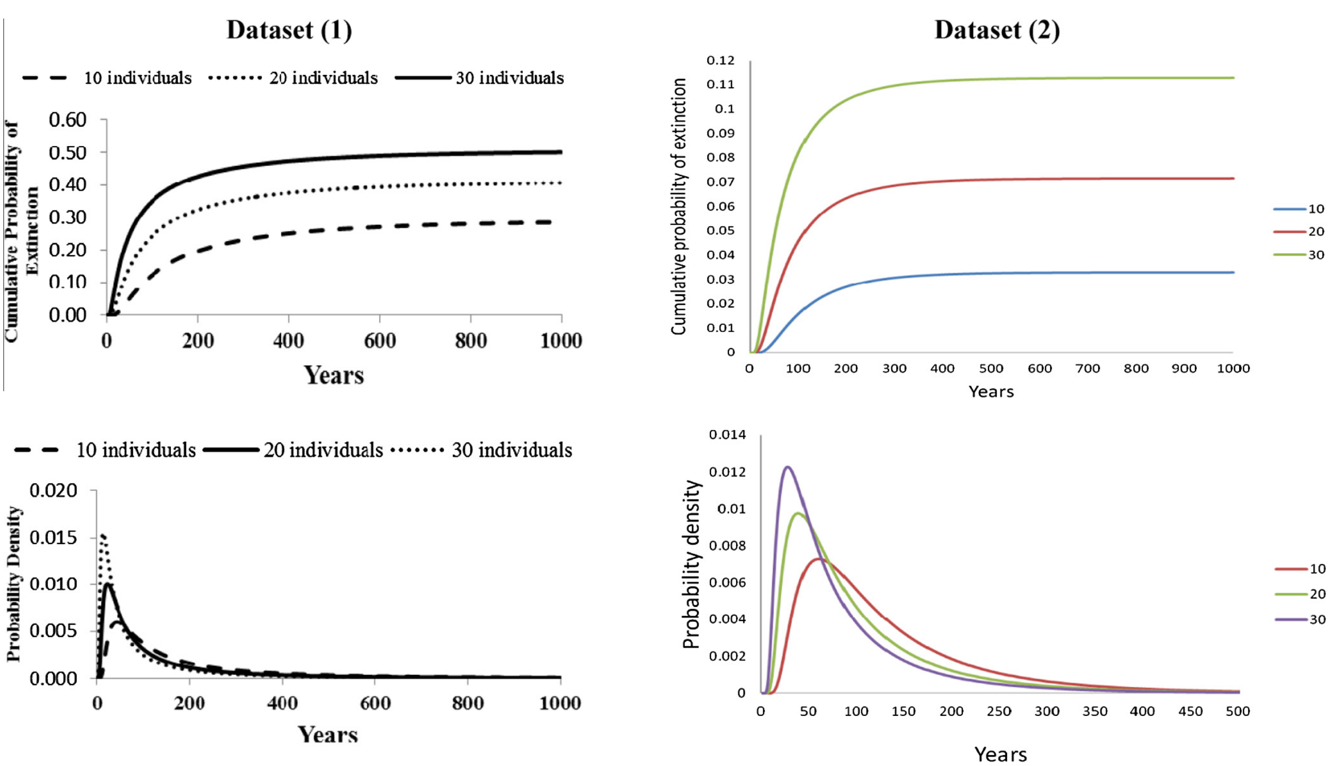

Figure 7 Cumulative probability of extinction (above) and probability density (below) of the Peregrine Falcon in the next 20 and 100 years respectively based on dataset (2) of the trapped falcon on a threshold of 10, 20 and 30 individuals (left) and a threshold of 10, 20 and 30 individuals for dataset (2).

Peninsula during the last two decades, which make consequently more birds using the Arabian Peninsula as a migration route. Analysis of questionnaires returned from falconers and trappers in Saudi Arabia suggested that there is a possibility that more Saker Falcon populations from steppe areas lying north of the most arid zones of Central Asia are using the Arabian Peninsula route on migration (Kenward et al., 2007, 2013). Another suggestion for the increase in the number of trapped flacons is the possibility that the trapping areas present optimal trapping areas.

4.3. Estimating numbers of falcons trapped in the future

Predicting the number of Saker and Peregrine that could be trapped in the future is very difficult to determine with an acceptable degree of confidence. The results of the time series analysis presented in this study suggest that the predicted number of trapped Saker will be largely stable although with annual fluctuations for the next ten year period, whilst the predicted number of trapped Peregrine Falcons shows a decline with annual fluctuations initially, followed by a consistent decline towards the middle of the next ten year period. However, the population viability analysis of the trapped populations in Saudi Arabia of the two falcon species indicated a possible decline of trapped Saker Falcons in the next ten years; however the level of trapping does not appear to threaten overall population stability. The difference in the probability of extinction between the two datasets (1 and 2) is probably due to the difference in the mean number for both species in the two datasets. However, if the present range of threats continues alongside the current rate of trapping, then there will possibly be a significant effect in the near future on the migratory population of the Saker Falcon in Saudi Arabia.

On other hand, the results of the present study are in agreement with an earlier analysis completed by Dixon (2009), which showed that the population estimates for the Saker Falcon in Asia do not fit with the estimated annual harvesting levels suggested by Environmental Research and Wildlife Development Agency "ERWDA" (2003). However, the information from the falcon hospital presented in ERWDA (2003) probably suggests that a number of falcons were trapped outside Saudi Arabia and entered without CITES legal documents or were smuggled across international borders. This situation probably has a greater impact on the global population for the two species of falcons, especially if the falcons were trapped in the breeding area.

4.4. Implications of this study and recommended actions

The threats to Saker and Peregrine are well established and are comprehensively covered in the Global Action Plan currently being developed by the Saker Falcon Task Force (STF). Among the high priority threats addressed in this plan is trapping (Kovács et al., 2014). To secure a favourable conservation status for the Saker, the GAP highlights the priority actions to be implemented by all range states. As highlighted in this paper, the key conservation action within Saudi Arabia is to promote sustainable trapping during the migration periods, especially in northern Saudi Arabia and along the Red Sea coast. Increasing the knowledge of the migration routes for both Saker and Peregrine, an effective system of monitoring the number of birds trapped within Saudi Arabia, reducing the number of birds trapped by promoting captive breeding stock and an increase in awareness raising activities with falcon trappers and falconers should all be part of a package of conservation measures implemented by the Saudi Arabian authorities. Implementing these actions within Saudi Arabia alongside the measures taken by other range states in accordance with the Global Action Plan should secure a favourable conservation for both the Saker and Peregrine, and importantly preserve the traditional Arabian culture of falconry. Moreover, the methods used in this study could be applied for estimating viability of other global or regional important species especially the migratory species.

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