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Simultaneous decline in Steppe Eagle (*Aquila nipalensis*) populations and Levant Sparrowhawk (*Accipiter brevipes*) reproductive success: coincidence or a Chernobyl legacy?

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Visual migration surveys, especially at bottlenecks, can be a vital tool to evaluate population fluctuations in environmentally sensitive species. Raptors are considered to be important bioindicators that can help identify environmental catastrophes. Substantial proportions of the global population of Steppe Eagles (*Aquila nipalensis*) and Levant Sparrowhawk (*Accipiter brevipes*) concentrate at Eilat, Israel, during the spring and autumn migrations, but counts from seven autumn and seven spring migration surveys indicate a constant decline in Steppe Eagle numbers. Further, the number of juveniles observed in these counts dropped steadily from 30% in the early 1980s, to 1.4% in 2000. The numbers observed at Eilat are well below the range of the numerical fluctuations observed in previous surveys. In Levant Sparrowhawks, no decline in total numbers is evident, but a significant change in the adult to juvenile age ratio was noted between the population trapped in the 1980s and that sampled in the late 1990s. The cumulative evidence of the decrease in the total numbers of Steppe Eagles, the decreasing proportion of subadults within the population, and the decrease in adult:young ratio in the Levant Sparrowhawk population trapped leads us to suggest that the Chernobyl accident on 26 April 1986 may have negatively affected wildlife populations, not only to the west with the spread of the radio-active plume, but farther east than previously assumed.

Introduction

Many articles have been published on the chemical, radioactive, and other types of contamination or pollution that continue unmonitored to date (cf. Chaussade 1990). There are also few publications about the effects of environmental mutagens (e.g. Ellegreen *et al.* 1997), and the effects on birds in general (e.g. Camplani *et al.* 1999) and raptors in particular (Henny *et al.* 1998). On 26 April 1986 a nuclear accident demolished Chernobyl Unit 4 in an enormous explosion of the reactor core, that spewed disintegrated radioactive fuel into the atmosphere. An atomic fire burned for two days before Swedish authorities alerted the world that nuclear fallout had entered the atmosphere. Although research papers pertaining to the effects on humans have been published (e.g. Bengsston 1987, Kazakov *et al.* 1992), few relate to the avian communities that breed in the affected regions, mostly owing to govermental restrictions and fear of radioactive exposure. However, in recent years a small number of researchers have studied the effects that the Chernobyl accident has had on birds, both at the breeding grounds (Ellegreen *et al.* 1997, Camplani *et al.* 1999) and on migration (Vigorita and Sgorbati 1991).

In Eilat, where Eurasia and Africa meet, there is a concentration area where many species of migratory raptors can be surveyed (Shirihai *et al.* 2000). Surveys of migrants passing thru these regions, like those conducted in northern Israel and at Eilat become important for indices to evaluate population status (e.g. Shirihai and Christie 1992, Yosef 1995, Shirihai *et al.* 2000). After Safriel (1968) drew attention to the migratory bottleneck at Eilat, and Christensen *et al.* (1981) published their report on this phenomenon over Eilat, several counts have been conducted in spring and autumn (Shirihai 1987, 1988, Shirihai and Christie 1992, Shirihai and Yekutiel 1991, Yosef 1995).

Israel is on the only land bridge between three continents, a junction for birds migrating south from Eurasia to Africa in autumn and north to their breeding grounds in spring (Safriel 1968). In autumn, except for Steppe Eagles *(Aquila nipalensis*) that concentrate at Eilat and stochastic events, southbound birds tend to migrate over a broad front. In the spring, the Red Sea and the Gulf of Aqaba act as a long deflection barrier forcing northbound raptors to concentrate in a very narrow area over the Eilat Mountains (Grieve 1996).

Large proportions of Steppe Eagles concentrate at Eilat during both autumn and spring migration (Shirihai *et al.* 2000). Age class has been documented on the visual migration surveys and on average 70% of those that avail of the Eilat flyway are adults (Shirihai *et al.* 2000) and an as yet unknown proportion of the juveniles follow the central Negev route. Here we report a change that we have noticed from surveys of migrant Steppe Eagles that were initiated in 1977 and continue to date (Shirihai and Yekutiel 1991, Shirihai and Christie 1992, Yosef 1995, 1996, 1998b, Leshem and Yom-Tov 1996a, 1996b, Shirihai *et al.* 2000). Simultaneously a co-operative raptor trapping and ringing programme of the SPNI and the IBRCE was conducted from 1994–1998. This programme was restarted by IBRCE in 1996 and continues to date. One of the species caught in large numbers is the Levant Sparrowhawk (*Accipiter brevipes*). The Levant Sparrowhawk is a typical raptor with reversed sexual size dimorphism and dichromatism (Cramp and Simmons 1980, Clark and Yosef 1997, Forsman 1998b, Gorney *et al* 1999, Yosef and Fornasari 2000). Levant Sparrowhawks are considered scarce (Cramp and Simmons 1980, Wallace 1983) and are one of the three-raptor species whose breeding distribution is limited to the western Palearctic (Hagemeijer and Blair 1997). Recent studies indicate that in spring Levant Sparrowhawks concentrate in the Eilat-Aqaba region in great numbers (e.g. 45 000–55 000 per season; Shirihai *et al.* 2000) and migrate north along the rift valley towards Syria and Lebanon (Frumkin *et al.* 1995), heading for Romania, Ukraine, Russia and Syria (Yosef 1998a).

Here we present a unique data set wherein overall population and number of juvenile Steppe Eagles and adult:juvenile ratios in Levant Sparrowhawks observed on passage were monitored before, during and after the Chernobyl accident in spring 1986 at one of the most important avian migratory bottlenecks of the western Palaearctic, at Eilat, Israel. We argue that these changes coincided with the Chernobyl disaster.

Methods

Visual raptor migration surveys have been conducted at Eilat sporadically since 1977 (for details of method of survey and positions see Shirihai and Christie 1992, Yosef 1995, Shirihai *et al.* 2000). All soaring birds are counted by deploying volunteers at traditional counting posts across the front of the passage route. Distances between observation posts are such that minimal overlap occurs. However, at the end of each day, data between neigbouring positions are compared to check and eliminate possible double counts (Shirihai *et al.* 2000). Ageing of Steppe Eagles in flight is relatively easy. Experienced observers can classify the birds into either juvenile (first-year), 2nd-winter, 3rd-winter, 4th-winter, 5th-winter or adult (Porter *et al.* 1981, Forsman 1998a, 1998b, Clark 1999).

Levant Sparrowhawks were captured and ringed in the area immediately to the north of Eilat, Israel. Levant Sparrowhawks are aged based on plumage, molt, and eye color; adults have brown eyes with a slight reddish cast and juveniles have pale to medium brown eyes (Clark and Yosef 1998). We quantified the relative abundance of the various sex and age classes for all seasons of raptor trapping at Eilat between 1984–1988 (cf. Clark and Yosef 1997, Gorney *et al.* 1999) and in 1992 and 1996–2000 (Yosef and Fornasari 2000, RY unpubl. data). We make the assumption that the numbers of birds trapped an unbiased sample of the population migrating through the region because most are caught in mist nets and not on lure animals (RY unpubl. data). The trapping methods have not changed over the years and was ruled out as a possible factor that influenced differential trapping of the two age groups.

Unless otherwise stated, all measured data are presented as mean ±SD, N, and range. We used simple linear regression to evaluate trends and chose P = 0.05 as the minimum acceptable level of significance.

Results

The average for nine (1977, 1983, 1986–1988, 1994, 1997, 1998 and 2000) spring surveys in the Eilat mountains was 17 449 ± 7 335 (9 283–31 198) Steppe Eagles. In seven autumn migration surveys (1980, 1986, 1987, 1996–1999) conducted at Eilat, the average number of Steppe Eagles counted was 8 309 ± 8 346 (1 278–24 243). The larger numbers were observed in the 1980s; the lower counts are consistently from the 1990s for both the autumn (simple linear regression y = –292.84x + 584 768, R2 = 0.6747, P = 0.0247) and spring (y = –77.711x + 156 665, R2 = 0.7991, P = 0.001) surveys (Figures 1 and 2). There are no obvious year-to-year reciprocal fluctuations of numbers, only a severe drop between 1987 and 1988. Since the late 1980s the numbers have stabilised at approximately a third of the numbers observed in the 1980s.

In addition to the overall decrease in numbers, the ratio

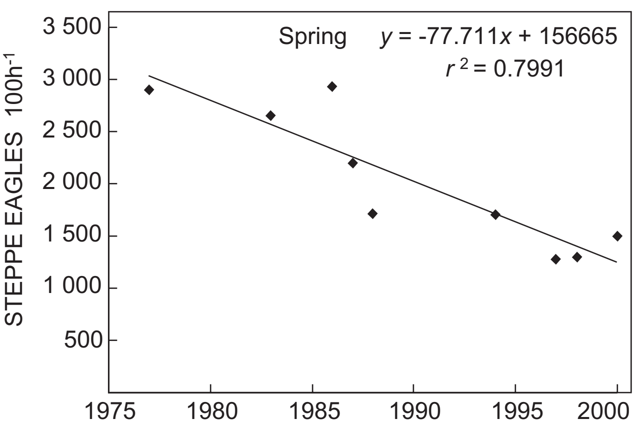

Figure 1: Numbers of Steppe Eagles per 100 hrs of observation on spring counts at Eilat, Israel (bars) and the percent of juveniles (diamonds) identified per season

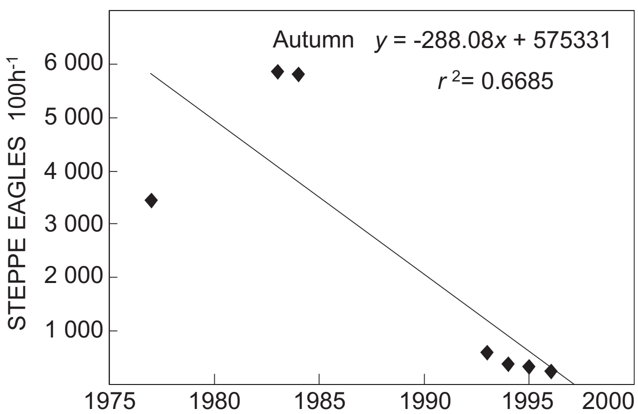

Figure 2: Numbers of Steppe Eagles per 100 hrs of observation on autumn counts at Eilat, Israel.

of juveniles in the migratory population has decreased considerably (Figure 1). The average percentage of juveniles in the 1980s was 30% and the 1990s it fell to 9%.

We captured and ringed 1 827 Levant Sparrowhawks from mid-April till early May. Unlike Steppe Eagle numbers, a higher ratio of juvenile Levant Sparrowhawks was recorded in 1987, and only thereafter was there a decline in the number of juveniles trapped. The average age ratio of juveniles:adults was 1.4:1.0 (±0.34) in 1984–1987 and 0.7:1.0 (±0.33) in 1988–2000 (Table 1).

Discussion

The changes in relative numbers of adult and juvenile Steppe Eagle and Levant Sparrowhawk and in the absolute numbers of Steppe Eagles observed at Eilat is cause for concern. Not only are Steppe Eagle numbers well below the range of the fluctuations observed prior to 1986, but the percent of juveniles seen dropped from 30% in the 1980s to less than 9% in the 1990s (Figure 1). There is little information on ecological parameters that may have affected numbers on the wintering grounds (Simmons 1997). In winter Steppe Eagels feeds predominantly on allate termites, the emergence of which is unpredictable in space and time, except as linked to thunderstorms, which themselves are unpredictable in terms of yearly and local variation in amount and timing. Consequently, Steppe Eagles are locally and regionally sparse (or even absent) in some years and temporarily abundant and occurring in large flocks in the Kalahari veld at times after heavy rain. Hence, although Simmons (1997) reported that there was no evidence that Steppe Eagles have either increased or decreased in southern Africa, it is almost impossible to evaluate the population status on the wintering grounds.

The importance of evaluating the Steppe Eagle populations at Eilat is further suggested by the fact that in a recent study, Meyburg *et al.* (1998) showed that of 14 Steppe Eagles caught in Saudi Arabia and one in South Africa, eight wintered in Africa, and all returned to the breeding grounds via the Eilat flyway.

Table 1: Age ratio of Levant Sparrowhawks (*Accipiter brevipes*) trapped at Eilat, Israel. Pre-Chernobyl years are separated from post-Chernobyl years

Year	Juvenile	Adult	Ratio Juvenile s:Adults
1984	88	70	1.28:1.0
1985	13	8	1.63:1.0
1986	70	71	1.01:1.0
1987	35	20	1.75:1.0
Mean (Pre-Chernobyl)			1.40:1.0
1988	24	37	0.65:1.0
1992	2	19	0.10:1.0
1996	90	127	0.71:1.0
1997	63	57	1.11:1.0
1998	150	217	0.69:1.0
1999	135	261	0.52:1.0
2000	129	114	1.13:1.0
Mean (Post-Chernobyl)			0.70:1.0

There are several possible factors that can influence the population fluctuations reported for Eilat. It is possible that on the breeding grounds the major food resources have declined, or their breeding habitats have severely decreased. The latter is mentioned in the EBCC Atlas of European Breeding Birds (1997) and the Russian Red Data Book (2001) wherein it is reported that Steppe Eagles have declined, and even become extirpated, in most east European countries and in the past century the western limit of the species has withdrawn eastwards by as much as a thousand kilometers (Hagemeijer and Blair 1997). It is estimated that about 20 000 breeding pairs exist but does not explain the sudden decline in the mid 1980s. An alternative explanation for the decrease in our counts is that perhaps a larger proportion of the remaining population winters farther north than the traditional wintering grounds in Africa. Meyburg *et al.* (2003) suggested that increasing numbers of Steppe Eagles might winter in the Arabian Peninsula and could influence the numbers counted at Eilat. However, we consider the almost 40% drop in numbers observed at Eilat to be too large for an increased number of over-wintering eagles in the Saudi Arabian peninsula to be the likely reason for the lower counts. Alternatively, it is possible that a large proportion of the population migrates via routes either to the south and east of Eilat, or further west and to the north. However, the consistency of the decline strongly disfavours the alternative route idea, which, if responsible, should result in wide fluctuations among years. Also, these alternatives do not explain the decrease in the number of juvenile or immature birds. Shirihai and Christie (1992) report that an average of 30% of the population is non-adult. In contrast in recent surveys, only 9–13% are non-adult birds (Yosef 1996, Shirihai *et al*. 2000, RY unpubl. data). Because we know little about the numbers on the breeding and wintering grounds (Danilov-Danilyan *et al.* 2001), only the surveys in Eilat are available to elucidate the population trends.

Many bird atlases describe the Steppe Eagle as the commonest large eagle in the world (Del Hoyo *et al.* 1994, Simmons 1997). Our data show a major decline for the species on the major, known migratory route. For the Steppe Eagles observed at Eilat, the fact that the decline occurred immediately after 1986 and that the radioactive plume following the 1986 Chernobyl accident was blown in the direction of the known breeding grounds of the species (Figure 3), suggests that radioactive contamination could have negatively affected not only the survival of the adults but also their reproductive ability. The latter is of special concern because of the inability of the existing adult population to fledge enough young to sustain itself. This suggests that an additional crash in overall population may occur in future.

The implications of the data for Levant Sparrowhawks trapped at Eilat are similar to that of the Steppe Eagles. The findings of our banding study at Eilat are further substantiated by the fact that several of the Levant Sparrowhawks banded at Eilat have been recovered in subsequent years in areas affected by the Chernobyl disaster (Figure 3). The number of juveniles trapped in the 1980s was consistently greater than that of adults and in sharp contrast to that of the 1990s where the numbers of juveniles was almost always lower than that of adults (Table 1). The average ratio of juve-

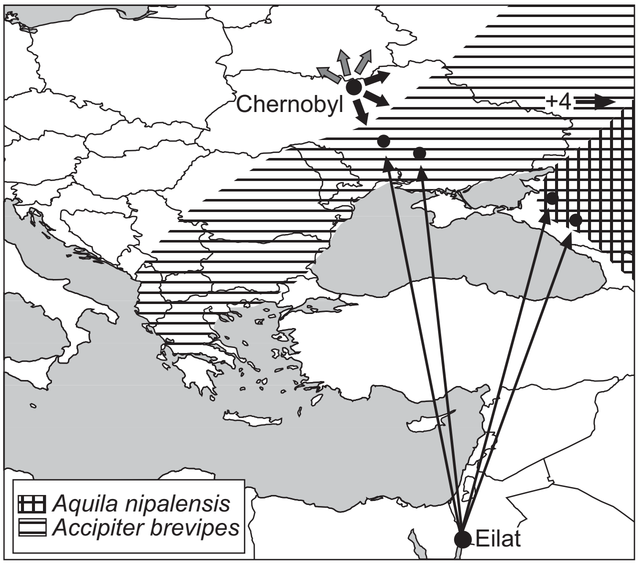

Figure 3: The wind directions at Chernobyl during days 1 and 2 after the disaster were to the north and north-west and then to the east and south-east from day 4 onwards. The western most distribution of Levant Sparrowhawk (hatched) and Steppe Eagles (squares) is shown in relation to Chernobyl. The locations of ring returns of Levant Sparrowhawk ringed at Eilat are also shown

niles:adults in the 1990s is half that of the 1980s. This suggests that the reproductive ability of the adult population of the Levant Sparrowhawks is impaired. Although numbers counted on the visual migration surveys have not changed (Shirihai *et al.* 2000), the number of young comprising the population has halved. It may be that a substantial proportion of adults succumbed to the contamination resulting in a peak of juvenile:adult ratio in 1987, but then a drop occurred from 1988 onwards. An effect of lingering radioactive-contamination was reported by Jonsson *et al*. (1999) in two fish species (brown trout, *Salmo trutta*, Arctic charr, *Salvelinus alpinus*) affected by Chernobyl radioactivity. The reduced ratio of young within the Levant Sparrowhawk suggests a decline in numbers of this species is likely in the near future.

The simultaneous decline in Steppe Eagle numbers observed on migration and the reduction in the relative percent of young, coupled with the inversion of the age ratio in the number of Levant Sparrowhawk trapped at Eilat, immediately after the Chernobyl accident in April 1986 suggests that it to be the reason of these demographic changes in the populations of these two, unrelated species. Although the two species breed in very different habitats, their distributional ranges overlap, and these areas are known to have received high dosages of contamination in the first week after the accident.

Our data illustrate how visual migration surveys and banding data can be used for population monitoring, and indicate when more intensive study is required to assess population levels and to elucidate the causes of the observed changes. Surveys of migrants also provide an important conservation tool to validate findings of breeding or wintering surveys. Surveys of migrants may often be the best and only available indices of population changes. This is the case for the Steppe Eagle and Levant Sparrowhawk on migration at Eilat.

This study also illustrates the importance of coordinating the monitoring of breeding populations as well as monitoring at migration bottlenecks. Hence, the conservation-related options that remain are whether global conservation efforts are concentrated in elucidating the true status of the species while viable population still exist, or to wait for the species to go almost extinct and then spend greater amounts of financial resources to manage their recovery.

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