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Author(s): Tulsi Ram Subedi, Robert DeCandido, Hem Sagar Baral, Surya Gurung, Sandesh Gurung, Chong Leong Puan and Shahrul Anuar Mohd Sah

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POPULATION STRUCTURE AND ANNUAL MIGRATION PATTERN OF STEPPE EAGLES AT THOOLAKHARKA WATCH SITE, NEPAL, 2012–2014

Tulsi Ram Subedi[1]
Centre for Marine and Coastal Studies (CEMACS), Universiti Sains Malaysia, 11800, Pulau Pinang, Malaysia
and
Nepalese Ornithological Union (NOU), P.O. Box 21016, Kathmandu Nepal

Robert DeCandido
1831 Fowler Avenue, The Bronx, NY 10462 U.S.A.

Hem Sagar Baral
Zoological Society of London – Nepal office, P.O. Box 5867, Kathmandu, Nepal

Surya Gurung
Dhikur Pokhari VDC 6, Kaski District, Gandaki Zone, Nepal

Sandesh Gurung
Central Department of Zoology, Tribhuvan University, 44600 Kathmandu, Nepal

Chong Leong Puan
Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia
and
Institute of Tropical Forestry and Forest Products (INTROP), Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia

Shahrul Anuar Mohd Sah
Centre for Marine and Coastal Studies (CEMACS), Universiti Sains Malaysia, 11800, Pulau Pinang, Malaysia
and
School of Biological Sciences, Universiti Sains Malaysia, 11800, Pulau Pinang, Malaysia

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In 2015, the International Union for Conservation of Nature (IUCN) listed the Steppe Eagle (*Aquila nipalensis*) as a globally endangered species due to a rapid population decline in the last decade (BirdLife International 2015). In the Asian region, the Steppe Eagle is a long-distance migrant breeding in China and Mongolia and wintering in Nepal, India and beyond (del Hoyo et al. 1994). This species is a broad-front migrant through the Himalayan range, leaving its breeding ground between August and October, and returning between January and May (Welch and Welch 1991, Ferguson-Lees and Christie 2001). It is the most common eagle in Asia that migrates to the Indian subcontinent via the central Asian flyway (Bildstein 2006).

The population of the Steppe Eagle has declined throughout its breeding range between 1997–2011 and 2013–2015 (Ferguson-Lees and Christie 2001, Zduniak et al. 2010, Karyakin 2013, BirdLife International 2015), with an extremely rapid decline in Europe (Zduniak et al. 2010). In Asia, the primary threats are intensification of agriculture, overgrazing of steppe habitats by domestic animals (Bird and Symes 2009, Ma and Zhao 2013), and poisons used by farmers to eliminate rodents, particularly in China (Ma et al. 2010).

There have been relatively few season-long counts conducted on this species and other raptors that migrate along the central Asian flyway. In Nepal, *Aquila* eagle

[1] Email address: Tulsi.biologist@gmail.com

migration was reported for the first time in 1976 from the southern flank of the Himalayas. Fleming (1983) estimated over 45,000 eagles on migration based upon 7 d of counts beginning on 31 October 1976. A few years later, de Roder (1989) counted 7852 eagles on migration during an 18-d survey beginning on 20 October 1985. Of these migrants, 28% were juveniles, 28% immatures, and 44% adults. Although DeCandido et al. (2001), den Besten (2004) and Gurung et al. (2004) made additional observations in central Nepal and India in the early 2000s, we still know little about year-to-year population fluctuations, annual migration pattern, and age structure of migrating Steppe Eagles. Thus, we began an annual autumn migration watch in the area of previous studies that afforded a close view of the migrants, so that we could (1) study daily and annual migration patterns of migrating Steppe Eagles through the central Asian flyway; and (2) better estimate age structure of these eagles at Thoolakharka watch site, Nepal.

METHODS

We studied Steppe Eagle migration in west-central Nepal from two watch sites located within 3 km of each other across the Hyangja Valley in Kaski district (Fig. 1, 2). The primary watch site used from mid-October through early December 2012–2014 was in the village of Thoolakharka, (28°18.188′N, 83°49.788′E), at an elevation of 2050 masl in the foothills of the Himalayan mountains at the edge of the Annapurna Conservation Area, ca. 25 km south of the Annapurna Himalayan Mountains and 35 km northwest of the city of Pokhara. The site affords a 360° view of the surrounding countryside, and is an important site in the central Asian flyway for counting migrating raptors, including globally threatened and near threatened species (Zalles and Bildstein 2000). Agricultural land dominates the lower parts of the Annapurna foothills and nearby valleys, while oak (*Quercus* spp.)–rhododendron (*Rhododendron arboreum*) forests occur at higher elevations (Inskipp and Inskipp 1991, Zalles and Bildstein 2000).

Early (from mid-September to mid-October) in the season, when fog envelops Thoolakharka for days at a time, raptors migrate at lower elevations, and we counted migrants from the 1760-m Paudur Hill (28°17.416′N, 83°49.183′E) above the small town of Kande (Khare). On a clear day, it is possible to observe the watch site at Thoolakharka from Paudur Hill across the Hyangja valley approx. 1.5 km away. At both sites, most Steppe Eagles pass

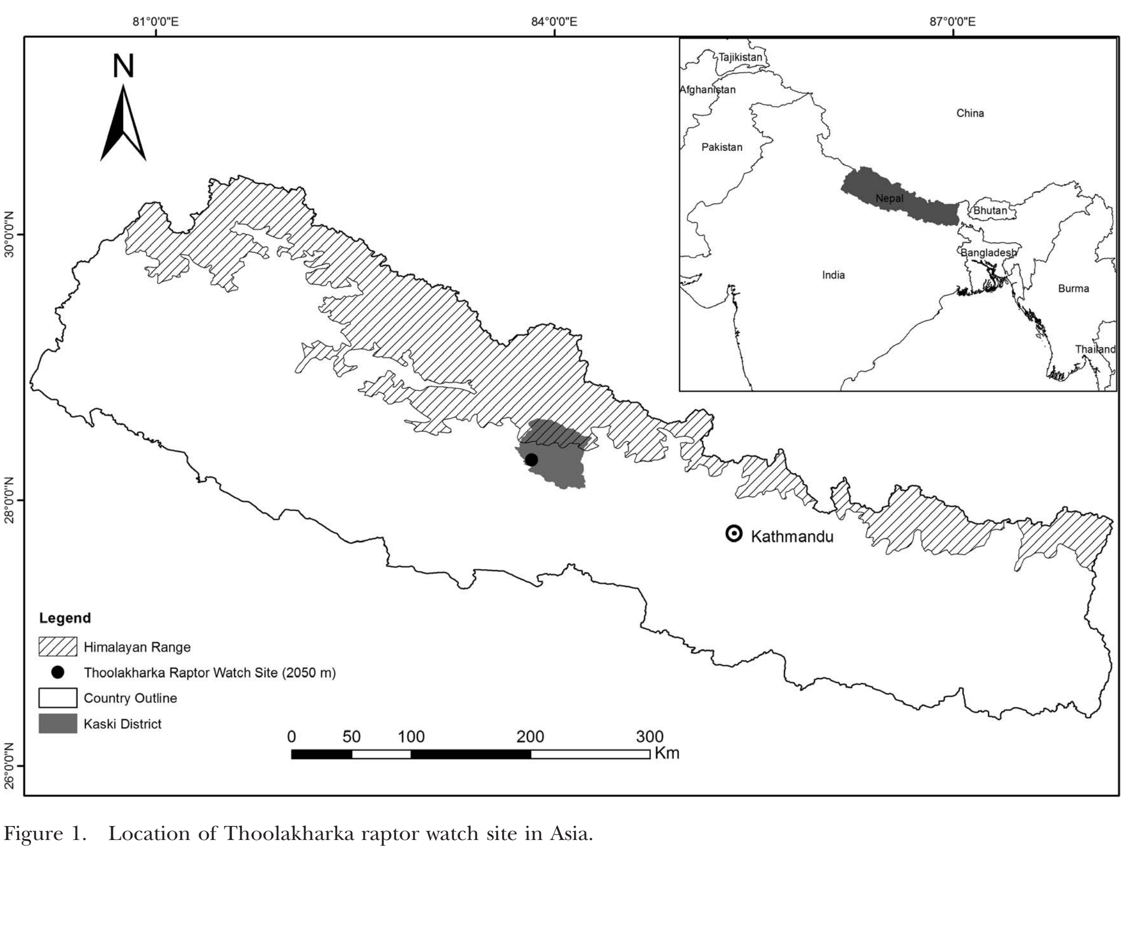

Figure 1. Location of Thoolakharka raptor watch site in Asia.

close to the observation stations, approximately 50 m or less from observers, who can easily identify them with unaided vision. When eagles passed farther away, observers used 10× binoculars and a 20–60× spotting scope.

In 2012, observations began on 16 September and continued until 4 December (81 d); in 2013–2014, we counted raptors from 16 September to 8 December (85 d). Tulsi Subedi (TS) and Sandesh Gurung (SG), occasionally assisted by others, made observations from 0700 to 1700 H daily. Steppe Eagles migrating east to west were spotted, identified, and counted following the protocols of the Hawk Migration Association of North America (HMANA 2006). We were able to assign many to one of three age classes based on plumage characters described by Clark (1996), Forsman (2005) and Naoroji (2006): (a) Juveniles (first plumage); (b) Subadults (second to fourth plumage); and (c) Adults (fifth plumage).

To account for changes in count effort and facilitate interannual comparison, we adjusted data to bird numbers per 100 hr of observation. We truncated the data by date to include only the central 90% of the passage for each season for the analysis. We reported 5%, 50% (median) and 95% passage dates by age classes for each year. We performed a *G*-test on the yearly proportions of the three age classes to test whether the proportions remained similar over the 3 yr. Considering the non-normal nature of the data with unequal variances across samples, we performed Mood's median tests (Conover 1999) to assess whether there were significant differences among years in the median numbers of juveniles, subadults, and adults, as well as overall eagle numbers. The Mood's median test was robust against outliers as well as skewed distributions, which was the case for our count data. For the total count, we determined the median that contributed to such a difference, if any, based on adjusted standardized residual values derived from chi-square test. If the absolute adjusted standardized residual value was >1.96, it was deemed significant at $P < 0.05$. All analyses were performed using SPSS version 16.

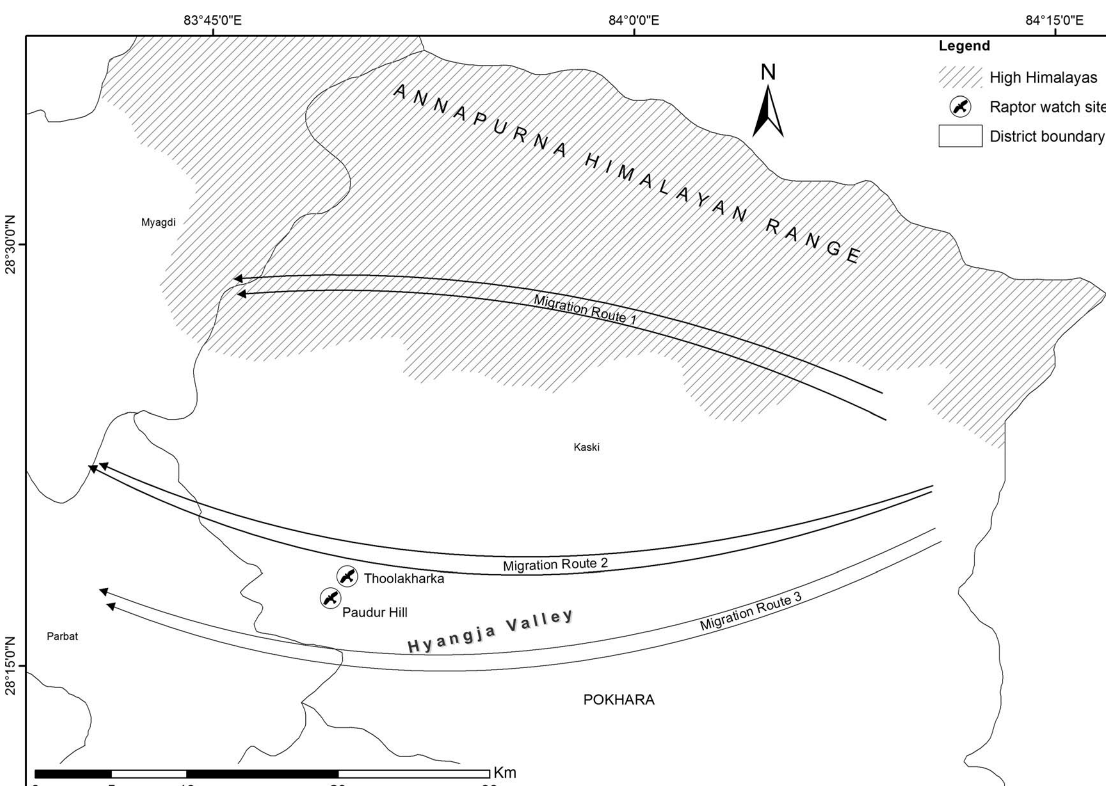

Figure 2. Approximate position and migration pattern of Steppe Eagles in response to local weather (mainly fog/clouds) over the Annapurna Himalayan range. On clear days, most of the Steppe Eagles follow Route 1 close to the Himalayas. When clouds envelop the Himalayan Mountains, migration shifts over toward Route 2 and still further south toward Route 3 when clouds also cover the Thoolakharka raptor watch site.

Table 1. Magnitude and rate of central 90% passage of Steppe Eagles at Thoolakharka, Nepal, 2012–2014.

	NO. OF INDIVIDUALS				STEPPE EAGLES / 100 HR			
AGE CLASSES	2012	2013	2014	MEAN	2012	2013	2014	MEAN
1st year	627	868	880	792	96.21	122.20	125.74	114.72
2nd–4th year	1195	1634	1539	1456	183.31	230.20	219.86	211.12
>4th year	1738	1968	1296	1667	266.55	277.23	185.14	242.97
Total	5937	7816	5549	6434	910.63	1100.79	792.77	934.73

RESULTS

We counted the highest number of Steppe Eagles (8684) in 2013, whereas the lowest number (6166) occurred in 2014. The earliest dates by year that Steppe Eagles passed the watch site were 5 October (2012), 7 October (2013), and 3 October (2014). Each year, we observed Steppe Eagle migration until the last day of the count in early December. Mean numbers (90% of passage) of each age class per year were 792 juveniles, 1456 subadults, 1667 adults, and 6434 total eagles (Table 1). The single highest daily count per season was on 3 November 2012 (572 birds), 20 November 2013 (1102 birds) and 7 November 2014 (614 birds). Steppe Eagle migration peaked from late October through late November and on average, the peak passage of all ages combined occurred in the third week of November (Fig. 3). However, the peak passage for juvenile birds was at least 1 wk earlier than the passage of adults and subadults. Most of the eagles (67.4%) were counted between 1200–1700 H, with a peak passage (22.5%) between 1400–1500 H (Fig. 4).

We aged approximately 60% of the Steppe Eagles during 2012 to 2014, and identified fewer juveniles (20%) than subadults (37%) or adults (43%). The proportion of juvenile birds was highest in mid- to late October, and slowly decreased through December. By comparison, the proportion of subadults remained more or less constant from late October to early December, whereas adults increased after early November, and were the most common age class identified from approximately 5 November to 30 November. Based on the calendar date, median passage dates of each age group in 2012–2014 differed among years, varying from 12 November to 20 November (Table 2).

The proportions of the three age classes in 2012 differed significantly from those of 2013 ($G = 18.4$, $P < 0.001$) and 2014 ($G = 147.4$, $P < 0.001$). Mood's median test indicated there was no significant difference among years in the median number of Steppe Eagles identified by age ($\chi^2 = 0.032$, $P = 0.984$). With respect to age classes, we obtained similar results: there were no significant differences in the number of juveniles ($\chi^2 = 1.655$, $P = 0.437$), subadults ($\chi^2 = 1.125$, $P = 0.570$), or adults ($\chi^2 = 3.240$, $P = 0.198$) among the three years. When unidentified Steppe Eagles were

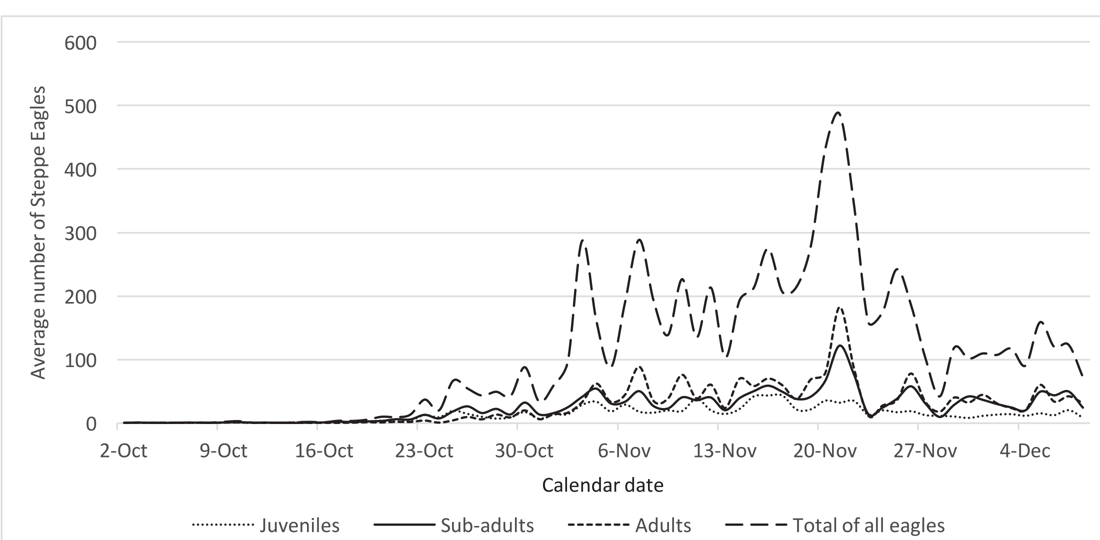

Figure 3. Average number of Steppe Eagles of different age classes observed during the study periods in autumn (2012–2014) at Thoolakharka, Nepal.

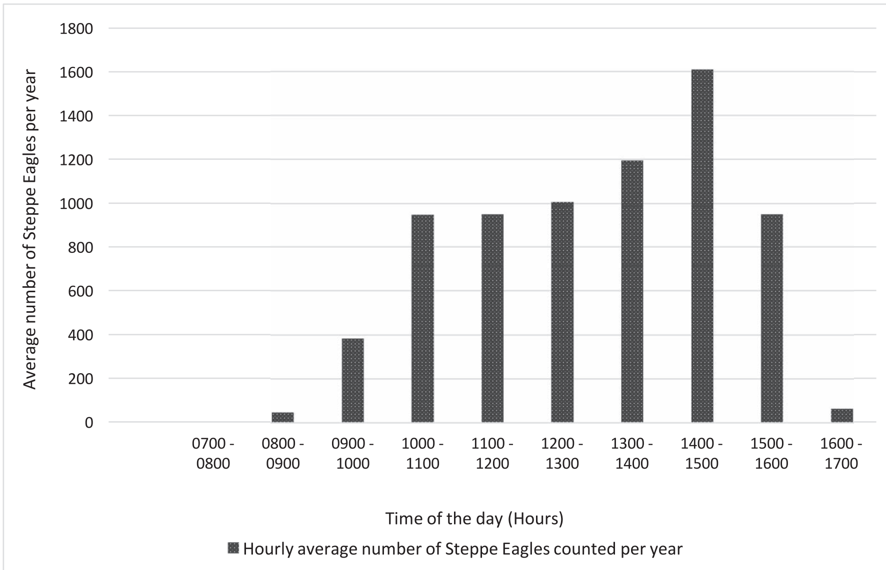

Figure 4. Hourly average number of Steppe Eagles counted per year at Thoolakharka, Nepal (2012–2014).

incorporated into the total count, the medians of the number of birds counted differed significantly among the three years ($\chi^2 = 6.318$, $P = 0.042$): the median of the 2014 count was significantly smaller than those of 2012 and 2013, based on adjusted standardized residual values.

DISCUSSION

Compared to previous studies (Fleming 1983, de Roder 1989) that estimated anywhere from 10,000 to 45,000 Steppe Eagles passing through this part of Nepal, our maximum season count was 8684 (2013). Our daily high count (1102) was almost 300 fewer than the daily high count in de Roder (1989). Our results were similar to those of den Besten (2004), who counted 8194 along the same flyway in Dharamsala, India, with a high count of 914 on 20 November 2001.

Contrary to Bijlsma (1991) and DeCandido et al. (2001), we found the percentages of subadults were much lower, and adults much higher, than in previous studies. In Eilat, Israel, about 60–70% of migrating Steppe Eagles were adult (Shirihai and Christie 1992), which differed from studies in the same flyway at Beersheba and the Dead Sea, where 90% were nonadults (Ben Zohar 1986), and at the northern Suez in Egypt, where 70% were nonadults (Bruun 1985). Therefore, we can easily hypothesize that different age groups take different migration routes. We do not know whether there has been a change in the population structure since the earlier studies, but we believe understanding the timing of migration for each age class is important for determining changes in overall population structure.

The proportion of juvenile birds slowly decreased from early November through early December. By comparison, adult numbers increased in November, but the proportion of subadult birds remained more or less stable throughout the migration season. This result differed from the 1985 study along the same flyway (de Roder 1989), which showed that the percentage of juveniles counted slowly increased, while subadults decreased and adults remained more or less stable throughout the observation period. Our results were more similar to those of the autumn migration study in Eilat, Israel, where juveniles dominate during the early season and adults during the late season (Shirihai and Christie 1992).

We presume weather was a key factor that affected the timing and number of Steppe Eagles observed at the watch site. We observed a strong weather effect in 2014, with many foggy days in comparison with previous years; migrating raptors may have followed a different route, such that we could not see them due to enveloping fog at both watch sites. When fog covers the Annapurna Himalayas, the migration route shifts further south to directly over the watch site and still further south when fog also envelops the Thoolakharka watch site, making counting there impossible (Fleming 1983; Fig. 2). Our observations in 2012–2014 showed the majority of eagles passed in the afternoon, with a peak (22.5% of all migrants) between 1400–1500 H. These results agreed with previous observations by Fleming (1983), de Roder (1989) and DeCandido et al. (2001). In the late morning, clouds build from the interaction of the rising warmer air from the nearby valleys with colder air flowing over the Annapurna Mountains. Migrating eagles shift their migration from Himalayan Mountains (Annapurna Range) southward over the watch site, particularly if

Table 2. Central 90% passage periods and median passage dates for Steppe Eagles at Thoolakharka, Nepal, 2012–2014.

AGE CLASSES	90% PASSAGE DATES (NO. OF DAYS)			MEDIAN PASSAGE DATE (NO. OF BIRDS)			
	2012	2013	2014	2012	2013	2014	MEDIAN[a]
1^{st} year	23 Oct–2 Dec (41)	2 Nov–4 Dec (33)	24 Oct–5 Dec (43)	11 Nov (24)	16 Nov (87)	12 Nov (14)	(41.7)
2^{nd}–4^{th} year	30 Oct–2 Dec (34)	3 Nov–6 Dec (34)	24 Oct–6 Dec (44)	14 Nov (59)	21 Nov (316)	8 Nov (32)	(135.7)
>4^{th} year	2 Nov–2 Dec (31)	5 Nov–5 Dec (31)	30 Oct–7 Dec (39)	12 Nov (148)	20 Nov (193)	17 Nov (86)	(142.3)
Total	1 Nov–1 Dec (31)	5 Nov–4 Dec (30)	25 Oct–6 Dec (43)	12 Nov (512)	20 Nov (1102)	13 Nov (105)	(573.0)

[a] Average of medians obtained for three years.

there is a light to moderate wind from the northeast (Fig. 2). On clear days, we observed the main migration stream very close to the Himalayan Mountains to the north. Additionally, we found that Steppe Eagles have a longer migration period than previously known, beginning in early October and lasting at least 60 d through early December, with some migration continuing through late December (Gurung et al. 2004).

After adjusting the annual counts for observer effort, the mean numbers of birds for the three age classes was quite similar, about 189 birds per 100 hr. Our study suggests that juvenile birds have different migration timing than adults and subadults. In all years studied, the median passage date for juveniles was earlier than the median passage date of all Steppe Eagles counted. Similarly, Lesser Spotted Eagle (*Aquila pomarina*) juveniles leave the breeding grounds before adults (Meyburg et al. 1995). In 2014, however, the median passage date for subadult birds was earlier than those of other age classes.

The present study provides baseline data on population structure and trends of this iconic species. We believe significant numbers of Steppe Eagles breeding in Mongolia and China use this migration flyway (DeCandido et. al. 2013) along the southern flank of the Annapurna Range, with many passing the watch site at the easily accessible tourist town of Thoolakharka. This affords an exceptional opportunity to perform long-term population monitoring of this species.

ESTRUCTURA POBLACIONAL Y PATRONES ANUALES DE MIGRACIÓN DE *AQUILA NIPALENSIS* EN EL PUNTO DE OBSERVACIÓN THOOLAKHARKA, NEPAL, 2012–2014

RESUMEN.—Estudiamos la migración este-oeste de la especie en peligro *Aquila nipalensis* en Thoolakharka, Nepal (elevación 2050 m snm) desde mediados de septiembre hasta principios de diciembre en los años 2012–2014, para estimar la estructura de edades de las poblaciones y describir su patrón anual de migración. Registramos 6100 a 8700 individuos/año y determinamos la edad de aproximadamente el 60% de las águilas que pasaron: 20% juveniles (902), 37% subadultos (1679) y 43% adultos (1910). Observamos el mayor volumen migratorio (67%) después de las 1200 H, con un pico entre las 1400–1500 H. Para estos tres años, la fecha mediana de paso de juveniles fue anterior a la fecha mediana de paso de los subadultos y adultos. La proporción de diferentes clases de edad en 2012 fue significativamente diferente de la registrada en 2013 ($G = 18.4$, $P < 0.001$) y 2014 ($G = 147.4$, $P < 0.001$). No hubo diferencias significativas entre años en el número en cada clase de edad ($\chi^2 = 1.655$, $P = 0.437$; $\chi^2 = 1.125$, $P = 0.570$; y $\chi^2 = 3.240$, $P = 0.198$, respectivamente para juveniles, subadultos y adultos). Sin embargo, las medianas del número total de individuos migratorios de *A. nipalensis* registrados cada año fueron significativamente diferentes ($\chi^2 = 6.318$, $P = 0.042$). No observamos diferencias en los

patrones anuales de migración de *A. nipalensis*, pero registramos menos individuos de esta especie pasando a través del área que lo que habían estimado estudios anteriores de corto plazo.

[Traducción del equipo editorial]

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