6 Raptor Migration across and around the Himalayas

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History of Research

Given the remote and rugged terrain of the Himalayas, it is not surprising that published observations of raptor migration in the region have, until recently, been sporadic.

The earliest useful record we could find is Scully's descriptions of raptors collected during 19 months in the Gilgit region in 1879–1880 that included seasonal occurrences and status of 15 species: Western Osprey *Pandion haliaetus* (English and scientific names follow Gill & Donsker, 2015), Black Kite *Milvus migrans*, Griffon Vulture *Gyps fulvus*, three harriers *Circus* spp., three hawks *Accipiter* spp., Common Buzzard *Buteo buteo*, Booted Eagle *Hieraaetus pennatus* and four falcons *Falco* spp. (Scully, 1881). Other early reports include those of Donald (1905, 1923), who in February 1905 observed a large concentration of Western Marsh *Circus aeruginosus*, Pallid *C. macrourus* and Pied harriers *C. melanoleucos* in eastern India south of the Himalayas (Donald, 1905), which, presumably, had travelled across or around the Himalayas from their breeding grounds in central and eastern Asia to overwintering sites along the Indo-Gangetic Plain south of the Himalayas (Naoroji, 2006). Eighteen years later, Donald recorded approximately 40 *Aquila* eagles flying east-north-east to west-south-west at intervals of one to five minutes at Jhatingri (Donald, 1923). These were the first of numerous reports of a substantial movement of raptors along what we call the East-to-West Southern Corridor (see later in this chapter).

Following these early observations, there were few further records until the 1970s, when several regional and international authorities began reporting their work in the area, most of which was concentrated in the central Himalayas of Nepal.

Koning (1976) described overwintering concentrations of raptors in the Indo-Gangetic Plain of Pakistan during five consecutive winters in 1970–1974 that included close to 10,000 sightings representing 33 species. Thiollay (1979) recorded 151 migrants of 15 species during several days of observation in Mustang, central Nepal in late September–early October 1978. Based on a series of observations between 1971 and 1980, that built on Donald's earlier work (Donald, 1923), Fleming reported an approximately 1000-km-long east-to-west autumn migration corridor along the southern slopes of the Himalayas stretching from northeastern India through Nepal and into northwestern India. The flights were dominated by large numbers of Steppe Eagles *Aquila nipalensis* (Figure 6.1), together with smaller numbers of Greater Spotted Eagles *Clanga clanga* and Eastern Imperial Eagles

Figure 6.1. Adult Steppe Eagle on 11 November 2014 in Thulakharka (Nepal). Photo credit Hawk Mountain Sanctuary Archives (A black-and-white version of this figure will appear in some formats. For the colour version, please refer to the plate section.)

Aquila heliaca. Single-day counts ranged from 1 to 630 birds, with migrants passing at altitudes of between 1700°m to 3800 m above sea level (a.s.l.) between 9:00 and 16:00 local time, in flocks of up to 20 individuals (Fleming, 1983). Fleming concluded that the approximately 45,000 migrants, which passed mainly from late October to late November, presumably travelled from breeding areas in central Asia towards wintering grounds presumably in India (Naoroji, 2006; Pande *et al.*, 2013).

De Roder (1989) conducted the first systematic counts of visible raptor migrants in the Himalayas near Annapurna in central Nepal between 20 October and 7 November 1985 when he recorded close to 8500 raptors representing 19 species; more than 90% were identified as Steppe Eagles (28% juveniles birds, 28% subadults and 44% adults). De Roder concluded that between 10,000 and 20,000 Steppe Eagles migrated through the region in autumn (De Roder 1989), an estimate Bijlsma (1991) and Inskipp and Inskipp (1985) confirmed.

In a global directory of raptor migration 'watch-sites' (Zalles & Bildstein, 2000), the major raptor migration routes and bottlenecks described included two in Nepal and one in western China. On the heels of that publication, additional attention began to focus on raptor migration in the region. Finally, Den Besten conducted the first systematic counts of visible raptor migrants in northwest India in the autumn of 2001 and spring of 2002. Counting at a site approximately 50 km west of Donald's (1923) observation points, Den Besten (2004) reported nearly 13,850 raptors between 23 October and 30 November in autumn, and from 19 February through 29 March in spring, including 16 species, 97% of which were Steppe Eagles.

In addition, systematic raptor migration counts have been carried out since 2000 at several sites between northwest India and Nepal. DeCandido *et al.* (2001) counted autumn migrants near the Annapurna range for eight days in late October–early November in 1999, recording a total of 950 migratory raptors of eight species, 86% of

which were identified as Steppe Eagles. Of these, 15% were juveniles, 65% subadults and 20% adults. During this count, a local teacher, Gurung, became involved in the fieldwork. Although military conflict affected the migration count for several seasons, Gurung and his family conducted an autumn migration count from late October through early December 2003 (Gurung *et al.*, 2004), during which they recorded close to 7000 migratory raptors representing 10 species, 94% of which were identified as Steppe Eagles. Since 2012, Subedi and DeCandido have conducted counts from mid-September to early December in Thula Kharka, central Nepal (Subedi & DeCandido, 2013, 2014; Subedi, 2015), and nowadays, incipient long-term counts of visible migrants are well under way, at least in this part of the region.

The Biogeographic Context

Approximately 40% of all raptor species migrate, with the tendency to undertake migration increasing with increasing latitude and seasonality, as the latter often acts to reduce prey availability for raptors in winter (Bildstein, 2006). Asia, the world's largest continent, is host to at least 66 of the world's 130 or so species of migratory raptors, and most of these occur in the Palearctic region north of the Himalayas. Of these 66 species, 45 are known to migrate from and through the Himalayas (Table 6.1). That said, many raptors circumnavigate the region en route to wintering areas principally in Southeast Asia, the Indian subcontinent, the Middle East and eastern and southern Africa. Although many researchers (e.g. Moreau, 1972; Newton, 2008; Hawkes *et al.*, 2012) have suggested that avian migrants follow these longer routes because of the lower temperatures, higher altitudes and lower oxygen levels they would face if they took a more direct route over the mountains, circumstances specific to migratory raptors also may play a role.

Although raptors are relatively large-bodied, they have oversized wings and, as a result, are lightly wing-loaded birds, many of which use low-cost soaring flight to complete their diurnal migrations (Bildstein, 2006). 'Soaring,' or updraught-assisted non-flapping flight (*sensu* Kerlinger, 1989), is an energetically efficient form of flight, and most species of migratory raptor employ it, at least episodically. In fact many long-distance migrants are so-called obligate soaring migrants (*sensu* Bildstein, 2006) that depend on soaring flight to complete their migratory journeys. Updraughts necessary for soaring flight include both thermals, or pockets of warm rising air, and deflection or 'orographic' updraughts that occur when horizontal winds strike surface discontinuities, including mountains (Bildstein, 2006; see Ohlmann, Chapter 14, and Heise, Chapter 15). In many parts of the world, particularly in the tropics, raptors congregate in large flocks along 'thermal pathways' (*sensu* Berthold, 2001) while migrating. The high-altitude, rugged terrain of the Himalayas precludes this type of pathway and hence its use by migrating birds of prey. Orographic updraughts do occur, particularly along the southernmost slopes of the Himalayas, and it is not surprising that this creates the region's only well-known raptor migration pathway and that this corridor is dominated numerically by Steppe Eagles, a raptor known to be an obligate soaring migrant (Spaar & Bruderer, 1996; for details, see Heise, Chapter 15). Raptors, including falcons and, to some extent, accipiters and harriers,

Table 6.1. Raptors that migrate across the Himalayan region, including the western Himalayas (Pakistan and northwestern India), central Himalayas (Nepal) and eastern Himalayas (northeastern India and Bhutan). (RM = Regular migrant, V = Vagrant, ? = status uncertain, ND = no data). [1–5] Conservation status BirdLife International (2015).

	Himalayan region		
Migratory species	Western	Central	Eastern
Complete migrants[a]:			
Western Osprey *Pandion haliaetus*[1, A]	RM	RM	RM
Short-toed Snake Eagle *Circaetus gallicus*[1, A]	RM	RM	ND
Pallid Harrier *Circus macrourus*[3, A]	RM	RM	ND
Pied Harrier *Circus melanoleucos*[1, A]	ND	RM	?
Montagu's Harrier *Circus pygargus*[1, A]	RM	RM	ND
Greater Spotted Eagle *Clanga clanga*[2, A]	RM	RM	RM
Steppe Eagle *Aquila nipalensis*[1, A]	RM	RM	RM
Lesser Kestrel *Falco naumanni*[1, A]	RM	RM	RM
Amur Falcon *Falco amurensis*[1, A]	?	RM	RM
Eurasian Hobby *Falco subbuteo*[1, A]	RM	RM	?
Partial migrants[b]:			
Black-winged Kite *Elanus caeruleus*[1, B]	?	?	?
Black Baza *Aviceda leuphotes*[1, B]	V	RM	RM
Crested Honey-Buzzard *Pernis ptilorhynchus*[1, A]	RM	RM	RM
Red Kite *Milvus milvus*[3, A]	V	V	ND
Black Kite *Milvus migrans*[1,C]	RM	RM	RM
Pallas's Fish Eagle *Haliaeetus leucoryphus*[2, B]	RM	?	?
White-tailed Eagle *Haliaeetus albicilla*[1, A]	?	RM	?
Lammergeier (Bearded Vulture) *Gypaetus barbatus*[3, B]	?	ND	ND
Egyptian Vulture *Neophron percnopterus*[4, A]	RM	RM	ND
White-rumped Vulture *Gyps bengalensis*[5, B]	ND	?	ND
Himalayan Vulture *Gyps himalayensis*[3, B]	RM	RM	?
Griffon Vulture *Gyps fulvus*[1, C]	?	?	?
Cinereous Vulture *Aegypius monachus*[3, A]	RM	RM	ND
Western Marsh Harrier *Circus aeruginosus*[1, A]	RM	RM	?
Eastern Marsh Harrier *Circus spilonatus*[1, A]	V	V	ND
Hen Harrier *Circus cyaneus*[1, A]	RM	RM	RM
Shikra *Accipiter badius*[1, B]	ND	?	ND
Besra *Accipiter virgatus*[1, B]	?	?	RM
Eurasian Sparrowhawk *Accipiter nisus*[1, C]?	RM	RM	RM
Northern Goshawk *Accipiter gentilis*[1, A]	?	?	?
Common Buzzard *Buteo buteo*[1, A]	RM	RM	RM
Long-legged Buzzard *Buteo rufinus*[1, A]	RM	RM	RM
Upland Buzzard *Buteo hemilasius*[1, B]	?	?	?
Eastern Imperial Eagle *Aquila heliaca*[2, A]	RM	RM	ND
Golden Eagle *Aquila chrysaetos*[1, B]	?	?	ND
Bonelli's Eagle *Aquila fasciata*[1, A]	ND	?	?
Booted Eagle *Hieraaetus pennatus*[1, A]	RM	RM	RM
Common Kestrel *Falco tinnunculus*[1, B?]	ND	RM	RM
Merlin *Falco columbarius*[1, A]	?	?	?
Oriental Hobby *Falco severus*[1, B]	RM	RM	RM

Table 6.1. (cont.)

Migratory species	Himalayan region		
	Western	Central	Eastern
Saker Falcon *Falco cherrug*[4, A]	RM	RM	ND
Peregrine Falcon *Falco peregrines*[1, A]	RM	RM	?
Irruptive migrants[c]:			
Slender-billed Vulture *Gyps tenuirostris*[5, B]	?	ND	ND
Crested Serpent Eagle *Spilornis cheela*[1, B]	?	?	ND
Mountain Hawk-Eagle *Nisaetus nipalensis*[1, B]	ND	?	?
Total	**39**	**43**	**29**

[1] Least concern
[2] Vulnerable
[3] Near threatened
[4] Endangered
[5] Critically endangered
[a] Species or regional populations in which at least 90% of all individuals regularly migrate.
[b] Species or regional populations in which fewer than 90% of all individuals regularly migrate.
[c] Species or regional populations in which the extent of movement varies annually, typically due to between year shifts in prey abundance.
[A-C:] Type of migrant with:
[A] Palearctic migrant,
[B] Indomalayan migrant, and
[C] Indomalayan and Palearctic migrant. English and scientific names follow Gill and Donsker (2015).

Notes: 1. Eastern Buzzards *Buteo japonicus* and Himalayan Buzzards *B. burmanicus* are included as Common Buzzards *B. buteo*, not as separate species as proposed by Gill and Donsker (2015) and Riesing *et al.* (2003), because of identification concerns.
2. Because of the lack of information on the migration status of Red-headed Vulture *Sarcogyps calvus*, Lesser-spotted Eagle *Clanga pomarina* and Barbary Falcon *Falco pelegrinoides* in the Himalayan region, these species are not included in the migration list. That said, all three have been recorded as migrants at the Khare watch-site by de Roder (1989), Gurug *et al.* (2004) and Thiollay (1979).

that migrate principally by using flapping flight do apparently migrate across the Himalayas, but only across broad fronts, making the extent of their movements far more difficult to assess and quantify at visible migration watch-sites (see Dixon *et al.*, Chapter 8).

The emerging development of satellite-tracking technology promises to increase our knowledge regarding the extent of such movements (Dodge *et al.*, 2014). It thus appears that the Himalayas present a formidable barrier to raptor migration and that these mountains, together with the Tibetan Plateau, present a significant barrier to migrating raptors that limits the existence of concentrated migratory movements.

Patterns of Raptor Migration in the Tibetan-Himalayan Region

As is true in most regions in the world, the visible migrations of raptors are better known for autumn (i.e. post-nuptial or outbound) movements than for spring (i.e. pre-nuptial or

return) movements, largely because the former follow the breeding season and occur when populations are at their annual peak, whereas the latter occur after a period of winter mortality (Bildstein, 2006). Because of this, much of what follows focuses on the geography of autumn movements of raptor migrants through the region. Fortunately, the movements of a small but growing number of raptors are now being tracked by satellite in central and eastern Asia (Dixon *et al.*, 2011; Dixon *et al.*, 2012; Dixon *et al.*, Chapter 8; Batbayar & Lee, Chapter 7), following similar work in North America and Western Europe (Bildstein, 2006; Dodge *et al.*, 2014), giving avian movement ecologists the opportunity to follow individual raptors on both their outbound and return migrations. Information from these studies, albeit largely anecdotal to date, is summarized later in this chapter, along with findings from raptor migration watch-sites.

The Himalayas, which span approximately 2400 km east to west through parts of China, Bhutan, Nepal, India and Pakistan, are traversed or partially circumnavigated by at least 45 species of migratory raptors each autumn (Table 6.1). Presumably, most if not all of these migrants also migrate through the region in slightly smaller numbers in spring. It is believed that in autumn, most raptors migrate across the Himalayas on a broad front, using valley or river systems as short-distance passageways and navigational aids, and thereafter concentrate south of it along a major east-to-west flyway (Roberts, 1991; Chettri *et al.*, 2006; DeCandido *et al.*, 2013). These raptors include populations of 30 Palearctic migrant species that breed in central and eastern Asia and that migrate through and around the Himalayas to overwinter in the Indian subcontinent, the surrounding areas, the Middle East and eastern and southern Africa. A further 18 populations of Indo-Malayan migrant raptor species breed in the Himalayas and migrate shorter distances altitudinally, longitudinally or latitudinally within the region. Of the 45, 10 are complete migrants, 32 are partial migrants and 3 are classified as irruptive migrants (*sensu* Bildstein, 2006) (see Table 6.1 for details and definitions of types of migrants). Based on satellite-tracking data, a small number of banding recoveries and wing-tag re-sightings, raptor migration watch-site counts and sporadic observations, we characterize the movements as occurring along four corridors of uncertain magnitude: the (1) *Western Circum-Himalayan Corridor*, (2) *Eastern Circum-Himalayan Corridor*, (3) *East-to-West Southern Corridor* and (4) more broad-frontal *Trans-Himalayan Corridor* (Figure 6.1).

Circum-Himalayan corridors. Moreau (1972) suggested that the Himalayas and the Tibetan Plateau formed an effective barrier for many avian migrants. This appears to be true at least for raptors, with individuals of many species avoiding a direct crossing by circumnavigating this high-altitude barrier either to the west or east, or, in a few instances, by wintering to the north.

In autumn, the western edge of the Himalayas appears to be a concentrating point for several streams of migrants that avoid the Himalayas by migrating south through the Indus River Valley (Roberts, 1991). In spring, a first-year male Pallid Harrier fitted with a satellite tracking device on its wintering grounds on the western edge of the Indo-Gangetic Plain in northwestern India avoided the Himalayas completely by migrating north from India through western Pakistan and Afghanistan, and then north to its presumed breeding grounds in central Kazakhstan (Terrauble *et al.*, 2012). Additional satellite-tracking and ringing data suggest that Pallid Harriers breeding in

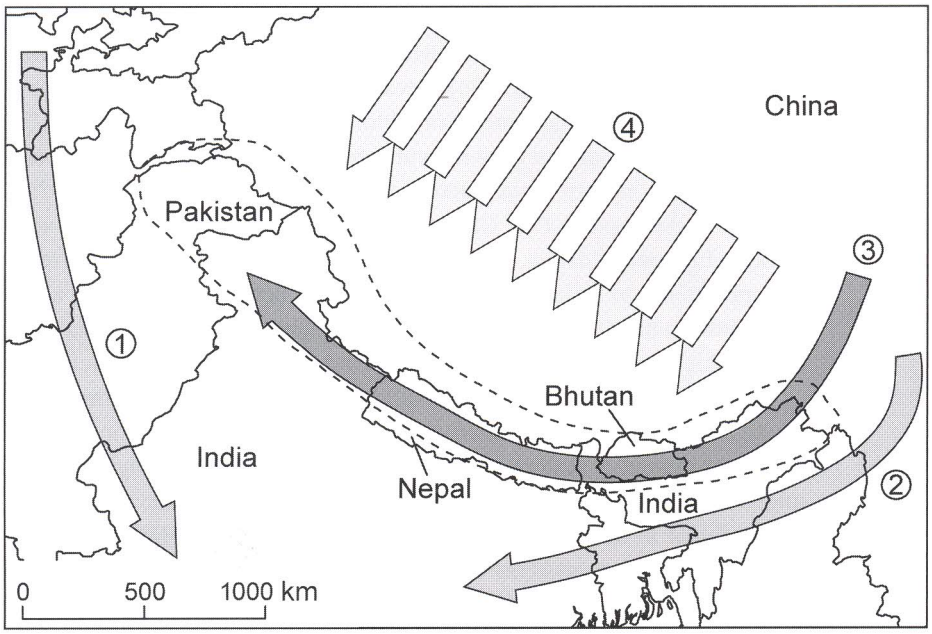

Figure 6.2. Autumn raptor migration corridors across and around the Himalayas: (1) Western Circum-Himalayan Corridor, (2) Eastern Circum-Himalayan Corridor (3) East-to-West Southern Corridor, (4) Broad-Frontal Trans-Himalayan Corridor (see text for details).

Kazakhstan overwinter both in sub-Saharan Africa and the Indian subcontinent (Terrauble *et al.*, 2012), indicating that movements of this tracked bird are probably representative of this population of the species. As many as 3000 harriers, mainly Montagu's Harriers *C. pygargus* together with lesser numbers of Pallid and Western Marsh Harriers, have been recorded in the wintering grounds in the Indo-Gangetic Plain of western India (Clarke *et al.*, 1998). These observations, together with the fact that relatively few harriers (< 70 individuals) have been seen on passage at migration watch-sites in the Himalayas (e.g. de Roder, 1989; Subedi & DeCandido, 2013; 2014; Subedi, 2015) (Figure 6.2), suggests that many, if not most, members of this genus avoid crossing the Himalayas via the western Circum-Himalayan Corridor.

On the eastern edge of the Himalayas, Amur Falcons *Falco amurensis* congregate temporarily in large numbers in autumn in northeastern India and Bangladesh to feed and fatten prior to embarking on the second stage of migration through the Indian subcontinent and across the Indian Ocean to equatorial eastern and southern Africa (Clement & Holman, 2001; Bildstein, 2006; Dixon *et al.*, 2011). Although fewer than 150 of these kestrel-sized falcons have been recorded migrating through Nepal in autumn (e.g. de Roder 1989; Subedi & DeCandido, 2013; 2014; Subedi, 2015), it is not clear whether they move along north–south or east–west axes, or both (Inskipp & Inskipp, 1985). Presumably, most individuals of this species follow an elliptical course around the Himalayas that has them migrating west and north of the mountains during their return migration in spring (Bildstein, 2006; Anderson, 2009).

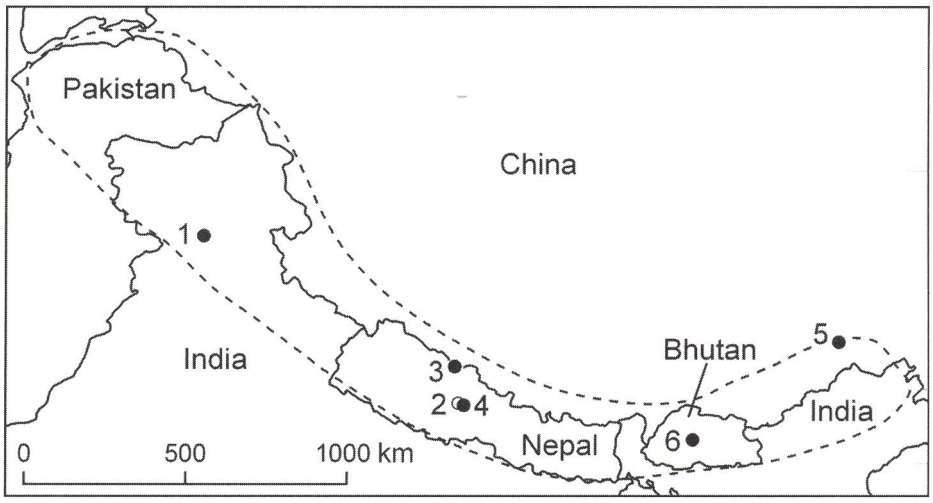

Figure 6.3. Locations of the six raptor-migration watch-sites in the Himalayas: (1) McLeod Ganj, northwestern India, (2) Khare, central Nepal, (3) Upper Kali Gandaki, northwestern Nepal, (4) Thula Khara, central Nepal, (5) Güncang, Tibetan Autonomous Region, western China; (6) Lawala Pass, western Bhutan (see text for details of species and counts).

The northern edge of the Himalayas is used both as a migration corridor and a wintering grounds for at least three migratory raptor species. A Steppe Eagle and two Saker Falcons *F. cherrug* fitted with satellite-tracking units in Mongolia and the Russian Altai, respectively, left their breeding grounds in early autumn and overwintered on the Tibetan Plateau north of the Himalayas (Eastham, 1998; Ellis *et al.*, 2001; Potapov *et al.*, 2002). Although individuals of both these species also overwinter in Africa and in the Indian subcontinent (Koning, 1976; Ferguson-Lees & Christie, 2001; Meyburg *et al.*, 2012; Pande *et al.*, 2013), it remains unclear how they move through or around the Himalayas. Also, a Peregrine Falcon *F. peregrinus calidus* fitted with a satellite-tracking device in the eastern Taymyr Peninsula, northern Russia, overwintered on the western Tibetan Plateau (Dixon *et al.*, 2012), although most individuals from this population overwinter further south, in the Indian subcontinent (Dixon *et al.*, 2012; Dixon *et al.*, Chapter 8).

Much remains to be learned about the extent to which raptors circumnavigate the Himalayas both during outbound migration in autumn and return migration in spring. The growing use of satellite-tracking devices on medium-sized and larger birds of prey promises to reveal much about the scale and nature of such movements (cf. Dodge *et al.*, 2014).

The East-to-West Southern Corridor. This well established raptor-migration corridor (de Roder, 1989; DeCandido *et al.*, 2013; Subedi & DeCandido, 2013, 2014; Subedi, 2015) may be the region's most significant, and many individuals avoid traversing the Tibetan Plateau by travelling east to west along the southern Himalayas along a mid-altitude corridor roughly parallel to the most southerly southern slopes of the

range. Migrants presumably follow an initial route to the east of the Himalayas (i.e. circa 100°E), from north to south and then turn west once they reach a point that is aligned with its southern slopes (i.e. circa 27°N). This 'geographic detour' enables the birds that take it to soar at low cost in orographic updraughts (Bildstein, 2006) while migrating at lower altitudes than they would otherwise use had they crossed the Tibetan Plateau east-to-west (see Ohlmann, Chapter 14; Heise, Chapter 15).

Steppe Eagles are the most studied, as well as the most common migrants in this corridor (DeCandido *et al.*, 2013). A recent estimate suggests that as many as 50,000 (DeCandido *et al.*, 2013) *Aquila* and *Clanga* spp., mainly Steppe Eagles, migrate along this corridor each autumn, concentrating at lower-altitude (i.e. 800–4500 m) bottlenecks near Annapurna, Kali Gandaki, Arun and Dudh Kosi in Nepal, and at Kangra and Dharamsala in northwestern India (Pande *et al.*, 2013). An average of 7150 Steppe Eagles has been recorded in three consecutive autumn migration counts at Thula Kharka, central Nepal, with juveniles (i.e. less than one year old) greatly outnumbered by sub-adult (two to four years old) and adult eagles (i.e. five years old or older) (Subedi, 2015).

The Trans-Himalayan Corridor. Although little information has been collected based on visible migration along this most likely diffuse corridor (Inskipp & Inskipp, 1985), satellite tracking suggests that it may be significant for several species, including Peregrine Falcon (Dixon *et al.*, 2012; Dixon *et al.*, Chapter 8), or even SteppeEagle (Batbayar & Lee, Chapter 7), and possibly Cinereous Vultures (*Aegypius monachus*), with migrants travelling along major valleys and gorges of up to approximately 5000 m, including the Kali Gandaki River Valley and the Tsangpo-Brahmaputra River Valley (Chettri *et al.*, 2006).

Five of the 10 Peregrine Falcons fitted with satellite-tracking units on their breeding grounds in the eastern Taymyr Peninsula in northern Russia in 2011 migrated through the Himalayas on a broad front between northwestern Pakistan and Bhutan (Dixon *et al.*, 2012; Chapter 8). Although the number of tracked individuals is small, it appears likely that Arctic Peregrine Falcons *F. p. calidus* migrating through the Himalayas breed in northern Russia between the Gydan Peninsula and the Lena Delta (Dixon *et al.*, 2012; Chapter 8). In addition, an average of 21 Peregrine Falcons has been recorded at Thula Kharka in central Nepal (Subedi, 2015).

Re-sightings of Cinereous Vultures wing-tagged on the breeding grounds in central Mongolia suggest that although most of this population overwinters in South Korea, a few individuals overwinter in the lowlands of central Nepal in the Himalayas, presumably having travelled either along the eastern edge of the range or through it (Batbayar *et al.*, 2008; Kenny *et al.*, 2008). An average of 59 Cinereous Vultures has also been recorded at Thula Kharka in central Nepal (Subedi, 2015).

Finally, travelling across Himalayas may be risky for migrating raptors. A Steppe Eagle was found dead at 7925 m on the South Col of Mount Everest in 1960 (Singh, 1961).

Altitudinal movements. Altitudinal migration consists of relatively short-distance seasonal movements between high-altitude breeding sites and lower-altitude overwintering areas (Newton, 2008). Such migration almost certainly occurs in the Himalayas. Unfortunately, the relatively short distances involved, coupled with the fact that such movements often occur coincidentally with longer-distance latitudinal movements,

means that altitudinal migration is far less well understood than its latitudinal counterpart (Bildstein, 2006).

What is known for the Himalayas is that the degree to which raptors migrate altitudinally in winter can depend on weather conditions (Inskipp & Inskipp, 1985; Grimmentt *et al.*, 1999, 2000; Inskipp *et al.*, 1999). Pallas's Fish Eagle *Haliaeetus leucoryphus*, a species that migrates latitudinally between the Tibetan Plateau and the lowlands of the eastern Himalayas, and as such is something of a north–south migrant, does so in part because its ability to secure sufficient aquatic prey in winter is affected by the icing over of high-altitude streams and rivers (Ali, 1977; Ali & Ripley, 1978). Observations of small numbers of Crested Serpent Eagles *Spilornis cheela* at migration watch-sites at Thula Kharka in central Nepal indicate that this reptile-eating species may also migrate altitudinally in the region (Subedi & DeCandido, 2013, 2014). Other species that are known to migrate altitudinally elsewhere in their ranges have been recorded infrequently at one or more watch-sites in the Himalayas, including White-rumped Vulture *G. bengalensis*, Himalayan Vulture *G. himalayensis*, Shikra *Accipiter badius*, Besra *A. virgatus*, Upland Buzzard *B. hemilasius* and Mountain Hawk-Eagle *Nisaetus nipalensis* (De Roder, 1989; Den Besten, 2004; Gurung *et al.*, 2004; Feijen *et al.*, 2005; Subedi & DeCandido, 2013, 2014).

Migration Strategies Demonstrated by Occurrences during the Non-breeding Season in and around the Himalayas

Based on satellite-tracking data, we know that Palearctic populations of Steppe Eagle, Saker Falcon and Peregrine Falcon overwinter on the Tibetan Plateau, often at elevations in excess of 4500 m. a.s.l. (Eastham, 1998; Ellis *et al.*, 2001; Potapov *et al.*, 2002; Dixon *et al.*, 2012).

Larger raptors, including obligate and facultative scavengers such as vultures and Steppe Eagles, also congregate in winter in large numbers around rubbish and carrion dumps in the southern Himalayas and immediately to the south (Chhangani & Mohnot, 2008; Pande *et al.*, 2013). Observations during 10 winters between 1995 and 2004 in Rajasthan, northwestern India showed that Griffon, Himalayan and Cinereous vultures overwinter regularly in the area, with numbers peaking in January–February (Chhangani & Mohnot, 2008).

Six species of harriers also overwinter in large numbers in the Indian subcontinent, mainly in open habitats (Clarke *et al.*, 1998; Verma, 2007; Verma & Prakash, 2007). Montagu's and Western Marsh Harriers are the most common, whereas Pied, Pallid, Hen *C. cyaneus* and Eastern Marsh *C. spilonatus* harriers are less common (Naoroji, 2006).

Steppe Eagle, a species that overwinters in Africa (Meyburg *et al.*, 2012), also overwinters in both the Indian subcontinent (Naoroji, 2006; Sharma & Sundar, 2009; Pande *et al.*, 2010, 2013) and the Tibetan Plateau (Ellis *et al.*, 2001), with many individuals congregating in large numbers around rubbish dumps in Rajasthan, Gujarat, Maharashtra and Karnataka in western and northwestern India (Sharma & Sundar, 2009; Pande *et al.*, 2010, 2013).

Several Peregrine Falcons fitted with satellite units in the Eastern Taimyr Peninsula, northern Russia overwintered in the Indian subcontinent along the Indo-Gangetic Plain (Dixon *et al.*, 2012; Chapter 8).

Recently and Currently Active Raptor Migration Watch-Sites

Visible raptor migration has been observed at six raptor migration watch-sites (*sensu* Zalles & Bildstein, 2000) in and around the Himalayas (Figure 6.1). At McLeod Ganj (900 m; Figure 6.2), in Himachal Pradesh, northwestern India, counts were conducted on 38 days in autumn 2001 (between 23 October and 30 November) and 29 days in spring 2002 (between 19 February and 29 March). Sixteen species were seen either on autumn or spring migration, or in both seasons. In autumn, a total of 8228 individuals was recorded, including 1 Crested Honey-buzzard *Pernis ptilorhynchus*, 11 Greater Spotted Eagles, 3 Booted Eagles, 8194 Steppe Eagles, 2 Eastern Imperial Eagles, 11 Eurasian Sparrowhawks *A. nisus*, 1 Northern Goshawk *A. gentilis*, 2 Hen Harriers, 1 Long-legged Buzzard *B. rufinus*, 1 Common Buzzard, and 1 Common Kestrel *F. tinnunculus*. In spring a total of 5618 individuals was recorded, including 4 Crested Honey-buzzards, 15 Greater Spotted Eagles, 9 Booted Eagles, 5204 Steppe Eagles, 1 Eastern Imperial Eagle, 1 Shikra, 35 Eurasian Sparrowhawks, 4 Northern Goshawks, 1 Western Marsh Harrier, 3 Hen Harriers, 1 Pallid Harrier, 80 Black Kites, 1 Upland Buzzard, 180 Long-legged Buzzards, 2 Common Buzzards, 64 Common Kestrels, and 13 unidentified raptors (Den Besten, 2004).

At Khare (1650 m; Figure 6.2), in the Janakpur Zone, central Nepal, counts were conducted in 1984, 1985, 1999 and 2003. Twenty-five species were seen in autumn between late October and early December. The counts that follow are the highest recorded numbers in any year: 10 Lammergeiers (a.k.a. Bearded Vulture *Gypaetus barbatus* (Figures 6.4, 6.5), 74 Egyptian Vultures *Neophron percnopterus*, 2 Crested Honey-Buzzards, 3 White-rumped Vulture, 233 Himalayan Vulture, 14 Red-headed Vultures *Sarcogyps calvus*, 8 Booted Eagles, 7852 Steppe Eagles, 9 Eastern Imperial Eagles, 3 Shikras, 13 Besras, 7 Eurasian Sparrowhawks, 1 Western Marsh Harrier, 66 Hen Harriers, 2 Pallid Harriers, 3 Montagu's Harriers, 97 Black Kites, 30 Long-legged Buzzards, 32 Common Buzzards, 77 Lesser Kestrels *F. naumanni*, 138 Amur Falcons, 19 Eurasian Hobbys *F. subbuteo*, 3 Saker Falcons, 2 Peregrine Falcons and 2 Barbary Falcons *F. pelegrinoides* (De Roder, 1989; Bijlsma, 1991; Zalles & Bildstein, 2000; DeCandido *et al.*, 2001; Gurung *et al.*, 2004).

At Upper Kali Gandaki (800–4500 m; Figure 6.2) in Dhaulagiri Zone, northwestern Nepal, counts were conducted in 1978 and 1984. Seventeen species were seen in autumn between late September and early November. The counts that follow are the highest recorded in either year: 1 Western Osprey, 1 Crested Honey-buzzard, 16 Booted Eagles, 63 Steppe Eagles, 4 Eastern Imperial Eagles, 1 Lesser-spotted Eagle, 23 Eurasian Sparrowhawks, 2 Northern Goshawks, 3 Western Marsh Harriers, 3 Hen Harriers, 1 Pallid Harrier, 32 Black Kites, 5 Long-legged Buzzard, 20 Common Buzzards,

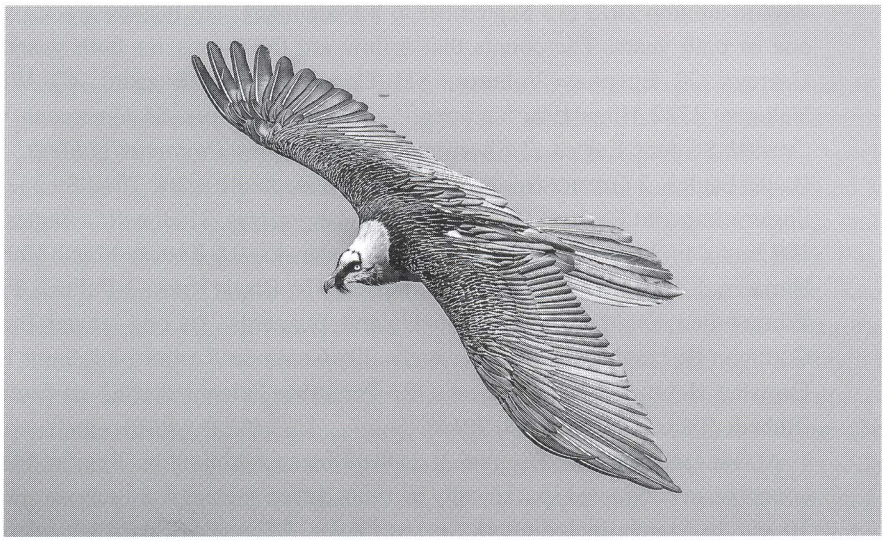

Figure 6.4. Soaring adult Lammergeyer on 23 November 2014 in Thoolakharka (Nepal; on maps referred to as Thuli Kharka: 28°22 N, 82°19'E), which is a well-known raptor migration site. Photo credit Hawk Mountain Sanctuary Archives. (A black-and-white version of this figure will appear in some formats. For the colour version, please refer to the plate section.)

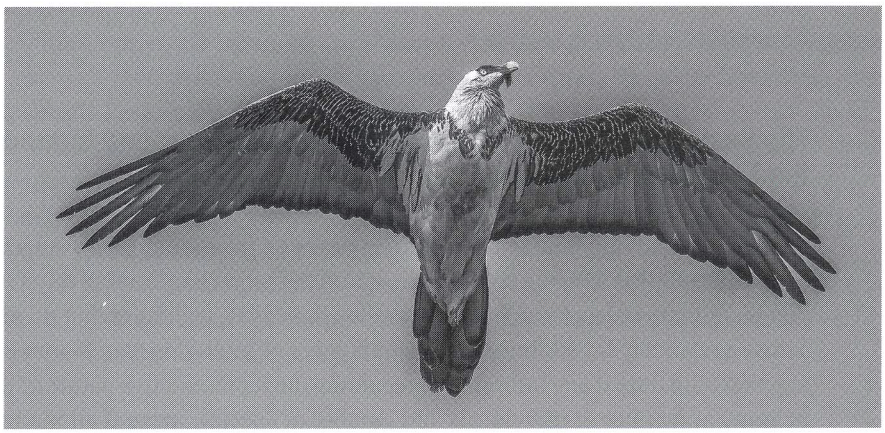

Figure 6.5. Adult Lammergeyer on 26 November 2014 in Thoolakharka (Nepal). For more information on this spot, see http://raptorsofnepal.blogspot.nl/ Photo credit Hawk Mountain Sanctuary Archives. (A black-and-white version of this figure will appear in some formats. For the colour version, please refer to the plate section.)

11 Lesser Kestrels, 39 Common Kestrels and 7 Eurasian Hobbys (Thiollay, 1979; Bijlsma, 1991; Zalles & Bildstein, 2000).

At Thula Kharka (2050 m; Figure 6.2), in Gandaki Zone, central Nepal, counts were conducted during 80 days in autumn 2012 (15 September to 4 December) and during 85

days in autumn 2013 (15 September to 8 December). Thirty-four species were seen in one or both years. The counts that follow are the means for both years: 4 Western Ospreys, 32 Egyptian Vultures, 511 Crested Honey Buzzard, 63 White-rumped Vultures, 1742 Himalayan Vultures, 64 Griffon Vultures, 65 Cinereous Vultures, 15 Crested Serpent Eagles, 2 Short-toed Snake Eagles *Circaetus gallicus*, 3 Mountain Hawk-Eagles, 2 Greater Spotted Eagles, 132 Booted Eagles, 7640 Steppe Eagles, 0.5 Eastern Imperial Eagle, 5 Golden Eagles *A. chrysaetus*, 21 Bonelli's Eagles *A. fasciata*, 108 Eurasian Sparrowhawks, 6 Northern Goshawks, 0.5 Eastern Marsh Harrier, 14 Hen Harriers, 1 Pallid Harrier, 0.5 Pied Harrier, 416 Black Kites, 1 Pallas's Fish Eagle, 1 White-tailed Eagle *H. albicilla*, 6 Upland Buzzards, 7 Long-legged Buzzards, 141 Common Buzzards, 67 Lesser Kestrels, 200 Common Kestrels, 84 Amur Falcons, 145 Eurasian Hobbys, 3 Saker Falcons, 23 Peregrine Falcons and 82 unidentified raptors (Subedi & DeCandido, 2013, 2014).

At Güncang (3170 m; Figure 6.2), in the Tibetan Autonomous Region, western China, counts were conducted sporadically in 1986. Seven species were seen in spring between 10 and 16 March, including 48 Steppe Eagles, 2 Eurasian Sparrowhawks, 1 Northern Goshawk, 3 Hen Harriers, 167 Black Kites, 2 White-tailed Eagles and 2 Common Buzzards (Robson, 1986; Zalles & Bildstein, 2000).

At Lawala Pass (3400 m; Figure 6.2), in Thimphu Province, in western Bhutan, counts were conducted sporadically in 1999. Seven species were seen in autumn between 13 and 14 November, including 1 Egyptian Vulture, 10 Himalayan Vultures, 2 Mountain Hawk-Eagles, 6 Steppe Eagles, 1 Golden Eagle, 4 Hen Harriers, 1 Peregrine Falcon and 22 unidentified raptors (Feijen *et al.*, 2005).

The Scale and Diversity of Raptor Migration across and around the Tibetan-Himalayan Region

Fieldwork involving counts of visible migrants at traditional raptor migration watch-sites suggests, that with the possible exception of Steppe Eagle, relatively few species of raptors migrate in large numbers across the Himalayas, and those that do migrate do so across a relatively broad front. The small number of migration watch-sites in the region, together with little if any information regarding the representative nature of the sites both in terms of number of individuals and number of species, make it all but impossible to gauge the total number of raptors that migrate through the region. That said, with a minimum of 45 migratory species, including 30 regular migrants, the region hosts one of the greatest assemblages of migratory raptors anywhere, in part because it occurs at the junction of the Palearctic and Indo-Malayan Biogeographic Realms, two of the world's most raptor-diverse realms (Ferguson-Lees & Christie, 2001). Much remains to be learned about raptor migration in this still 'ornithologically' remote region. Counts at raptor migration watch-sites, together with the emerging technology of satellite tracking, promise to close many gaps in our current knowledge, particularly regarding how weather and terrain combine to shape the movements of birds of prey in truly mountainous areas.

Conservation Considerations

Twelve of the 45 raptor species that migrate across and around the Himalayas are of global conservation concern, including seven Palearctic and five Indo-Malayan species (Table 6.1). According to BirdLife International (2015), the following species are classified as Globally Threatened: White-rumped Vulture and Slender-billed Vulture (*Gyps tenuirostris*) in the category Critically Endangered; Egyptian Vulture and Saker Falcon in the category Endangered; Greater Spotted Eagle, Pallas's Fish Eagle and Eastern Imperial Eagle in the category Vulnerable; and Pallid Harrier, Red Kite, Lammergeier, Himalayan Vulture and Cinereous Vulture in the category Near Threatened. Conservation concerns vary among the species, although the main threats include unintentional poisoning via veterinary drugs (Naoroji, 2006; Ogada *et al.*, 2012), pesticide misuse, human persecution, the live-bird trade and land-use change (Naoroji, 2006). Indeed, since the early 1990s, several populations of Asian vultures have declined by more than 95 percent (Ogada *et al.*, 2012). Several non-steroidal anti-inflammatory drugs (NSAIDs), including most notably Diclofenac, have been shown to be the major cause of the collapse of populations of vultures. Vultures are exposed to Diclofenac and other NSAIDs when they feed on drug-treated carcasses of livestock and die from kidney failure, with clinical signs of extensive visceral gout and renal damage (Das *et al.*, 2011). Fortunately, veterinary use of Diclofenac has been banned in India, Nepal and Pakistan, and in some regions vulture population declines have slowed (Galligan *et al.*, 2014).

In addition, the draining of swamps, marshes and other wetlands, together with chemical contamination of the system, poses a direct threat to fish eaters, including Pallas's Fish Eagles (Naoroji, 2006).

The six species of harriers that overwinter in the Indian subcontinent depend on natural grasslands both as roosting and foraging areas that are currently being reduced and fragmented for agricultural and other uses and that have been planted with invasive alien species (Naoroji, 2006; Verma, 2007).

Saker Falcons are potentially under threat from over-trapping for falconry (Eastham *et al.*, 2000). Most of the legal and illegal trapping takes place in autumn and early winter when the falcons are migrating (Potapov *et al.*, 2002).

Suggestions for Future Studies

Previous investigations of raptor migration across the Himalayas have focused on opportunistic (e.g. Bijlsma, 1991) and planned counts of visible migrants (e.g. Subedi & DeCandido, 2013; 2014) at migration watch-sites and other likely and accessible locations (Bildstein *et al.*, 2008). With this in mind, sampling the numbers of migrating raptors across a geographically expanded network of migration sites, coupled with greatly increased coverage in spring, would offer a cost-effective and efficient method for long-term monitoring of these birds (Zalles & Bildstein, 2000;

Bildstein, 2006; Bildstein *et al.*, 2008), particularly when the species in question concentrate along well-defined narrow fronts while moving through the region (Farmer *et al.*, 2010). Unfortunately, most practitioners in the field still view the migratory movements of birds of prey as 'fixed, and all-but immutable in place despite a growing body of field and experimental evidence that suggests otherwise. In fact, the picture that is now emerging from the literature indicates that migration behaviour in general, and migration geography in particular, are dynamic and flexible attributes of many species, and that both can shift quickly in response to changing ecological conditions' (Bildstein *et al.*, 2008). Important cases in point are the roles of global climate change and land-use change on bird migration. Elsewhere, one sees the effects of these factors, but in the Himalayas, knowledge regarding potential impacts is still in its infancy. Conservationists and governments urgently need clear baseline information to assess this, and our chapter does exactly that.

In addition, we also believe that counts at migration watch-sites alone are insufficient for monitoring and understanding raptor migration in the region and that the new investigative technology of satellite tracking will play an essential role in furthering knowledge in the field. The implementation of new systems employing GPS-logging, solar-powered 'mini' units on small as well as large birds of prey, coupled with cellular-telephone-based tracking units, will play a major role in helping raptor migration scientists better understand the geographical and temporal nuances in migration behaviour, and thereby help interpret watch-site count data more accurately. This is especially likely if new efforts follow the lead offered by recent studies of the physiological costs of migratory flights across the Himalayas by researchers studying the movements of Bar-headed Geese (*Anser indicus*) travelling through the region (Hawkes *et al.*, 2012, Chapter 16; Bishop *et al.*, 2015). Specific questions that need to be addressed include the extent to which raptors in general are capable of high-altitude flight such as that exhibited by raptors such as Rüppell's *Gyps rueppellii* and Griffon Vultures (Laybourne, 1974; Bögel, 1990).

Simply put, as we move forward, it is essential that we work together with volunteer raptor-watchers and the greater conservation and scientific communities, and that we use adaptive data management, data sharing and effective collaborations in our efforts (Dodge *et al.*, 2014).

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Bird Migration Across the Himalayas

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