FORKTAIL 25 (2009): 105–117

Over-ocean raptor migration in a monsoon regime: spring and autumn 2007 on Sangihe, North Sulawesi, Indonesia

FRANCESCO GERMI, GEORGE S. YOUNG, AGUS SALIM, WESLEY PANGIMANGEN and MARK SCHELLEKENS

During spring and autumn 2007 we carried out full-season raptor migration counts on Sangihe Island, Indonesia. In autumn, 230,214 migratory raptors were recorded. Chinese Sparrowhawk *Accipiter soloensis* comprised approximately 98% of the flight. The count results indicate that the largest movements of this species towards the wintering grounds of eastern Indonesia occur along the East Asian Oceanic Flyway, and not the Continental Flyway as previously thought. Both spring and autumn migrations occurred in the face of monsoon headwinds. The relationship between migrant counts and day-to-day variation in wind direction in Sangihe differed between the two seasons. More migrants were counted during crosswind conditions in spring when their route takes them along closely spaced islands than during similar conditions in autumn, when they run the risk of being blown off course during longer over-water legs. Displacement over the sea by crosswinds coupled with records from other islands point to the existence of an additional and heretofore unknown eastern route, involving longer water crossings, between Mindanao and the northern Moluccas via the Talaud Islands. We gathered evidence that Chinese Sparrowhawk behave nomadically during the non-breeding season, following local food abundances of seasonal insect outbreaks induced by rains. Predictable landfall time on Sangihe suggests that traditional roosts of thousands of migrants occur on small islands along this oceanic route. Unmonitored land use conversion on these remote islands could result in the loss of vital roosting habitats.

INTRODUCTION

The migration of raptors in the East Asian Continental and Oceanic Flyways has been sporadically investigated throughout this vast region, which stretches for more than 80 degrees of latitude from north-east Siberia to eastern Indonesia and New Guinea (McClure 1974, Lane and Parish 1991, Chong 2000, Zalles and Bildstein 2000, Chong and Nitani 2001, Bildstein and Zalles 2005, Higuchi *et al.* 2005). From the breeding areas in the northern third of eastern Asia, the migratory flight splits into two major corridors: the East Asian Continental Flyway, a 9,000 km long, mostly overland route stretching from Siberia and China to mainland South-East Asia and the Indonesian Archipelago; and the East Asian Oceanic Flyway, a 7,000 km island-hopping route extending from north-eastern Siberia, eastern China, Korea and Japan to Taiwan, the Philippines and Indonesia, involving water-crossings of up to 300 km (Fig. 1). With hundreds of thousands of raptors migrating along this route, the latter is the world's major oceanic raptor migration system. However, despite a recent increase of regular watch sites across the region, substantial gaps remain in our knowledge of the spatial and temporal migration routes, the numbers of migrants on passage and their ecology in the largely undefined wintering grounds. To date, the migration of raptors in the East Asian Flyways remains the least understood in the world (Ferguson-Lees and Christie 2001, Bildstein 2006).

Taiwan is the only country in the Oceanic Flyway where a long-term monitoring programme has been implemented, providing a highly detailed account of raptor migration through the island and useful information to predict movements towards lesser-studied neighbouring countries (Lin and Severinghaus 1998, Chen C.S.C. 2005, 2006, 2007, Chen C.S.C. and Sun 2007, Chen Y.J. 2006, Cheng *et al.* 2006, Sun 2006, Raptor Research Group of Taiwan 2008). Other studies along the Oceanic Flyway

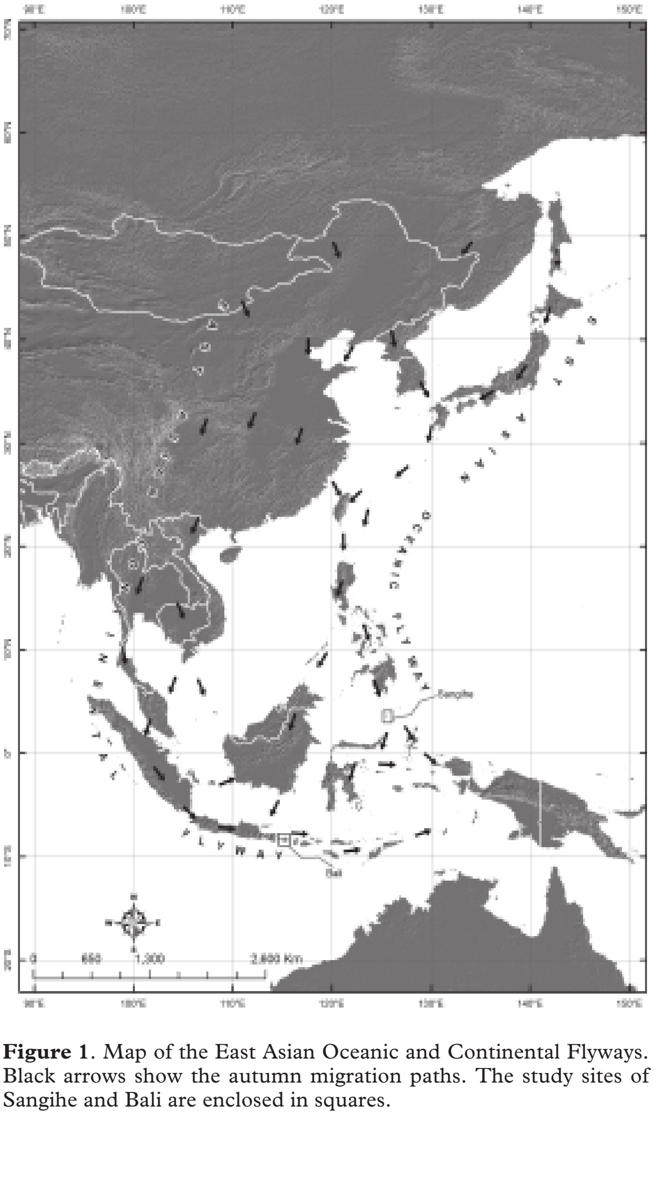

Figure 1. Map of the East Asian Oceanic and Continental Flyways. Black arrows show the autumn migration paths. The study sites of Sangihe and Bali are enclosed in squares.

have been carried out in Japan (Brazil and Hanawa 1991, Kugai 1996, Nitani 2000, *in litt.* 2007, Shiu *et al.* 2006), whilst until now no structured counts have been undertaken in the Philippines.

In Indonesia, where nearly all Chinese Sparrowhawks *Accipiter soloensis* overwinter, raptor migration studies remain very much in their infancy, and the few works of relevance were all conducted along the Continental Flyway. After Ash's discovery of a migration route over Bali in 1982 (Ash 1984), two studies were carried out as partial-season counts (Ash 1993, Nijman 2004), but they provided only an incomplete and in instances erroneous account of the autumn passage over Bali and Java (Nijman *et al.* 2006). Subsequently, several counts were carried out across the country by a network of Indonesian NGOs, birdwatching clubs and local universities during the 2001–2004 period (Sukmantoro *et al.* 2005). A more concerted and intensive research initiative was undertaken in Bali in 2004–2005, where more than 90,000 raptors were observed on migration in autumn 2005, yielding a previously unrecognised dimension of raptor movements throughout Indonesia (Germi 2005, Germi and Waluyo 2006). Based on these findings, we hypothesised that other major corridors within the archipelago might have been overlooked, in particular from the Oceanic Flyway. An examination of autumn migration count results from established watch sites in Japan and Taiwan suggested that the large numbers of southbound raptors were likely to winter not only in the Philippines, but also in eastern Indonesia and possibly New Guinea. The geography of the Oceanic Flyway indicates two likely entry corridors to Indonesia: (a) from the Philippines into Borneo via Palawan (Simpson 1983, Ellis *et al.* 1990, Davison 1997, Lim *et al.* 2002), and (b) the volcanic arc of islands between Mindanao (Philippines) and Sulawesi (Indonesia), the so-called Sangihe and Talaud Archipelago. The few published records of migrating raptors from Sangihe-Talaud and North Sulawesi (Meyer and Wiglesworth 1898, White 1976, White and Bruce 1986, Rozendaal and Dekker 1989, Riley 1997, Hornbuckle 2001) supported our hypothesis and suggested that a significant but still unquantified migration occurred along this corridor, hence prompting the undertaking of this study.

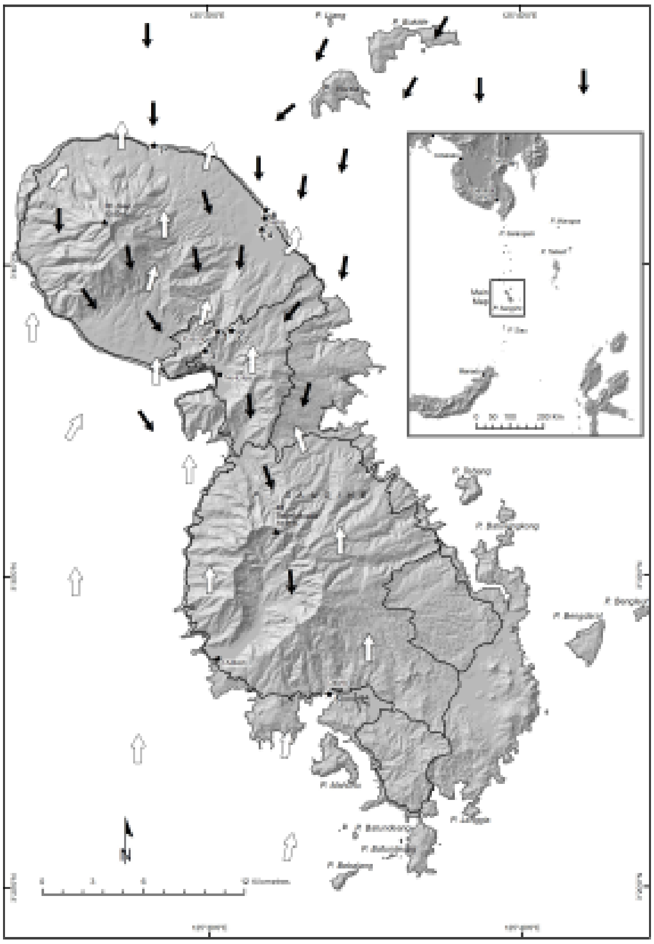

Figure 2. Map of Sangihe Island. White and black arrows show, respectively for spring and autumn 2007, main paths and sightings of large flocks on migration. The watch sites used are numbered 1–7: (1) Pusunge; (2) Lenganeng; (3) Bowong Baru; (4) Naha; (5) Dagho; (6) Kalekube; (7) Bulong.

METHODS

Study area

Sangihe island (03°35′N 125°32′E) is part of the Sangihe and Talaud Archipelago, an arc of volcanic islands that rises from a narrow submarine ridge extending from Sulawesi to the Philippine island of Mindanao. This 'stepping-stone' route involves water-crossing distances of between 3 and 190 km. Sangihe is 48 km long and 6–19 km wide, with a surface area of 737 km² and a rugged topography (BPS 2006). The north is dominated by Mt Awu (1,340 m), an active volcano, and in the south by the extinct volcanic caldera of Mt Sahendaruman (1,031 m; Fig. 2). Little natural forest habitat is left, restricted to the higher altitudes of the mountainous areas. Most of the island has been converted to a mosaic of plantations, shifting gardens and secondary forest. The vegetation is dominated by coconut *Cocos nucifera* plantations in the east and north, whilst in more mountainous areas nutmeg *Myristica fragrans* and clove *Eugenia aromatica* are the main crop trees (Riley 2002, Whitten *et al.* 2002). The average temperature is 26–28°C with little seasonal variation; the average rainfall is >3,000 mm per year, with a distinct wet season from November to March (BPS 2006).

Survey techniques

Of the chain of islands forming the suspected migration corridor between Mindanao and Sulawesi, we chose Sangihe because of previous records of migrants and the logistical facilities available. We extrapolated the passage periods in reviewing the scant published records from peer-reviewed literature and birdwatching trip reports: all records of migrants from Sangihe and adjacent areas within Indonesia, and count results from established regular watch sites in southern Taiwan, were collated in order to predict the more likely passage dates on the island. We assumed that casual records of large migrating flocks, all from non migration-related studies, possibly reflected periods of peak passage. Interviews with local villagers also provided a clue to the migration periods. Before fieldwork started, one of us (FG) visited the skin collections at Tring Museum, UK, to study the age-related plumages of Chinese Sparrowhawk and Japanese Sparrowhawk *Accipiter gularis* for field identification purposes.

Migration counts on Sangihe were conducted during 1 March–16 April 2007 (spring migration) and 20

September–30 November 2007 (autumn migration). In order to investigate wintering presences, additional fieldwork was carried out between 1 December 2007 and 1 March 2008. General survey techniques and migration count protocols adopted the guidelines summarised by Bildstein and Zalles (1995) and Bird and Bildstein (2007). Following a preliminary analysis of appropriate 1:50,000 topographic maps and reconnaissance of the island by car and on foot, five strategically located watch sites were selected in spring, and an additional two in autumn (Fig. 2). Four watch sites (Naha airfield, Bulong, Kalekube and Dagho) were at or near sea-level, whilst the other three (Pusunge, Lenganeng and Bowong Baru) were on mountain ridges or hill-tops and provided unrestricted views and close sight of the migrants; nevertheless the latter three were often engulfed in low clouds, particularly during spring. The watch site at Pusunge (03°37′52″N 125°30′18″E, 584 m) has a 360° view over the northern and central part of the island, and was used as the main watch site through the study. Approximately 70–80% of the possible flight front over the island was in view from the watch-sites of Pusunge and Naha; however we gathered evidence that migration also occurred over the sea, at and beyond the limit of aided vision. Moreover, low cloud cover reducing visibility, especially during March and early October (both peak migration periods), probably resulted in unknown numbers of migrants passing undetected. Dense low clouds affecting visibility and wind direction and speed were the main criteria we used to select the watch site on each day. Passage deflected toward the sheltered side of the island, thus forcing us to move to the more suitable watch site if cloud cover and wind direction changed during the same day.

Counts were normally made from 06h00 to 17h00 by a team of 1–3 observers, totalling 393 hours of observation in spring and 754 hours in autumn. Locations and directions were determined using a handheld global positioning system unit (Garmin GPS 48) and compass. Migration and weather data were recorded on a standard form produced by HMANA (Hawk Migration Association of North America), modified for local requirements. The directions from which migrants were more likely to appear were constantly scanned with 10× and 8× binoculars and 20–60× telescopes, and between these scans the areas above and on each side of the observer were also checked. Single individuals or flocks were followed until identification and direction of travel were established. At ridge watch sites with combined views to the north and south, raptors were recorded only from one side, generally from the arriving direction, in order to avoid double counting. Most passing raptors were counted individually, but in instances of large flocks (>200 individuals), 'blocks' of ten or more birds were multiplied within the flock, or the migrants were counted individually as they streamed in lines out of thermals. Whenever possible, counts of large flocks were repeated 2–3 times, often by two observers simultaneously, and if count results differed we used the average value.

Weather data were logged hourly. Wind direction, wind speed and air temperature were recorded with a handheld anemometer (Skywatch Meteos) and compass. Visual estimates were made of cloud cover, visibility and precipitation. Additionally, Naha Meteorological Station (Sangihe) provided hourly readings from the airport grounds on wind speed and direction, upper winds, temperature, rainfall and barometric pressure throughout the study periods. However, because the island weather observations include the effects of island-induced circulations that do not extend to the over-ocean migration areas, regional weather analyses also were performed. Weather in the vicinity of Sangihe varies on two timescales, a seasonal reversal in the monsoon flow between winter and summer, and lesser variations in wind speed and direction over periods of roughly a week. The latter are driven by a variety of atmospheric waves, of which mixed Rossby gravity waves (Roundy and Frank 2004) are the biggest contributor near Sangihe. Weather data were collected to cover each of these timescales. The seasonal cycle of the monsoon winds along the suspected migration route was documented using the tropical climatology of Sadler *et al.* (1987a,b). These data are monthly means with two-degree latitude and longitude resolution, sufficient to cover both the spatial and temporal variations of the monsoon flow. Day-to-day variation in wind was documented using the global reanalysis (see next paragraph) produced by the National Center for Atmospheric Research (NCAR) and the National Centers for Environmental Prediction (NCEP) (Kalnay *et al.* 1996). These data are six-hour averages with 2.5 degree latitude and longitude resolution. For this study, the winds at the 1,000 mb pressure level (approximately 100 m above sea level) and the 925 mb pressure level (approximately 750 m above sea level) were analysed for 00h00 GMT, 08h00 local standard time at Sangihe. The winds are presented in the form of migration 'wind roses'. For each day the wind vector is plotted as a vector directed out from the origin. The vector extends in the downwind direction for a distance proportional to the wind speed. At the end of each vector is a circle with an area proportional to the number of migrating raptors observed in Sangihe that day. This format shows the relationship of migrant numbers to both wind speed and direction on a single plot. Migration wind roses were created for both the full season and the peak migration period, but only the latter will be shown here so as to focus on the relationship between migrant counts and day-to-day variations in wind speed and direction. The days within the two tails of the migration period are not shown because they have low counts by virtue of their timing at the start and end of the migration period rather than because of any day-to-day variation in the weather. The spring migration wind roses thus extend from 12 March through 1 April while the autumn migration wind roses extend from 20 September through 29 October.

Reanalysis is the term used by meteorologists to describe the gridded fields of wind components and other weather variables that result from assimilating point observations into a time-dependent model of the atmospheric physics. These fields provide a more accurate estimate of the atmospheric state than do the point observations themselves because they make use of the modelled physics to interpolate in space and time between observations. The reanalysis used here is the result of a national effort to produce a definitive global meteorological dataset covering the last 60 years.

Statistical techniques

The statistical significance of the conclusions drawn from the wind roses was tested by fitting linear regression models to predict migration counts at Sangihe as a function of the south-to-north component of the wind (headwind or tailwind depending on season) and the absolute value of the west-to-east component of the wind (crosswind in both seasons). Plots of the predicted versus observed counts suggested a need to transform the observed counts. Both logarithmic and square-root scaling proved successful depending on season. Significance testing for each of the hypotheses was based on 95% confidence intervals for the predictor coefficients. Correlation between the de-scaled (i.e. raw count) model predictions and Sangihe counts is also reported.

RESULTS

During two field seasons in spring and autumn 2007, we recorded 88,773 and 230,214 migratory raptors respectively on passage at the site (Figs. 3–4). Species seen migrating were Osprey *Pandion haliaetus haliaetus*, harriers *Circus* sp., Chinese Sparrowhawk, Japanese Sparrowhawk, Grey-faced Buzzard *Butastur indicus* and Peregrine Falcon *Falco peregrinus calidus*.

Visible raptor movements on Sangihe and adjacent regions did not coincide with following winds. The annual

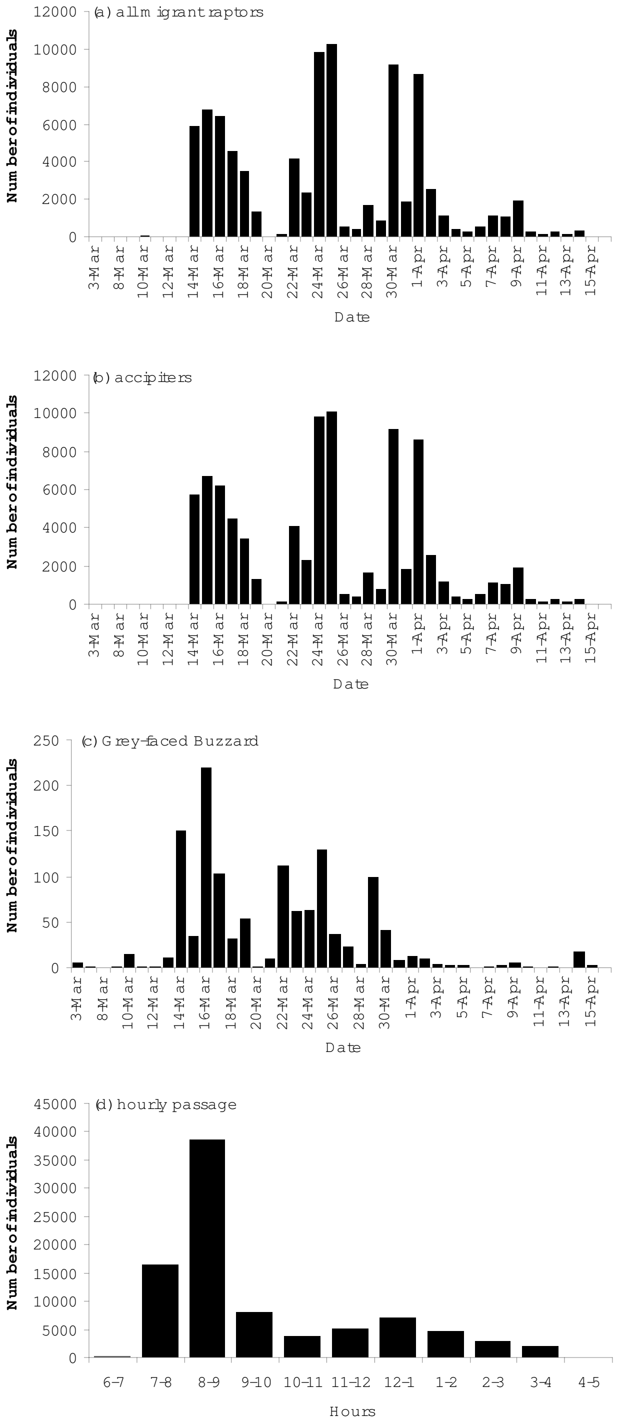

Figure 3. March–April 2007: daily totals of (a) all migrant raptors; (b) accipiters (Chinese Sparrowhawk *Accipiter soloensis* and Japanese Sparrowhawk *A. gularis*); (c) Grey-faced Buzzard *Butastur indicus*; and (d) hourly passage of all raptors on Sangihe.

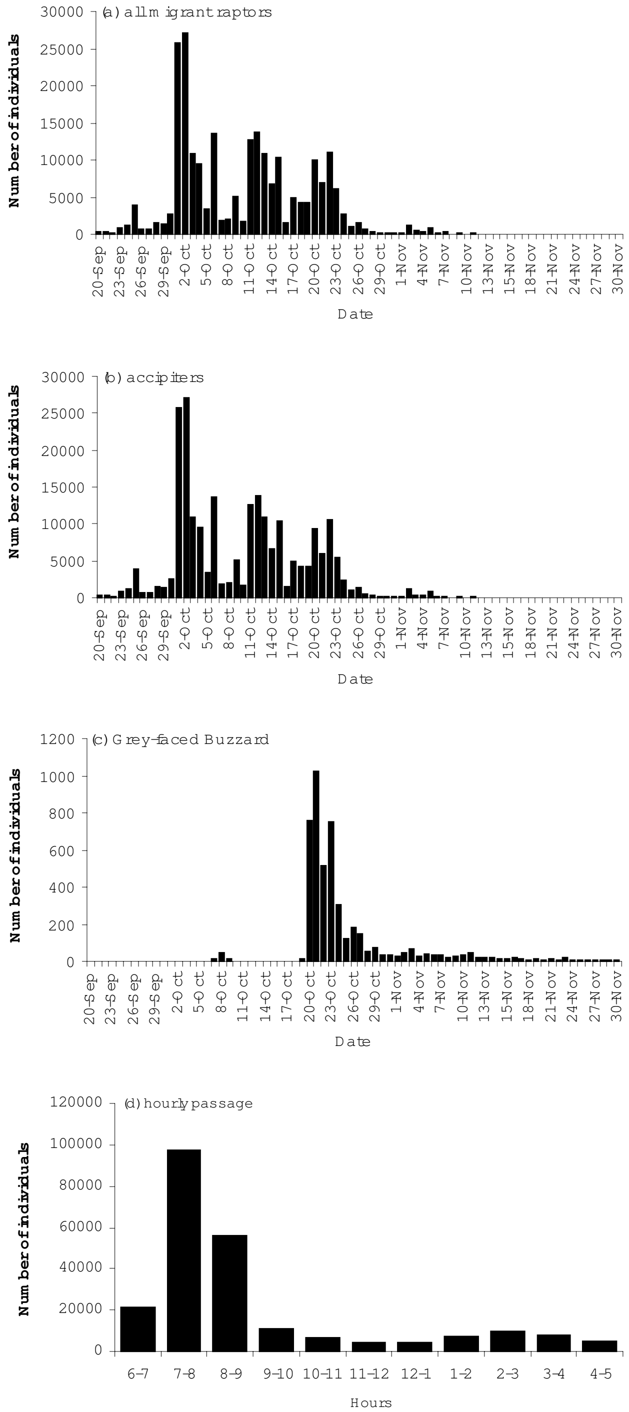

Figure 4. September–November 2007: daily totals of (a) all migrant raptors; (b) accipiters (Chinese Sparrowhawk *Accipiter soloensis* and Japanese Sparrowhawk *A. gularis*); (c) Grey-faced Buzzard *Butastur indicus*; and (d) hourly passage of all raptors on Sangihe.

reversal of the monsoon flow (Fig. 5) is timed later in both spring and autumn than the bulk of migration, so migrants face headwinds in both seasons. In spring, the winter north-east monsoon flow remains in place over the Philippines and north-eastern Indonesia through March and April. Likewise, in autumn, the summer south-west monsoon flow produces headwinds during September. The monsoon flow dies over Sangihe during October and November as the winter monsoon pushes south into the northern (October) and central (November) Philippines. Thus, for spring migration the monsoon flow is opposing throughout the migration period whereas during autumn migration the monsoon headwinds fade to near calm in the vicinity of Sangihe during the peak migration period. These climatological patterns are reflected in the Sangihe-area reanalysis 100 m wind vectors for the 2007 migration season (Fig. 5). Thus, despite the daily variations in wind speed and direction caused by the passage of atmospheric waves, the spring and autumn migration were mostly into opposing winds (*sensu* Richardson 1978).

The timing of the autumn migration throughout Sangihe was such that the bulk of the migrants passed

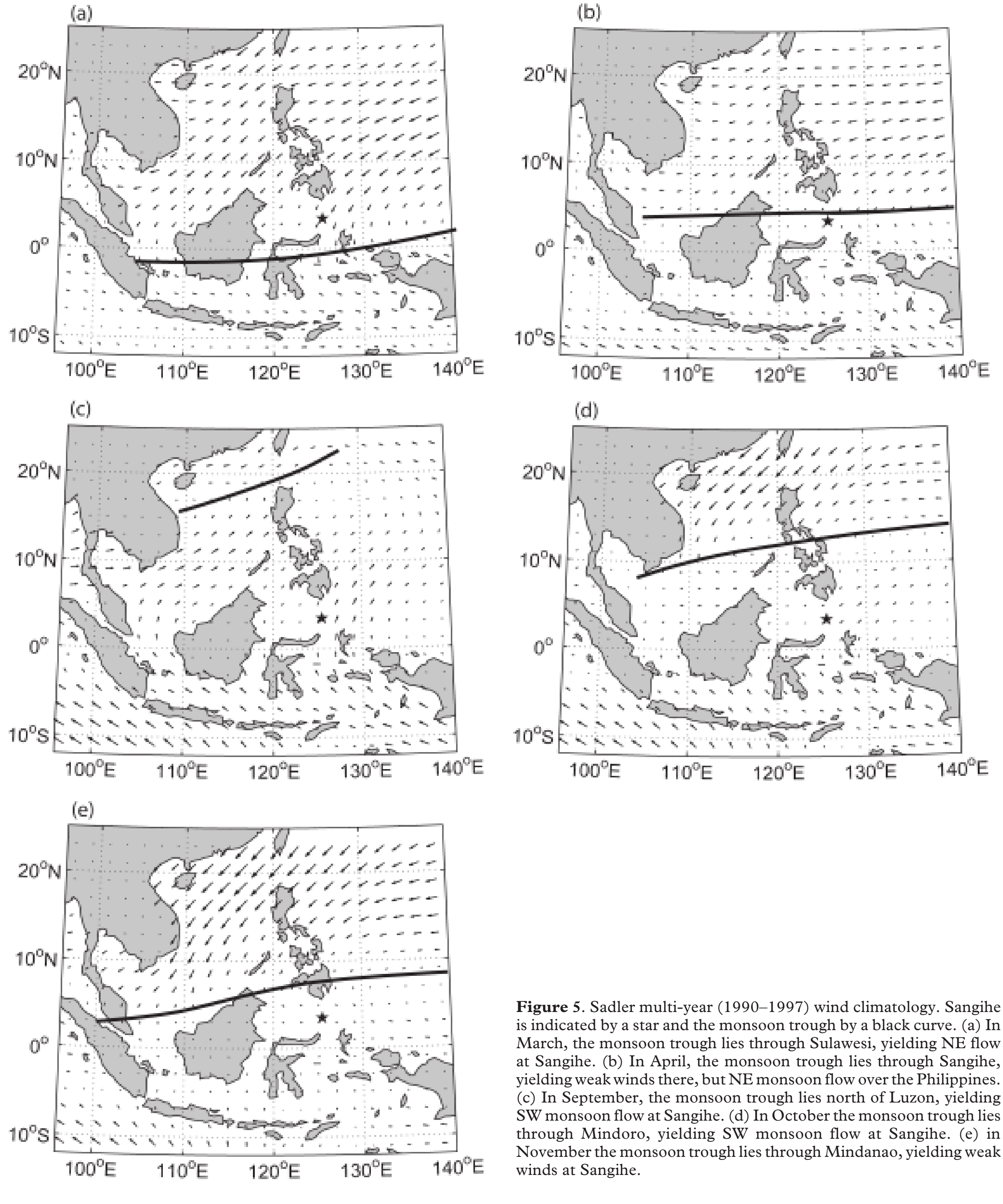

Figure 5. Sadler multi-year (1990–1997) wind climatology. Sangihe is indicated by a star and the monsoon trough by a black curve. (a) In March, the monsoon trough lies through Sulawesi, yielding NE flow at Sangihe. (b) In April, the monsoon trough lies through Sangihe, yielding weak winds there, but NE monsoon flow over the Philippines. (c) In September, the monsoon trough lies north of Luzon, yielding SW monsoon flow at Sangihe. (d) In October the monsoon trough lies through Mindoro, yielding SW monsoon flow at Sangihe. (e) in November the monsoon trough lies through Mindanao, yielding weak winds at Sangihe.

before the monsoon trough set up over the Philippines on 26 October, and well before the north-east monsoon reached the island. Thus, migration occurred ahead of the heavy precipitation (i.e. rainy season) associated with the trough. The autumn migrants thereby avoided long-range flight through heavy precipitation at the price of facing adverse winds. Likewise, spring migration had passed Sangihe before the monsoon wind reversal progressed north to the island**.** The year 2007 was typical in terms of both monsoon behaviour and the degree of day-to-day variability in the monsoon flow (Sadler *et al.* 1987a, b). Maps of the 100 m winds based on 2007 reanalysis data closely match those of the Sadler climatology for both the spring and autumn migration months. Furthermore, the observed degree of wind variability is typical of that induced by tropical waves in the Sangihe region.

Landfall on Sangihe occurred in an irregular succession of waves of flocks and single individuals, mainly between 06h00 and 09h00, suggesting that migrants had roosted overnight on a nearby island. Directions of arrival or departure showed compensation for wind drift. We have no evidence that raptors travelled at night, nor that they soared over-water in sea thermals. We located large communal roosts in the northern half of the island in spring, where take-off was not long after sunrise (±05h15) and well before good thermal conditions developed over land. Flocks were already formed as soon as they were detected in flight, so it appears that they had taken off as a flock, or with very little delay among individuals. Significant fluctuations in hourly passage of migrants were associated with time of day (Figs. 3–4) and wind speed: take-off, landfall and numbers of migrants aloft were higher during early morning hours (06h00–09h00) and during periods of low versus high winds, and the passage increased dramatically in days of light opposing winds, light wind from any direction, or no wind. Migrants flying into opposing winds in spring (north-easterlies) and autumn (south-westerlies) travelled at low altitude, especially over the sea, and selected sheltered paths on the island. Maximum headwinds in the reanalysis were only about 20 km/hr, well below the flight speed of the migrants. Migrants flying over water were almost always using powered flight, while on the island they progressed mainly in soaring and gliding flight. Flocks formed and broke both over the sea during flapping flight and on land in soaring and gliding flight, mainly one flock joining another already soaring in a thermal, then growing in size, and either continuing together or splitting when part of the migrants left that thermal or during the following glide. Flocks or singles encountering the sea upon leaving Sangihe showed no reluctance to undertake the crossing, either in flapping-gliding or in gliding from land thermals. Water crossing started at low altitude (±100 m or less) with opposing wind, up to ±600 m if land thermals were present, in weak wind from any direction and in calm conditions. Raptors soaring over the sea were always near shorelines and downwind, suggesting that migrants were

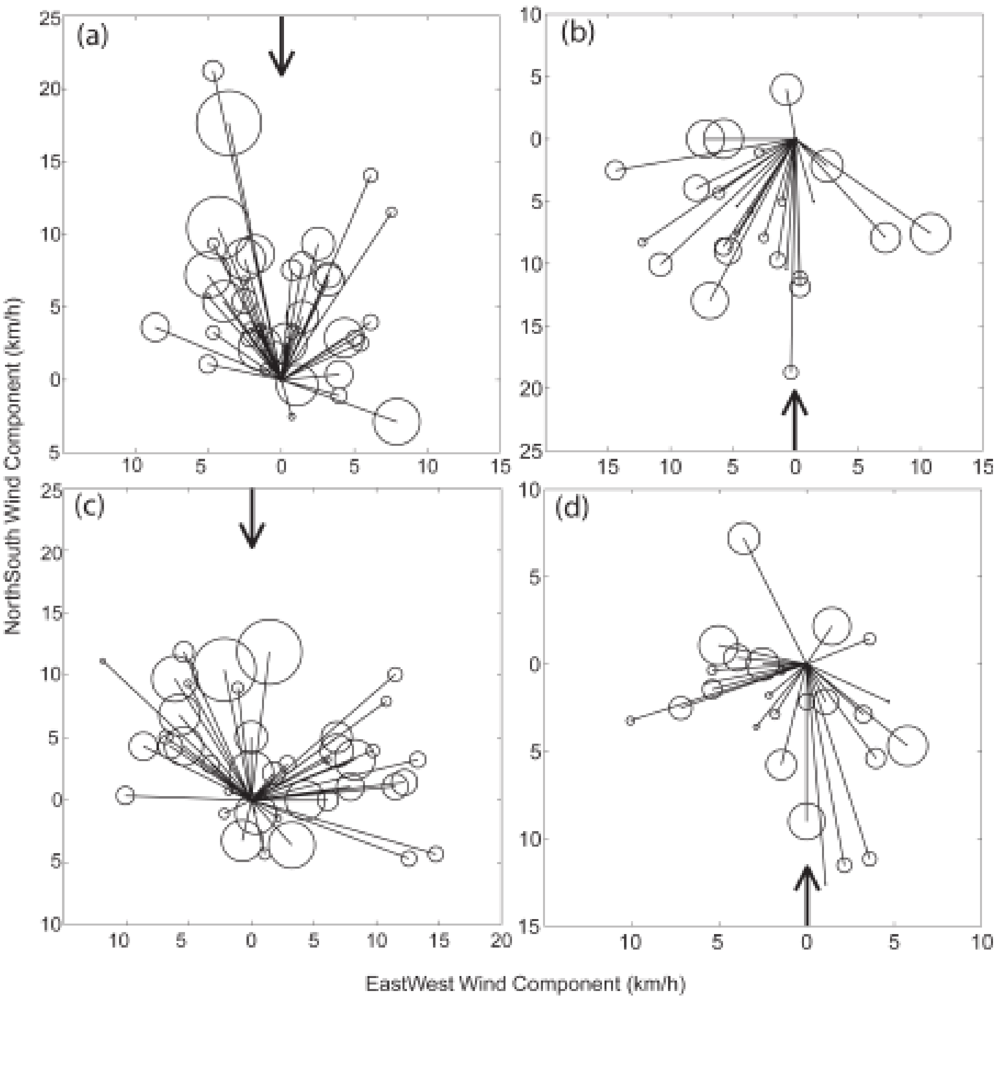

Figure 6. Wind roses at 100 m during (a) autumn 2007 migration, 20 September to 29 October, at Sangihe, 2.5N 125E; (b) spring 2007 migration, 12 March to 6 April, at Sangihe, 2.5N 125E. Equivalens wind roses are shown for the same time periods at (c) Mindanao, 5N 125E, during autumn, and (d) northern Sulawesi, 0N 125E, during spring. Vectors indicate daily direction and speed of winds at these places. Circle area indicates the number of migrants seen at Sangihe that day. The arrow indicates the direction of migration. Migration tails are excluded so as not to contaminate the wind-migration relationships with low counts from the beginning and end of migration.

Table 1. The most highly correlated regression models for Sangihe migrant numbers as a function of headwind/tailwind and crosswind components. Bold-faced regression coefficients are significant at the 95% level; those in italics are not. Correlation between the models' count predictions and the actual Sangihe counts are also shown.

Season	Response variable	Wind at	Intercept	Headwind	Crosswind	Correlation
Autumn	Log10 (Count)	Southern Mindanao	**3.07**	**0.057**	**-0.047**	0.54
Autumn	Sqrt (Count)	Sangihe	**39.5**	**2.55**	**-1.98**	0.37
Spring	Sqrt (Count)	Northern Sulawesi	**50.9**	**-2.35**	*-2.59*	0.30
Spring	Sqrt (Count)	Sangihe	**34.9**	**-1.38**	**1.92**	0.33

using land thermals displaced by the wind up to 3–5 km offshore.

The relationship between the daily number of migrants on Sangihe and the 100 m vector winds from the reanalysis is captured in Figs. 6a and 6c for the peak migration period (20 September through 29 October) of autumn 2007. Migrants face predominantly head or crosswinds both in southern Mindanao (their departure zone) and on Sangihe. Numbers seen at Sangihe each day do not appear to depend on the wind direction there, although they are often lower on those days with strong crosswinds in southern Mindanao. This relationship is statistically significant (Table 1), as is a tendency to larger numbers when there are headwinds in southern Mindanao. These relationships are weaker but still statistically significant for Sangihe wind components. This pattern remains when comparing the daily migrant numbers at Sangihe with the 100 m wind vector in southern Mindanao on the preceding day (not shown), but fades for longer lags. Thus, only the weather on the day of observation and the preceding day affects the migrant count. A similar pattern occurs when daily migrant numbers are plotted against the 750 m wind vectors. There are two explanations for this pattern. The first, that migrants prefer strong headwinds to strong crosswinds, is not supported by arguments based on energy requirements because both conditions slow ground speed dramatically. The second, that many of the migrants miss Sangihe during strong crosswinds, makes more sense, particularly in light of the wide spacing of the stepping-stone islands to the north. Observations of flocks bypassing Sangihe at the limit of observation support this hypothesis that strong crosswinds reduce the migrants' ability to direct their southbound route through Sangihe.

Daily migrant numbers during spring are likewise affected by the day-to-day variation between crosswinds and headwinds at both Sangihe and the departure points in northern Sulawesi. Figs. 6b and 6d for the spring peak migration period, 12 March through 6 April, show the relationship between the 100 m wind vectors at Sangihe and northern Sulawesi and the daily number of migrants at Sangihe. The number of migrants is lowest when the Sangihe winds directly oppose their track up the closely spaced island chain from northern Sulawesi. The same pattern occurs with northern Sulawesi winds, although two good migration days occurred with weaker north winds. This relationship is statistically significant (Table 1) with a tendency to larger numbers when there are tailwinds or crosswinds at Sangihe. The relationship is weaker and only the tailwind component is statistically significant for northern Sulawesi winds. This pattern fades at both Sangihe and northern Sulawesi with lags exceeding one day between migrant count and wind vector. Thus, as in autumn, only the weather on the day of observation and the preceding day affects the migrant count. Similar results are obtained using wind vectors at the 750 m level. This suggests that energy expenditure rather than navigation may be the dominant factor in spring. In contrast, during autumn the daily migrant counts are lower during crosswinds. This pattern may occur because the migrants must cross several long gaps between islands during the passage from Mindanao to Sangihe, making it easy for migrants to miss Sangihe during strong crosswinds. Conversely, during spring, the route from Sulawesi to Sangihe is marked by closely spaced and much larger islands, minimising the navigational challenge.

Spring

3 March–16 April 2007; 42 days, 393 observation hours. Osprey 6, Chinese Sparrowhawk 87,395, Japanese Sparrowhawk 76, Grey-faced Buzzard 1,294, Peregrine Falcon 2; total = 88,773. Prevalent wind direction: N–ENE (360°–70°). Mean wind speed at 100 m above sea level: 9.5 km/h.

The spring passage occurred into headwinds on almost every day. As we recorded small numbers of migrants from the first day (3 March 2007), some passage had probably occurred before that date. Flocks also passed over the sea parallel to the west coast; these were difficult to locate and we estimate that several thousand migrants passed undetected over water. In 2008 consistent northward migratory movements occurred from 27 February onwards, two weeks earlier than the previous year, indicating that in 2007 we probably missed the head of the spring migration. Passage was concentrated along the western, sheltered side of the island. As March–April is the end of the rainy season, frequent rain and dense low clouds on ridges and mountaintops resulted in poor or nil visibility at all elevated watch sites. Low cloud cover forced us to low-ground watch sites (i.e. Naha airfield, Fig. 2) on most days, from where passage was visible at a distance, identification of accipiters to species was often difficult and an unknown proportion of flocks passed undetected in clouds and on the opposite, sheltered side of the island. Weather improved in the second half of the season, when we moved permanently to high-ground watch sites (Pusunge and Lenganeng, Fig. 2). Local people recognise the existence of a large migration during October–November, but not in March–April, confirming that low cloud cover during the spring months seriously affects the detection of migrants.

Autumn

20 September–30 November 2007; 72 days, 754 observation hours. Harrier sp 1, Chinese Sparrowhawk 225,067, Japanese Sparrowhawk 421, Grey-faced Buzzard 4,710, Peregrine Falcon 15; total = 230,214. Prevalent wind direction: SE–SW (140°–240°). Mean wind speed at 100 m above sea level: 7.4 km/h.

As in spring, autumn winds were largely opposing the migrants' direction of travel. As we recorded migrants already from the 20 September, some passage had probably occurred before this date. Landfall on Sangihe was mainly along the north-east coast, with most flocks arriving from Bukide Island (20°–60°) and continuing south on the eastern, sheltered side of Sangihe. In days of calm or weak wind, passage concentrated on a direct north-to-south route, from Lipang Island to the north coast of Sangihe, then across Mt Awu and over Pusunge (Fig. 2). However, several observations of distant flocks travelling over the sea at the limit of visibility, especially in days of strong south-west wind, suggested that unknown numbers were deflected to a more easterly over-water route. Moreover, with strong south-westerlies, low-flying flocks seeking shelter and following the east coast were barely visible from our main watch site at Pusunge, so we consider that unknown numbers were missed on certain days. Rain cells also deflected the passage towards the dry side of the island. Minor southbound movements continued beyond our last counting day on 30 November.

Species accounts

OSPREY *Pandion haliaetus haliaetus*

Pre-2007 records: Dates of previous records (mainly October–January) suggest that individuals were migrant *P. h. haliaetus*. Recorded from Sangihe, Siau, Talaud and Sulawesi (Meyer and Wiglesworth 1898, Riley 1997).

2007: Extreme dates: 30 March–14 April (6 individuals). Recorded only in spring, but is possible that in autumn small numbers passed undetected over the sea. Singles on migration were recorded on the following dates: Mt Awu: 1 on 30 March; Kalekube: 1 on 30 March; Pusunge: 3 on 11 April and 1 on 14 April.

ORIENTAL HONEY-BUZZARD *Pernis ptilorhynchus orientalis*

Pre-2007 records: One specimen was collected on Salayar, southern Sulawesi, in November 1895 (Hartert 1896). Riley (1997) reported one individual on migration over Poa Island (Sangihe) on 19 October 1995.

2007: As we never observed Oriental Honey-buzzard during our study, we consider that this species does not enter Indonesia regularly from the Oceanic Flyway, but only from the western route along the Continental Flyway.

HARRIER *Circus* sp.

Pre-2007 records: The only certain record of a migratory harrier in Wallacea was one Eastern Marsh Harrier *Circus spilonotus* in North Sulawesi, apparently migrating north in April 1997 (Wardill and Katuuk 1998).

2007: We observed one dark brown harrier with a large white rump, which flew south over Pusunge on 29 September. The prominent white rump suggests a female or juvenile Pied Harrier *Circus melanoleucus* or Eastern Marsh Harrier. Both species are winter visitors to the southern Philippines and may reach Sulawesi.

CHINESE SPARROWHAWK *Accipiter soloensis*

Pre-2007 records: The relatively large number of specimens collected from Sangihe in the nineteenth century appears to have been overlooked by White and Bruce (1986) and Coates and Bishop (1997). Meyer and Wiglesworth (1898) list a total of six specimens from this island collected between 24 October and 3 November 1864, October 1865 and January 1866. White and Bruce (1986) note one immature bird observed near Petta, Sangihe, on 2 December 1978. Subsequently, Riley (1997) recorded this species on 13 October 1995 at Talawid Atas, with peak counts totalling c.550 birds which passed south during two hours over Poa Island on 18 October 1995 and 120 birds over Poa Island on 19 October 1995. Birds were most often seen in groups of 8–15 but on 18 October 1995 two groups of 150–180 birds were observed. On 17 March 1995 at least 120 birds were seen flying north over Naha (D. A. Holmes in Riley 1997). 'Only a few individuals wintering on Sangihe and Talaud' were reported by Riley (1997), but dates were not given. Also recorded on migration from Talaud, Siau, North Sulawesi and northern Moluccas (Meyer and Wiglesworth 1898, White 1976, White and Bruce 1986, Riley 1997, Gjershaug and Røv 2000).

2007: Extreme dates: 3 March–16 April (87,395); 20 September–30 November (225,067). Chinese Sparrowhawk, which is the most numerous migratory raptor in East Asia, comprised the overwhelming majority (98%) of all raptors on passage, with noticeably large numbers of juveniles during the autumn. In 2008, the first northbound migrants were observed on 27 February. Daily records of overwintering birds were collected from December 2007 to February 2008: individuals were recorded in singles or pairs, in primary and secondary forest up to 1,000 m asl and in all types of degraded or cultivated habitats, either by direct observation or by their conspicuous call. Wintering individuals were often observed still-hunting dragonflies (Odonata) and cicadas (Cicadidae) from prominent branches and the top of coconut trees. The most remarkable winter observations were those of small flocks travelling both southward and northward in the middle of the 'wintering' season, suggesting nomadic inter-island movements or perhaps pre-migration staging, or both. The most unusual of such records were the following: 17 heading north near Tamako on 22 January; 10 heading north near Tamako on 31 January; 18 and 7 making landfall near Naha and continuing southwards on 16 February. Most Chinese Sparrowhawks passed in large flocks ranging from hundreds up to ±6,000 individuals (Table 2). One northbound flock of ±3,000 passed over Lenganeng on 15 March, and two flocks of ±6,000 were observed from Pusunge on 4 and 6 October. In autumn, take-off of birds that had roosted overnight on the island occurred before 06h00, and large southbound flocks arriving from the north-east were observed over the sea as early as 06h45. Flocks travelling over water were observed flapping or soaring between 30–100 m above the sea, and Chinese Sparrowhawks always flew higher than Grey-faced Buzzards over both sea and land. Mixed flocks of Chinese Sparrowhawks and Grey-faced Buzzards were observed crossing under light rain from Bukide to Sangihe in flapping flight at 50–60 m. Migrants often passed inside dense low clouds on ridge-tops, and birds reacted to strong opposing winds encountered at altitude by scattering, diving suddenly, seeking shelter behind ridges, hugging the ground and following contours. Chinese Sparrowhawks were grounded by heavy rains, and were often heard calling from coconut groves when rain ceased, probably to maintain contact within the flock, but they did not take off again in the afternoon. During migration, individuals roosted and still-hunted from crop trees, building roofs and light poles around Naha airfield, where

Table 2. Flock sizes of accipiters passing on Sangihe, September–November 2007.

Flock size	No. of flocks	% of flocks	No. of accipiters	% of accipiters
Single Individuals	–	–	10,234	4.5
2–99	2,983	83	53,733	23.8
100–499	527	14.6	80,321	35.6
500–999	51	1.4	21,500	9.5
> 999*	42	1	59,700	26.5
Total	3,603		225,488	

* Two flocks of > 6,000 accipiters each were observed on 4 and 6 October 2007.

on several occasions they were observed catching unidentified prey from the ground. A large spring roost was located south of Mt Awu in coconut plantations at 03°37′N 125°27′E. Roosting Chinese Sparrowhawks were noticeably conspicuous when calling from perches on prominent tree branches or from the top of coconut trees, both during migration and winter.

JAPANESE SPARROWHAWK *Accipiter gularis*

Pre-2007 records: First recorded at Naha, 17 March 1995 (D. A. Holmes in Riley 1997) and on 14 October at Talawid Atas a single female, then a further six records with the maximum being a flock of 8 over Kedang on 21 October 1995 in association with Chinese Sparrowhawks, and a few more individuals from Talaud and Siau (Riley 1997). Also recorded in North Sulawesi (White 1976).

2007: Extreme dates: 3 March–15 April (76); 20 September–29 November (421). Japanese Sparrowhawk was recorded in singles, small monospecific flocks or in small numbers within large mixed flocks. Japanese Sparrowhawk migration behaviour was similar to that of Chinese Sparrowhawk. A juvenile on passage under light rain was observed catching a dragonfly that it subsequently ate in flight. As a result of the similar size between the two accipiters, Japanese and Chinese Sparrowhawks were not easily separated. Spotting and counting the former's small numbers embedded within large Chinese Sparrowhawk flocks was difficult, and any visual scan through soaring or gliding flocks always revealed a large majority, if not totality, of Chinese Sparrowhawks. Moreover, it was often impossible to separate individuals of the two species owing to similarities of transitional plumages amongst juveniles, and between juveniles of the two species versus adult Japanese Sparrowhawk. Light conditions and the minor differences in wing shape and mode of flight *during migration* caused additional difficulties (Wattel 1973, Leader and Carey 1995, Herremans and Louette 2000, Ferguson-Lees and Christie 2001, pers. obs.). The resulting under-recording of the latter species remains difficult to quantify, although the numbers involved were clearly very small. This is in accordance with previous studies in Bali and Java (Germi 2005, Germi and Waluyo 2006, Nijman *et al.* 2006) and with the numbers recorded on passage in Taiwan (158 individuals in autumn 2007: Raptor Research Group of Taiwan 2008).

GREY-FACED BUZZARD *Butastur indicus*

Pre-2007 records: Meyer and Wiglesworth (1898) recorded 8 individuals on Sangihe from October to January, and 8 individuals on Talaud in October and November. Also recorded in Siau, Sulawesi and northern Moluccas (White 1976, White and Bruce 1986, Riley 1997). McClure (1974), based on 106 ringing recoveries and hunting records, erroneously concluded that Grey-faced Buzzard does not go beyond the Philippines during autumn migration.

2007: Extreme dates: 3 March–15 April (1,294); 7 October–30 November (4,710). Grey-faced Buzzard was the second most numerous migrant, comprising 2% of the autumn flight. A small vanguard passed on 7–9 October, followed by several days of no passage before a sudden large influx from 20 October that lasted just over a week (Fig. 4). Smaller numbers were recorded daily until the end of the study. In 2008 the first individual migrating northward was recorded on 16 February, followed by 10 individuals on 20 February, 17 on 28 February and 14 on 3 March. Wintering individuals were recorded on several January and February 2008 dates from 1,000 m asl in primary forest to lowland cultivated areas. Southbound birds made landfall on Sangihe mainly from the north-east (Bukide Island), flapping-gliding at ±50 m over the sea. Small flocks were observed on several occasions soaring low over the sea near coastlines, but most individuals crossed from Bukide to Kalekube-Naha in flapping-gliding flight, including during light rain. The largest flock, ±150 individuals soaring over Naha airfield, was observed on 21 October. When in mixed flocks, Grey-faced Buzzards generally soared and glided lower and slower than the accipiters, generally followed at the tail of mixed flocks, and passed later in the day, with most migrant movements occurring in late mornings and afternoons. Individuals calling at night on the outskirts of Tahuna and soaring low over forest soon after sunrise indicated overnight stopovers on the island.

COMMON KESTREL *Falco tinnunculus*

Pre-2007 records: Riley (1997) reported one female on Poa Island (Sangihe) on 19 October 1995 on migration with Chinese Sparrowhawks.

2007: We never observed Common Kestrel during our study; instead we had almost daily observations of the resident Spotted Kestrels *Falco moluccensis,* not showing migratory behaviour.

PEREGRINE FALCON *Falco peregrinus calidus*

Pre-2007 records: Three October records from Sangihe and Siau (Riley 1997).

2007: Extreme dates: 17 March–2 April (2); 7 October–5 November (15). The large and pale migratory subspecies *calidus* was clearly distinguishable from the smaller and darker resident *F. p. ernesti*. Singles on passage on the following dates: Lenganeng: 17 March; Pusunge: 2 April; 7, 13, 16, 21 and 30 October; Naha: 22 and 26 October; two singles on 5 November. Pairs of *calidus* (female and male) travelling together were observed from Pusunge on 14, 18 and 23 October.

DISCUSSION

Our results reveal that major and previously unrecognised raptor migration movements occur between Mindanao (Philippines) and Sulawesi (Indonesia). The five species recorded on passage are long-distance, trans-equatorial migrants, and Chinese Sparrowhawk is a super-flocking migrant (*sensu* Bildstein 2006), assembling in flocks up to several thousands of individuals. The chain of stepping-stone islands which includes Sangihe funnels a flight of at least 250,000 raptors, overwhelmingly Chinese Sparrowhawk, and indicates that the East Asian Oceanic Flyway, and not the Continental Flyway as previously thought, is the main migration route to the wintering grounds of this species in eastern Indonesia, in both spring and autumn.

Raptors migrating into headwinds have been reported extensively in the literature (e.g. Haugh 1975, Richardson 1978, 1990, Kerlinger 1984, 1989, Elkins 2004). However, most authors find that following winds are a key component of favourable travelling conditions, especially for species that fly over large expanses of inhospitable habitat such as deserts and oceans. Our observations here demonstrate that raptors migrating through Sangihe in spring and autumn react differently to adverse winds than those observed in other parts of the globe. This difference in behaviour appears to reflect both the geography and wind climatology of this island-hopping route. The monsoon climate of Sangihe produces much more consistent wind directions in each of the migration seasons than would a mid-latitude climate. Thus, the only way to avoid adverse winds is to wait for the seasonal change in the monsoon. This transition from headwind to tailwind occurs, however, too late in both spring and autumn seasons to fit within the raptors' migration schedule. Another reason not to delay migration to await the shift in monsoon wind direction is that doing so would require flying through the band of heavy precipitation that forms along the border between the north-east and south-west monsoon. Moreover, the monsoon winds at Sangihe are less intense than those along many temperate routes. Hence, migrant raptors can make good progress by flying low enough in the atmospheric surface layer (i.e. the layer where wind speed increases logarithmically with height) that their airspeed significantly exceeds wind speed. Geography also plays a role in that the raptors seen at Sangihe are migrating in relatively short over-water legs between islands that provide food sources (e.g. insects). Thus, even slow progress against adverse winds can be supported by feeding stopovers on the larger islands.

Early morning flights are the norm both in Sangihe and Taiwan, and it is well known that flapping migrants (as an over-ocean flight would require) fly primarily in the early hours, when the air is calm and temperatures are cool. Moreover, the apparent need to cover the over-water legs during daytime is probably another explanation for this phenomenon. As there is no evidence of night migration in either Chinese Sparrowhawk or Grey-faced Buzzard (Kugai 1996), the highly predictable landfall time on Sangihe (06h00–09h00) indicates that large, regular night roosts occur on some islands along the corridor, and that morning take-off should be at or shortly after sunrise. We estimate that Chinese Sparrowhawk travelling speed over land, with strong thermal assistance and combining soaring-gliding and flapping-gliding flights was 40–50 km/hr. Our estimate closely matches the results from radar studies in Taiwan (Cheng *et al.* 2006, Sun 2006, Chen C.S.C. and Sun 2007), where Chinese Sparrowhawk mean flight speed, over water, averaged 50 km/hr. Extrapolating a mean over-ocean flight speed of 45 km/hr, it is evident that in order to reach Sangihe in the early morning hours, autumn super-flocks take-off at ±05h30 from the small islands between Marore and Dumarehe, up to 120 km to the north of Sangihe. Therefore, the reduced passage after 10h00 may reflect a direct non-stop flight from southern Mindanao, probably ±5 hours long (Fig. 4).

Chinese Sparrowhawk is considered a winter visitor to the Philippines, where it has been recorded from August to May (Dickinson *et al.* 1991, Kennedy *et al.* 2000, A. Gamauf *in litt.* 2008). Thus, comparing annual counts of southbound Chinese Sparrowhawks from Taiwan (a maximum of 409,000 in 2004) with our results from Sangihe (225,000 in 2007) it would appear that up to 180,000 individuals of this species may drop out in the Philippines to overwinter there. However, the apparent scarcity of winter records from this archipelago suggests that an unknown percentage of these migrants continue south-west into Borneo and southward into Wallacea. Our numerous records of Chinese Sparrowhawks and Grey-faced Buzzards during December–February indicate that these species are common wintering birds on Sangihe. Winter observations of Chinese Sparrowhawks feeding on large insects and small birds were made by us in Sangihe, Bali and Flores. These records come from a great variety of habitats ranging from primary and secondary forests, scrub, agricultural landscapes, towns, villages and 'kemiri' *Aleurites moluccana* forest on Flores, where prey includes dragonflies (Odonata), cicadas (Cicadidae), termite alates (Isoptera), swifts *Collocalia* sp. and munias *Lonchura* spp. In central Flores, where Chinese Sparrowhawks feed heavily on cicadas, the majority of this accipiter leaves the area in late November once cicada emergences terminate, and only small numbers remain through the winter (pers. obs.). These observations, coupled with the anomalous winter movements we noted in Sangihe (see species accounts), suggest that Chinese Sparrowhawk may be nomadic during the non-breeding season, opportunistically following local food abundances as seasonal insect emergences occur. Interestingly, large emergences of cicadas are known to occur during the rains in October–November in New Guinea and in October–February in the Moluccas (H. Duffels *in litt.* 2008), indicating that Chinese Sparrowhawk overwinter in eastern Indonesia and New Guinea when insect abundance is at its highest. Moreover, the widespread fragmentation of habitats occurring in Indonesia might even improve the feeding opportunities for an opportunistic migrant such as Chinese Sparrowhawk, as degraded habitats may offer numerous empty niches that are not used by resident species.

Our autumn observations show that significant numbers of migrants were deflected by the wind far out at sea, bypassing Sangihe and following the islands from a distance as a leading line, drifting further to the south-east and landing as a result in the northern Moluccas, as demonstrated by several records from these islands (White and Bruce 1986, Gjershaug and Røv 2000). The radar studies in Taiwan show that a large percentage of Chinese Sparrowhawks travel between 35–70 km off the coast along an established sea route: for example in autumn 2005, out of a total passage of over 205,000 Chinese Sparrowhawks recorded by radar, 62,356 individuals (30% of the total) passed on the sea route and remained mostly undetected by the ground-based observers. In the expectation that Chinese Sparrowhawks utilise the same ability for long-range over-ocean flights in the rest of the flyway, we presume that an unknown proportion of this species passed undetected off Sangihe. Since visual and radar counts of southbound Chinese Sparrowhawks in Taiwan varied between a minimum of 69,000 individuals in 2001 to a maximum of 409,000 in 2004, with an average of 200,000 in most years, the large fluctuations in Chinese Sparrowhawk numbers from yearly radar counts might be due either to migrants travelling below the radar horizon, as radar does not track flight below 200 m which occurs under variable weather conditions, or to the passage being too far out at sea to be detected even by radar.

Bearing in mind all the factors outlined above that bias census efforts, and collating Taiwan figures with the 225,000 Chinese Sparrowhawks we counted in Sangihe and the visible passage of 84,000 accipiters observed in Bali (Germi and Waluyo 2006), we estimate that at least 350,000 Chinese Sparrowhawks are streaming into eastern Indonesia annually, both through the Sangihe-Talaud Archipelago in the north and Bali in the west. Thereafter, our combined results provide strong evidence that up to 400,000 migratory raptors of at least seven species enter Wallacea each autumn. However, other than anecdotal information from Sulawesi's northern peninsula, there are very few observations of Chinese Sparrowhawk elsewhere on this island. Similarly, there are very few winter records of this species from the Moluccas and the Lesser Sundas. A handful of specimens and even fewer observations pertaining to Chinese Sparrowhawk and Grey-faced Buzzard provide solid, albeit sparse, evidence that both species occur further to the east in Wallacea and in the extreme western tip of New Guinea. That Chinese Sparrowhawk has been so uniformly 'overlooked' suggests to us the following: (1) this species has been genuinely overlooked due to a lack of observers present at the right time of year; and/or (2) there are insufficient suitable wintering areas in Wallacea, so a large proportion of the migrants are dispersing into remote and poorly surveyed areas as far as New Guinea, whilst others lead nomadic lives across the region, following seasonal food abundances such as insect outbreaks.

Our observations indicate that a more easterly route, involving longer water crossings caused by displacement by seasonal crosswinds and those associated with day-to-day variations in the monsoon flow, occur between south-eastern Mindanao and the Moluccas via Miangas and the Talaud Islands. This is supported by several records of Chinese Sparrowhawks and Grey-faced Buzzards from both Talaud and the northern Moluccas (Meyer and Wiglesworth 1898, White 1976, White and Bruce 1986, Riley 1997), and notably by the observation of 145 Chinese Sparrowhawks making landfall on Ternate Island from a northward direction on 7 October 1996 (Gjershaug and Røv 2000). Additional fieldwork on this unknown corridor is urgently needed. The possibility of such a scenario requires further investigation in order to determine the wintering grounds of this large number of migratory raptors. Moreover, the occurrence of regular, traditional roosting sites of thousands of migrants on small islands, as our observations from Sangihe demonstrate, implies that there are potentially serious threats for the conservation of these species. Unmonitored conversion of land use on these small, remote islands could result in loss of vital roosting habitats with very limited alternatives on an oceanic migration route. It is worth noting that significant declines in Chinese Sparrowhawk breeding pairs have been recently documented in Korea, where a 50–75% drop has occurred during the last 30 years in some local populations (Choi and Nam 2008). We recommend an urgent survey of the roosting sites along the Oceanic Flyway, as a high conservation priority for future research.

ACKNOWLEDGEMENTS

This study was funded by Natural Research Ltd. (UK) and Hawk Mountain Sanctuary Project Soar (USA). We wish to thank Dapel Masihore and Tadius Haribulan, who kindly admitted us onto their land at Pusunge; Naha Airport Authority for granting us permission to carry out part of the counts from the airfield; William Frank and Paul Roundy for their helpful discussions of monsoon meteorology and tropical waves; Muhamad Sain Kadir and Sujatno (Naha Meteorological Station, Sangihe), and Budi Yuniarto (Statistic Office of Sangihe) who provided local weather data; Mark Adams and the Natural History Museum, Tring (BMNH), for access to skins; Keith Bildstein and Norman Elkins for useful comments on the manuscript. We are also grateful to the following people for their kind cooperation at various stages of the study: Bas van Balen, Nick Blackbeard, Corry Shih-Chung Chen, Hans Duffels, Anita Gamauf, Jan Ove Gjershaug, When-Horn Lin, Victor Mason, Henk van Mastrigt, Mike McGrady, Vincent Nijman, Yasunori Nitani, Jon Riley, Myron Schekelle, Yuan-Hsun Sun, Mike Thornton, Dono Waluyo, Sumadi Wayan, Vanessa Wise and Toru Yamazaki.

REFERENCES

Ash, J. S. (1984) Bird observations on Bali. *Bull. Brit. Orn. Club*. 104: 24–35.

Ash, J. S. (1993) Raptor migration on Bali, Indonesia. *Forktail* 9: 3–11.

Bildstein, K. L. and Zalles, J. I., eds. (1995) *Raptor migration watch-site manual.* Kempton, USA: Hawk Mountain Sanctuary Association.

Bildstein, K. L. and Zalles, J. I. (2005) Old World versus New World long-distance migration in accipiters, buteos, and falcons. Pp.154–167 in R. Greenberg and P. P. Marra, eds. *Birds of two worlds: the ecology and evolution of migration.* Baltimore, USA: Johns Hopkins University Press.

Bildstein, K. L. (2006) *Migrating raptors of the world: their ecology and conservation.* Ithaca, USA: Cornell University Press.

Bird, D. M. and Bildstein K. L., eds. (2007) *Raptor research and management techniques.* Blaine, USA: Hancock House Publishers.

BPS (2006) *Sangihe in figures, 2006.* Tahuna, Indonesia: Statistic Office of Sangihe.

Brazil, M. A. and Hanawa, S. (1991) The status and distribution of diurnal raptors in Japan. Pp.175–238 in R. D. Chancellor and B.-U. Meyburg, eds. *Birds of Prey Bulletin*, 4. Berlin, Germany, London, U.K. and Paris, France: World Working Group on Birds of Prey and Owls.

Chen, C. S. C. (2005) ['Ground survey of raptor migration at Kenting National Park in autumn 2004.'] *Raptor Res. Taiwan* 4: 9–21. (In Chinese.)

Chen, C. S. C. (2006) ['Ground survey of raptor migration at Kenting National Park in autumn 2005.'] *Raptor Res. Taiwan* 6: 16–28. (In Chinese.)

Chen, C. S. C. (2007) ['Ground survey of raptor migration at Kenting National Park in autumn 2006.'] *Raptor Res. Taiwan* 7: 14–28. (In Chinese.)

Chen, C. S. C. and Sun, Y. H. (2007) ['Study on the spring and fall populations of staging raptors at the Kenting National Park in 2007.'] Taiwan: Construction and Planning Agency, Ministry of the Interior. (In Chinese.)

Chen, Y. J. (2006) ['Spring migration of Gray-faced Buzzard in Central and Southern Taiwan in 2005.'] Master Thesis. Taiwan: Institute of Wildlife Conservation, National Ping-tung University of Science and Technology. (In Chinese.)

Cheng, Y. S., Sun, Y. H. and Deng, T. W. (2006) ['Use of weather radar to study the fall migration of the Chinese Sparrowhawk on Hengchun Peninsula in 2005.'] *Taiwan J. Sci.* 21: 491–498. (In Chinese.)

Choi, C. Y. and Nam H. Y. (2008) Breeding density of the Chinese Sparrowhawk *Accipiter soloensis* in Korea. Presented at the Fifth Symposium on Asian Raptors. Tam Dao, Vietnam: ARRCN.

Chong, M. H. N. (2000) Asian raptor migration areas and population survey (Asian Raptor M.A.P.S.): cooperative raptor migration in haze project – autumn 1999 report summary. *Asian Rap. Bull.* 1: 12–15.

Chong, M. H. N. and Nitani, Y. (2001) Asian raptor MAPS: Asian Raptor Migration Project – autumn 2001 Report. *Asian Rap. Bull.* 2: 14–17.

Coates, B. J. and Bishop, K. D. (1997) *A guide to the birds of Wallacea: Sulawesi, the Moluccas and Lesser Sundas islands, Indonesia.* Alderley, Queensland, Australia: Dove Publications.

Davison, G. W. H. (1997) Bird observations on Pulau Laut, South Kalimantan. *Kukila* 9: 122–125.

Dickinson, E.D., Kennedy R.S. and Parkes, K.C. (1991) *The birds of the Philippines.* Tring: British Ornithologists' Union (Checklist 12).

Elkins, N. (2004) *Weather and bird behaviour*. London: T & A D Poyser.

Ellis, D. H., Kepler A. K. and Kepler C. B (1990) Evidence for a fall raptor migration pathway across the South China Sea. *J. Rap. Res.* 24 (1–2): 12–18.

Ferguson-Lees, J. and Christie, D. A. (2001) *Raptors of the world.* London: Christopher Helm.

Germi, F. (2005) Raptor migration in east Bali, Indonesia: observations from a bottleneck watch site. *Forktail* 21: 93–98.

Germi, F. and Waluyo, D. (2006) Additional information on the autumn migration of raptors in east Bali, Indonesia. *Forktail* 22: 71–76.

Gjershaug, J. O. and Røv, N. (2000) The raptor fauna in North Moluccas, Indonesia. Pp.240–247 in H. Ichinose, T. Inoue and T. Yamazaki, eds. *Proceedings of the First Symposium on Raptors of Asia.* Shiga, Japan: ARRCN.

Hartert, E. (1896) On ornithological collections made by Mr. Alfred Everett in Celebes and on the islands south of it. *Novit. Zool.* 3: 148–183.

Hornbuckle, J. (2001) Birdwatching trip report: Wallacea, Indonesia. Unpublished report available from Oriental Bird Club.

Kalnay, E. and coauthors (1996) The NCEP/NCAR 40-year reanalysis project. *Bull. Amer. Meteor. Soc.* 77: 437–471.

Kennedy, R. S., Gonzales, P.C., Dickinson, E. C., Miranda Jr., H. C. and Fisher, T. H. (2000) *A guide to the birds of the Philippines.* Oxford, U.K.: Oxford University Press.

Kerlinger, P. (1984) Flight behaviour of Sharp-shinned Hawk during migration. II: over water. *Anim. Behav.* 32: 1029–1034.

Kerlinger, P. (1989) *Flight strategies of migrating hawks.* Chicago, USA: University of Chicago Press.

Kugai, K. (1996) Autumnal migration of *Butastur indicus* Gray-faced Buzzard-eagle in Japan. *Okinawa Prefect. Mus. Bull.* 22: 153–172.

Haugh, J. R. (1975) Local ephemeral weather conditions and their effects on hawk migration routes. Pp.72–84 in M. Harwood, ed., *Proceedings of the North American Hawk Migration Conference 1974.* Washington, USA: Hawk Migration Association of North America.

Herremans, M. and Louette, M. (2000) A partial post-juvenile molt and transitional plumage in the Shikra (*Accipiter badius*) and Grey Frog Hawk (*Accipiter soloensis*). *J. Rap. Res.* 34: 249–261.

Higuchi, H. and coauthors (2005) Migration of Honey-buzzards *Pernis apivorus* based on satellite tracking. *Orn. Sci.* 4: 109–115.

Lane, B. A. and Parish, D. (1991) A review of the Asian-Australasian bird migration system. Pp.291–312 in T. Salathé, ed. *Conserving migratory birds.* Cambridge, U.K.: International Council for Bird Preservation. (ICBP Technical Publication No. 12).

Leader, P. J. and Carey, G. J. (1995) Identification of Japanese Sparrowhawk and Besra. *Hong Kong Bird Report* 1994: 157–169.

Lim, K. C., Sebastian, A., Lim, A. T. and Kong, F. S. (2002) A preliminary survey of raptor migration in Sarawak and Sabah, Malaysian Borneo. *Asian Rap. Bull.* 3: 7–9.

Lin, W. H. and Severinghaus, L. L. (1998) Raptor migration and conservation in Taiwan. Pp.631–639 in R. D. Chancellor, B.-U. Meyburg and J. J. Ferrero, eds. *Holartic birds of prey.* Merida, Spain: ADENEX and World Working Group on Birds of Prey.

McClure, H. E. (1974) *Migration and survival of the birds of Asia.* Bangkok, Thailand: United States Army Medical Component, South-East Treaty Organization Medical Research Laboratory.

Meyer, A. B. and Wiglesworth, L. M. (1898) *The birds of Celebes and neighbouring islands.* Berlin: Friedländer.

Nijman, V. (2004) Magnitude and timing of migrant raptors in central Java, Indonesia. *Ardea* 92: 161–168.

Nijman, V., Germi, F. and van Balen, B. (2006) Relative status of two species of migrant sparrowhawks on Java and Bali, Indonesia. *Emu* 106 (2): 157–162.

Nitani, Y. (2000) Result of the cooperative study of Asian raptor migration in hazy conditions in Japan. Pp.83–91 in D.M. Prawiradilaga, ed. *Proceedings of the Second Symposium on Raptors of Asia.* Cibinong, Indonesia: ARRCN.

Raptor Research Group of Taiwan (2008) Annual migration counts. Available at http://www.raptor.org.tw

Richardson, W. J. (1978) Timing and amount of bird migration in relation to weather: a review. *Oikos* 30: 224–272.

Richardson, W. J. (1990) Timing of bird migration in relation to weather: updated review. Pp.78–101 in E. Gwinner, ed. *Bird migration: physiology and ecophysiology.* Berlin Heidelberg, Germany: Springer-Verlag.

Riley, J. (1997) The birds of Sangihe and Talaud, North Sulawesi. *Kukila* 9: 3–36.

Riley, J. (2002) Population sizes and the status of endemic and restricted-range bird species on Sangihe Island, Indonesia. *Bird Conserv. Internatn.* 12: 53–78.

Roundy, P. E., and Frank, W. M. (2004) A climatology of waves in the Equatorial Region. *J. Atmos. Sci.* 61: 2105–2132.

Rozendaal, F. G. and Dekker, R. W. R. J. (1989) Annotated checklist of the Birds of the Dumoga-Bone National Park, North Sulawesi. *Kukila* 4 : 85–109.

Sadler, J. C., Lander, M. A., Hori, A. M. and Oda, L. K. (1987a) *Tropical marine climatic atlas, volume I, Indian Ocean and Atlantic Ocean, UH-MET 87-01.* Honolulu, USA: Dept. of Meteorology, University of Hawaii.

Sadler, J. C., Lander, M. A., Hori, A. M. and Oda, L. K. (1987b) *Tropical marine climatic atlas, volume II, Pacific Ocean, UH-MET 87-02.* Honolulu, USA: Dept. of Meteorology, University of Hawaii.

Shiu, H. J., Tokita, K., Morishita, E., Hiraoka, E., Wu, Y., Nakamura, H. and Higuchi, H. (2006) Route and site fidelity of two migratory raptors: Grey-faced Buzzards *Butastur indicus* and Honey-buzzards *Pernis apivorus*. *Orn. Sci*. 5: 151–156.

Simpson, D. M. (1983) Autumn migration of landbirds off North Borneo in 1981. *Sea Swallow*: 32: 48–53.

Sukmantoro, W., Suparman, U. and Sin, L. M. (2005) A study on migratory raptors in Sumatra, Kalimantan, Java, Bali and Nusa Tenggara, Indonesia: 2001–2004. Pp.150–165 in J. Abu, M. H. N. Chong, A. C. Sebastian and Y. C. Aik, eds. *Proceedings of the Fourth Symposium on Asian Raptors 2005.* Taiping, Malaysia: ARRCN and Malaysian Nature Society.

Sun, Y. H. (2006) Use of radar to study fall migration of Chinese Sparrow Hawk in 2004. [Abstracts of the Third Symposium on Ecology of Raptors in Taiwan, Taipei.] *Raptor Res. Taiwan* 6: 42–43.

Wardill, J. C. and Katuuk, F. S. G. (1998) Eastern Marsh-harrier in Sulawesi. *Kukila* 10: 151–152.

Wattel, J. (1973) *Geographical differentiation in the genus Accipiter*. Cambridge, Mass.: Nuttall Ornithological Club.

White, C. M. N. (1976) Migration of Palearctic non-passerine birds in Wallacea. *Emu* 76: 79–82.

White, C. M. N. and Bruce, M. D. (1986) *The birds of Wallacea (Sulawesi, the Moluccas and Lesser Sunda Islands): an annotated check-list.* London: British Ornithologists' Union (Checklist 7).

Whitten, T., Mustafa, M. and Henderson, G. S. (2002) *The ecology of Sulawesi.* Singapore: Periplus.

Zalles, J. I. and Bildstein, K. L. (2000) *Raptor watch: a global directory of raptor migration sites.* Cambridge, U.K. and Kempton, USA: BirdLife International and Hawk Mountain Sanctuary.

Francesco Germi, P.O. Box 284, Sharm El Sheikh 46619, South Sinai, Egypt. Email: fgermi@yahoo.co.uk

George S. Young, 503 Walker Building, Department of Meteorology, The Pennsylvania State University, University Park, PA 16802 USA Email: young@meteo.psu.edu

Agus Salim, Jl. Palem Putri VIII No. 5-7, Taman Yasmin V, Bogor, West Java, Indonesia. Email: asalim@cbn.net.id

Wesley Pangimangen, Lelipang, Tamako 95855, Sangihe, North Sulawesi, Indonesia.

Mark Schellekens, Jl. Raya Moni-Jopu 27, Woloara-Ende-Kelimutu, Flores, N.T.T., 86372, Indonesia. Email: ljmschellekens@yahoo.com