Bird Conservation International (2016) 26:243–255. © BirdLife International, 2015
doi:10.1017/S095927091500009X

Migratory behaviour of bird species occurring in critical numbers at Besh Barmag bottleneck in Azerbaijan

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Summary

A narrow coastal plain located between the Greater Caucasus and the Caspian Sea was recently discovered to be a major avian flyway through Transcaucasia. Here at the Besh Barmag bottleneck in Azerbaijan an estimated 1.24–1.51 million migrants passed through in autumn 2011 and a further 0.65–0.82 million in spring 2012, elevating this bottleneck to international importance. Furthermore, 34 bird species were observed in numbers in excess of the 1% threshold of world or flyway population in at least one of the observation seasons. Due to the high concentration of these species, any dangers affecting this passage can be threatening at a population scale. This study therefore aims to describe the migratory behaviour of these 34 species and subsequently to identify the dangers involved in passage through the area. Collision with anthropogenic obstacles was regarded as the main threat in the coastal plain. Ten (40%) of the species studied and observed in autumn 2011 were flying at the lowest altitudes and are therefore under threat on migration through the bottleneck due to overhead power lines, buildings, traffic and hunting. Planned infrastructural developments with heights of up to 200 m (e.g. towers, wind farms) pose a future threat for an additional 13 (52%) of the study species observed in autumn, making a total of 23 species that would be threatened. Only two species, Pygmy Cormorant *Microcarbo pygmaeus* and Grey Heron *Ardea cinerea*, can be expected to maintain their currently safe passage in future as they migrate mainly above 200 m above ground level. In spring 2012, all 14 (100%) of the species that used the coastal plain as flyway, migrated below 50 m and are therefore imminently threatened by collision. Although birds migrating over the Caspian Sea were concentrated at the lower altitudes, there was no identifiable threat for migrants using this flyway, but hazards can be expected in the oil production areas further south.

Introduction

Wherever topographical structures occur they influence the routes birds take between their breeding and wintering grounds. Mountain ranges and open bodies of water can act as barriers for migrating birds and lead to concentrations at certain points (Berthold 2000). Such a concentration point, or bottleneck, was recently discovered at Mount Besh Barmag in Azerbaijan (Heiss and Gauger 2011, Heiss 2013). Here, the Greater Caucasus almost reach the shore of the Caspian Sea, leaving a coastal plain a mere 2.5 km wide. Both topographical structures act as barriers for migrating birds and those which avoid crossing the Greater Caucasus range and the Caspian Sea concentrate in this coastal plain at Besh Barmag (Heiss and Gauger 2011). In addition, the north-south oriented coastline may act as guiding line for the considerable number of water-dependent birds that migrate offshore (Heiss and Gauger 2011, Heiss 2013).

Heiss (2013) estimated the passage of 1.24–1.51 million migrants in autumn 2011 and 0.65–0.82 million in spring 2012 and undertook an evaluation of the international importance of Besh Barmag for world and flyway populations of the observed bird species based on the 1% criterion adapted e.g. from BirdLife International (2001). According to this criterion, 1% of a world or flyway population is a critical threshold for the whole world or flyway population. Areas where this threshold is regularly reached need special protection (Yosef *et al.* 2000, BirdLife International 2001).

According to Heiss (2013), out of 278 species recorded at Besh Barmag bottleneck, 15 occurred in numbers exceeding the 1% threshold of their world populations: Eurasian Spoonbill *Platalea leucorodia*, Grey Heron *Ardea cinerea*, Dalmatian Pelican *Pelecanus crispus*, Pygmy Cormorant *Microcarbo pygmaeus*, Great Cormorant *Phalacrocorax carbo*, Little Bustard *Tetrax tetrax*, Black-winged Pratincole *Glareola nordmanni*, Pallas's Gull *Larus ichthyaetus*, Gull-billed Tern *Sterna nilotica*, Sandwich Tern *Thalasseus sandvicensis*, Common Tern *Sterna hirundo*, Whiskered Tern *Chlidonias hybrida*, White-winged Tern *Chlidonias leucopterus*, Blue-cheeked Bee-eater *Merops persicus* and Rosy Starling *Sturnus roseus*.

Heiss (2013) also found 19 species exceeding the 1% threshold of their flyway populations: Ruddy Shelduck *Tadorna ferruginea*, Common Shelduck *Tadorna tadorna*, Garganey *Spatula querquedula*, Northern Shoveler *Spatula clypeata*, Little Egret *Egretta garzetta*, Great White Egret *Ardea alba*, Purple Heron *Ardea purpurea*, Glossy Ibis *Plegadis falcinellus*, Western Marsh Harrier *Circus aeruginosus*, Pallid Harrier *Circus macrourus*, Steppe Eagle *Aquila nipalensis*, Common Crane *Grus grus*, Pied Avocet *Recurvirostra avosetta*, Northern Lapwing *Vanellus vanellus*, Caspian Tern *Hydroprogne caspia*, Black-headed Gull *Larus ridibundus*, Stock Dove *Columba oenas*, Common Starling *Sturnus vulgaris* and Corn Bunting *Miliaria calandra*.

In view of the high concentration of individuals of these species in relation to their world or flyway population numbers, they may be considered as highly vulnerable when migrating through the Besh Barmag bottleneck area as part of their annual cycle. Man-made structures in particular are known to threaten the passage of migrating birds at such concentration points and any risks incurred by migrating birds can be derived from their migration behaviour (e.g. Bruderer *et al.* 2000, Desholm and Kahlert 2005, Hilgerloh 2009, Hilgerloh *et al.* 2011). For the evaluation of wind farm projects, for example, it is especially the flight height that plays an important role (Hilgerloh *et al.* 2011, Hüppop *et al.* 2006). However, owing to the specific circumstances affecting different bottlenecks, migrants are exposed to different kinds of anthropogenic threats, e.g. hunting along the Mediterranean Sea especially in Italy (Cassola 1979, Giordano 1991), on Malta (Raine 2007), in the Middle East (Porter 2005) or in Georgia (Van Maanen *et al.* 2001), or wind farms in Gibraltar (de Lucas *et al.* 2004) or Egypt (Hilgerloh 2009, Hilgerloh *et al.* 2011). Up to the present, no information about migratory behaviour at Besh Barmag has been available and thus it is uncertain how far migrating birds are affected by anthropogenic threats during the passage through the Besh Barmag bottleneck. Accordingly, this paper follows the results of Heiss (2013), and describes the migratory behaviour of 34 species occurring in critical numbers at Besh Barmag and subsequently identifies hazards on their passage through the bottleneck.

Methods

Study area

Bird migration counts were conducted in the coastal plain at Mount Besh Barmag in Azerbaijan (40°59′N, 49°13′E) (see Heiss 2013). Besh Barmag is part of the easternmost foothills of the Greater Caucasus, which rise steeply from sea level to 500 m asl (Figure 1). The coastal plain itself is characterised by treeless, grazed steppes, human settlements and oil production areas.

Observational data on the principal migration types was gathered from three different observation points (Heiss 2013). Waterbird migration was observed from a fixed point at the shoreline of the Caspian Sea. An observation point in the coastal plain focused mainly on passerines migrating

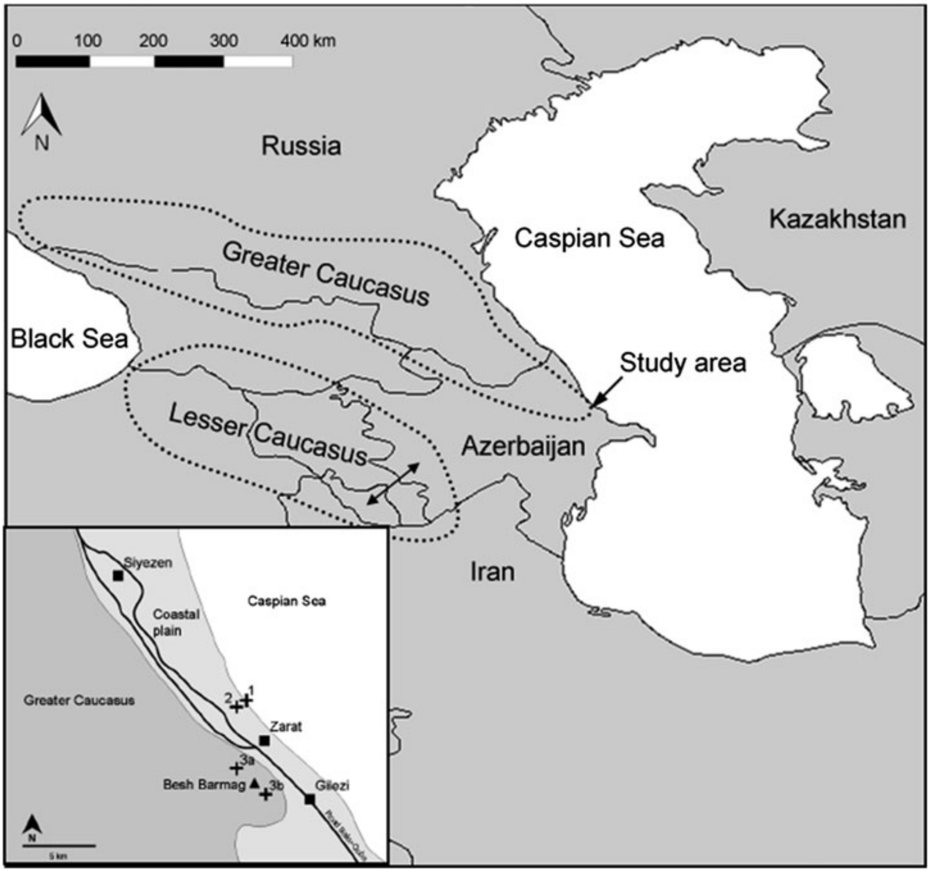

Figure 1. Location of the study area with the different observation points. 1 = coast, 2 = coastal plain, 3a = foothills (autumn 2011), 3b = foothills (spring 2012). (Modified from Heiss 2013).

through the plain. The third point, located on top of the foothills at Besh Barmag, was particularly suitable for counting migrating raptors (Figure 1).

Bird migration counts

Counting took place in autumn from 2 August to 17 November 2011 and in spring from 1 March to 29 May 2012. Counts were conducted even under poor weather conditions such as storm, rain or snowfall, but not on foggy days on account of the limited visibility. The observations were made with the aid of binoculars (10x42) and a spotting scope (20–60x).

In both seasons, counting was done daily starting at sunrise. For each observation hour the species, number, flight direction and flight height (0–10, 11–20, 21–30, 31–50, 51–100, 101–200, 201–500, 501–1000, > 1000 m) above ground level (agl) of the birds were recorded. In addition, for migrants recorded from the coastal observation point flying above the Caspian Sea (Figure 1) the distance to the shoreline (0–100, 101–200, 201–300, 301–400, 401–500, 501–1000, 1001–2000, 2001–3000, 3001–4000, 4001–5000, > 5000 m) was also logged. No instruments (e.g. radar or rangefinder) were available for measuring or calibrating these distances and therefore they are based solely on visual estimates. Furthermore, bird observations are numerically biased towards birds migrating at closer distances to the observer, their detectability rate exceeding that of

https://doi.org/10.1017/S095927091500009X Published online by Cambridge University Press

distant birds. The limits set by these two methodological constrains to the reliability of the results obtained in the present work are largely offset by the observer's extensive experience with bird migration studies, including those using radar to calibrate distance estimates. Flight height and distance, mainly of migrating raptors, were not logged at the foothill observation point (Figure 1), as these values are highly unstable, changing swiftly and substantially in response to the up-cycling and soaring behaviour of the migrants and to the uneven terrain.

The daily counting schedule consisted of at least six fixed observation hours and additional randomly distributed hours to cover the rest of the day (see Heiss 2013). This study design produced recreational pauses for the single observer, essential if a high level of concentration is to be maintained. Data for these observational gaps were later interpolated to arrive at more complete information on total daily numbers. For the interpolation of these gaps number of migrants in the fixed six-hour observation block was regarded as a 100% reference to compare diurnal migration patterns with days of different numbers of migrants. Then for each observation hour (the six fixed and random) the percentage of the reference total has been calculated. Afterwards, all percentages for each day and observation hour were merged into a data set and analysed with a local polynomial regression fitting curve (function 'loess'; degree of smoothening [span] = 0.7, other values = default) and a standard deviation using a symmetric nonparametric bootstrap confidence region surrounding the curve by use of the function 'scatboot' (confidence = 0.4, number of iterations [nreps] = 500, degree of smoothening [span] = 0.7, degree = 2, family = "gaussian") (Rogers 2011) with the aid of the statistical software package R version 2.9.2. (R Foundation for Statistical Computing 2009). The overall diurnal migration pattern obtained was referred to when interpolating gaps in the daily observation data. For each missing observation hour, the overall percentage was multiplied by the reference total of the relevant day. The observed totals and the interpolated totals were added to obtain an estimate of total number of migrants that day, which was done for each observation day. Furthermore, as each of the observations points was visited in a three-day-cycle, further gaps of two complete days occurred between visits. Data for these days of no observation were also interpolated to substantiate statements about the migration phenology and estimations of the total number of migrants. Here, the difference in the number of migrants of two-day totals was divided by the difference between two following observation days. Those were added stepwise (depending on the number of unwatched days) to the first of the two observation days, which generated a simple equal distribution of day totals. The interpolation method is described in detail in Heiss (2013).

Results

Phenology

Most of the 34 bird species under study migrated within both observation periods (Appendix S1 in the online supplementary material). Twenty-seven (79%) of the 34 study species migrated in greater numbers in autumn than in spring, whereas only seven species (21%) were more numerous in spring, these being Dalmatian Pelican, Great Cormorant, Western Marsh Harrier, Pallid Harrier, Steppe Eagle, Pallas's Gull and Rosy Starling (Appendix S1).

Flight behaviour

Eighty-four percent of the individuals passing through the coastal plain in autumn were observed between 0 and 50 m agl with a further concentration of 50% at the lowest altitudes between 0 and 20 m agl (Figure 2). Similarly, in spring the majority (95%) of individuals migrated at altitudes between 0 and 50 m agl with 62% at the lowest altitudes between 0 and 20 m agl (Figure 2). At species level, 10 (40%) of the study species in autumn 2011 and 14 (100%) in spring 2012 passed through at the lowest flight altitudes (below 50 m agl) (Appendices S2 and S3). Ninety-eight percent of individuals in autumn and 100% in spring used altitudes below 200 m agl for

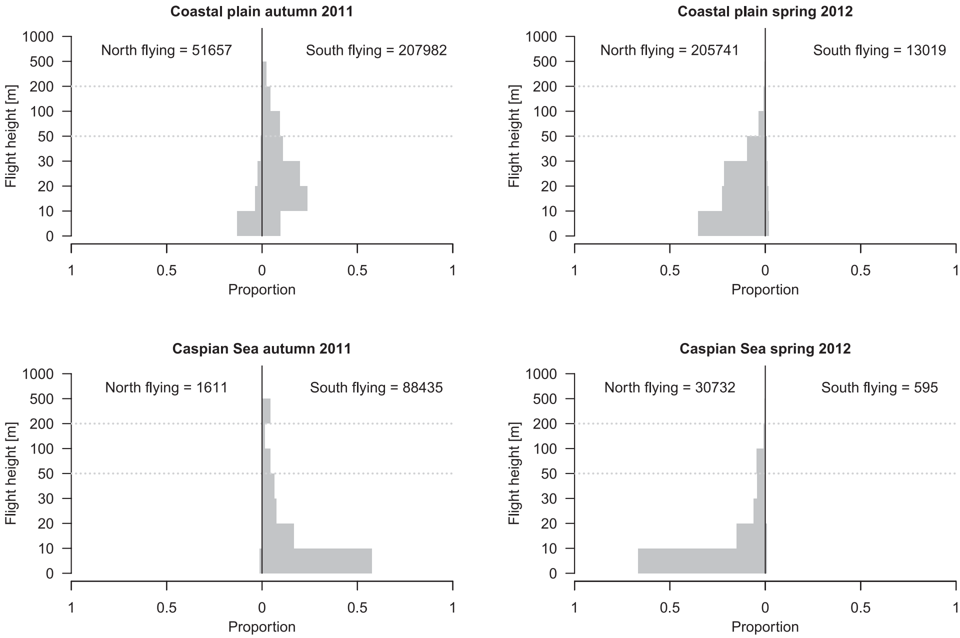

Figure 2. Flight heights of all assessed individuals including also those species that are not occurring in critical numbers at Besh Barmag bottleneck. Details of the species considered here can be found in Appendices S2–S5. Dotted lines show the anticipated collision risk (0–50 m agl = immediate risk, 51–200 m agl = possible future risk, >200 m agl = no immediate or possible future risk).

migration through the coastal plain (Figure 2), which at species level clusters to 23 (92%) study species in autumn 2011 and 14 (100%) in spring 2012 (Appendices S2 and S3). Only in Pygmy Cormorant and Grey Heron was a concentration of migrants observed above 200 m agl on autumn migration through the coastal plain.

Migration above the Caspian Sea was more pronounced at lower altitudes. In autumn 2011, 90% of individuals migrated below 50 m above sea level (asl), as did 94% in spring 2012 (Figure 2). Moreover, 96% of individuals migrated below 200 m asl in autumn 2011 and 100% in spring 2012 (Figure 2).

It was also noted that in the study species, observed flight distances from the shoreline did not follow a general pattern. All individuals considered, distances between 0.5 and 2 km were the most frequently recorded (Figure 3).

Discussion

Phenology

Although the entire migration period was covered by the observer (Appendix S1), in autumn four species are thought likely to have been incompletely counted and might occur in greater numbers than recorded. The Rosy Starling had probably already begun to pass through the bottleneck before the counting period started, the highest figures of the autumn migration falling at the beginning of the autumn count followed by a steady decrease until mid-August (Appendix S1). The majority had probably migrated in July. Western Marsh Harrier, Common Starling and Corn Bunting, on the other hand, were still migrating when the autumn counting period finished.

https://doi.org/10.1017/S095927091500009X Published online by Cambridge University Press

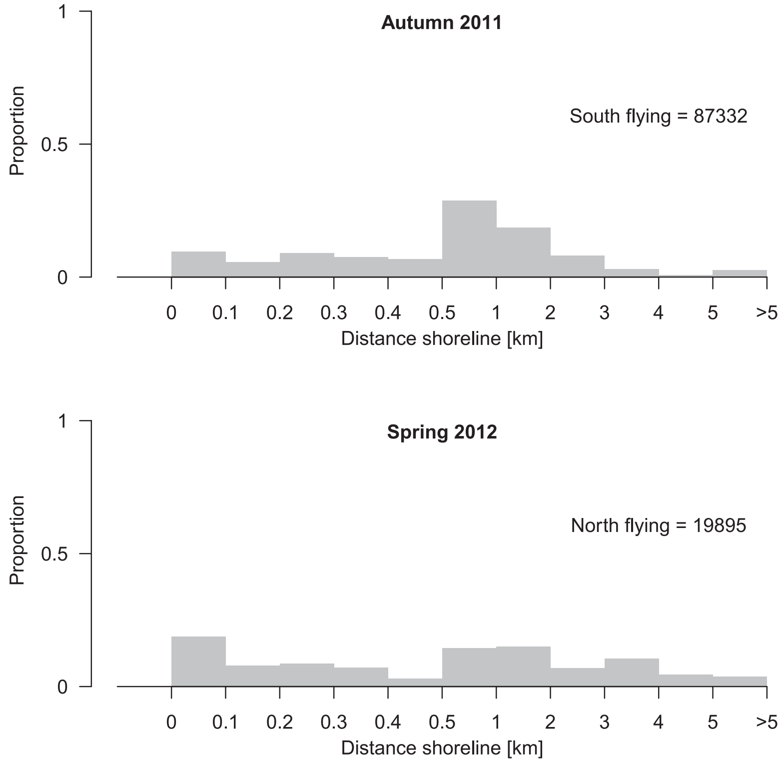

Figure 3. Migratory distance to the shoreline of all assessed individuals including also those species that do not occur in critical numbers at Besh Barmag bottleneck. Details of the species considered here can be found in Appendices S6–S7.

In spring, Great Cormorant, Dalmatian Pelican, Western Marsh Harrier and Pallas's Gull probably started migration before the beginning of the spring counts. These four species in spring 2012, along with the four previously mentioned species in autumn 2011, are therefore thought to have been incompletely counted and consequently underestimated in Heiss (2013). Moreover, winter movements are not covered by either of the two counting periods. Otherwise, the 1% threshold of the world or flyway population may have been crossed by a number of species not discussed in this study because they fell short of it. In particular, the numbers of some waterfowl, e.g. diving ducks (*Aythya* species), were extremely low relative to their enormous wintering numbers in Azerbaijan (Sultanov 2006, 2008). An extension of the counting periods would eliminate this uncertainty, but would not resolve problems of non-visible migration at night or the choice of a regionally different migration route.

The disparity between the mostly greater total migration numbers in autumn might plausibly be explained by mortality rates in the wintering areas, but it is more likely to be a consequence of loop migrations where birds follow different flyways in autumn than in spring, as was ascertained, for example, in Israel (Leshem and Yom-Tov 1998).

Migration through the coastal plain

Flight height above ground level is clearly an important parameter in assessing the collision risk for the observed individuals and so the observed flight heights were grouped into categories according to the degree of collision risk between birds and anthropogenic obstacles. Since low flying birds are confronted with the highest density of anthropogenic obstacles, the risk of collision increases with decreasing flight height. Thus a flight height between 0 and 50 m agl was regarded as an 'immediate risk' for migrants owing to existing hazards such as overhead power lines, buildings, traffic and hunting. From 51 to 200 m agl no immediate risk could be identified, but in the wake of infrastructural development wind farms or high buildings would lead to a 'possible future risk'. The flight heights above 200 m agl were regarded as risk-free, because no conceivable future constructions will exceed this height, and thus were characterised as being of 'no immediate or possible future risk'.

Most individuals passing through the coastal plain in autumn 2011 and spring 2012 were observed at heights between 0 and 50 m agl (Figure 2). Thus, most of the migrants observed in the coastal plain migrated in both seasons at a critical height and are therefore currently in danger of collision with anthropogenic obstacles. The migrants' preference for low flight altitudes can be linked to their search for optimum wind conditions. They prefer prevailing tail winds and avoid energy-consuming head or side winds (Alerstam 1979). When head winds occur, the birds reduce the energy cost by selecting a flight height offering the weakest head wind conditions, which occur at the lowest altitudes as a result of ground friction (Bruderer *et al.* 2000, Richardson 2000, Liechti 2006, Schmaljohann *et al.* 2009, Dokter *et al.* 2011). At the Besh Barmag bottleneck northerly winds dominated in both seasons, with a strong westerly component in autumn (Figure 4). These wind conditions lead especially in spring to uncongenial head winds, whose detrimental effect on energy consumption migrants offset by the selection of low flight heights (Figure 2).

One of the main threats to individuals migrating below 50 m agl through the coastal plain is the dense network of overhead power lines supplying electricity to several villages and an oil production area. Power lines are known to entail collision hazards (Bevanger 1994, Loss *et al.* 2014). In Azerbaijan as a whole several species have been reported victims of collisions with power lines (Sultanov 1991, Sultanov *et al.* 1991, Patrikeev 2004, Gauger 2007). At Besh Barmag the magnitude of their impact on migrating birds in general and on the study species in particular can only be determined through regular searches for collision victims.

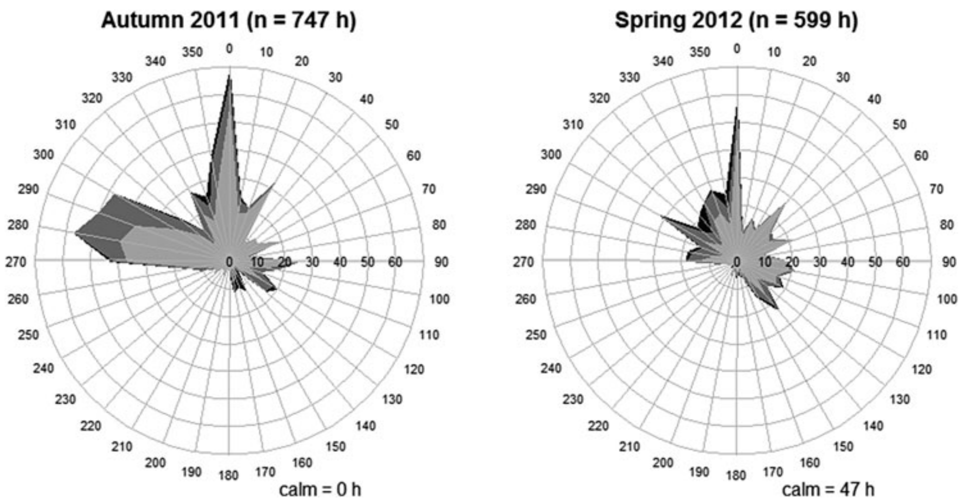

Figure 4. Local wind direction and speed per observation hour during the autumn 2011 and spring 2012 counts at Besh Barmag bottleneck (10° increments). Measurements for all observation hours at all observation points are included. Wind speed is indicated by colour (light grey = 1–5 ms^{-1}, dark grey = 6–10 ms^{-1}, black = >10 ms^{-1}). No direction is given for calm wind conditions (0–1 ms^{-1}).

Altitudes between 50 and 200 m agl must be regarded as critical flight heights if in the future infrastructural developments increase, for example with the construction of communication and broadcasting towers, high buildings or wind farms. With these additional threats the percentage of migrating individuals at risk would increase to between 84% and 98% in autumn and between 95% and 100% in spring (Figure 2). Despite the fact that Azerbaijan is still rich in oil and gas resources, the government recently established a regulatory institution known as the 'State Agency on Alternative and Renewable Energy Sources', which clearly suggests a political interest in the development of renewable energies. The indications are that the main future threat to the migrants may well take the form of wind farms. Wind turbines are large-sized obstacles and direct collisions with rotors and wind turbine towers have been observed (Dürr 2011). The first small wind farms have already been built just 25 km south-east of the study area directly in the migrants' path before or after passing through the bottleneck. Admittedly, the impact of these on migrants may be considered minor, thanks to the low height and small number of the turbines (just four turbines at Sitalcay, two at Xizi and one at Yashama) and to the width of the coastal plain at these sites. At the bottleneck itself, any future construction of wind farms in this 2.5–4 km wide stretch is likely to prove especially detrimental to a safe passage. The narrowness of the coastal plain here together with the barrier effect of wind farms (Drewitt and Langston 2006) set severe limits to any horizontal evasive movements. With the onset of infrastructural development, which is just a matter of time, the construction of more and larger wind farms and the erection of larger sized wind turbines with heights of up to 200 m will constantly increase the impact. And while this cannot per se be regarded as critical since migratory behaviour is known to vary among locations in response to species composition, topography or local weather conditions (Drewitt and Langston 2006), for this coastal region, as a main migratory corridor, detailed environmental impact studies on migrating birds (diurnal and nocturnal) are recommended before decisions are made as to the sites of future developments. A general prohibition of wind farms in the bottleneck area should be considered.

Above 200 m agl the passage is at present risk-free and is expected to remain safe in the future, as anthropogenic constructions are not expected to exceed this height in the bottleneck area. This puts two of the study species (Grey Heron and Pygmy Cormorant) theoretically out of danger on their autumn passage through the coastal plain (Appendix S2). But not in spring, when none of the study species will have a safe passage (Appendix S3).

In reasonably good daylight conditions such as those in which the study species were observed, birds have no difficulty visually recognising and steering round obstacles of all sorts, e.g. wind farms (Barrios and Rodriguez 2004, de Lucas *et al.* 2004, Desholm and Kahlert 2005, Hötker *et al.* 2006), but even so high numbers of fatalities are known to occur (e.g. Smallwood and Thelander 2008). Furthermore, even if avoidance manoeuvres safeguard migrants from direct collisions, they might still entail higher energy costs due to birds covering longer distances moving around obstacles, thus reducing the body mass and impairing the physical condition of individuals and leading thence probably to lower breeding success and consequently to a negative effect on the population. This negative effect is cumulative when obstacles succeed each other along the migration routes (Masden *et al.* 2009).

In visibility reduced by fog or rain, or in poor light conditions at twilight or at night, migrants are probably more likely to collide with obstacles. But no information about the migratory behaviour of the study species under such conditions is available and even radar studies, at present the only feasible working method in such conditions, would only be able to define a general behaviour as it cannot yet identify bird species with any certainty.

Migration along the Caspian Sea coast

Unlike on the coastal plain, there is currently no identifiable risk of collision in the study area above the open water body of the Caspian Sea. At the moment the absence of constructions here guarantees a safe passage for migrants. Even now, however, areas further south are already characterised by a large number of oil production constructions (e.g. around the Abşeron peninsula or the 'offshore oil city' Neft Daşları) and possible future developments such as offshore wind farms or an extension of oil production into the bottleneck area may be envisaged. Some idea of how migrants might be affected by this, both in the oil production area itself and along the Caspian coast of Azerbaijan in general, can be inferred from the migratory behaviour of birds as observed at the Besh Barmag bottleneck.

Just as onshore, the risk of collision is here too expected to be greater with decreasing flight height, migrants at the lowest altitudes running the highest risk. In both seasons the majority of birds migrated below 50 m asl (Figure 2) and are therefore imminently prone to collision with offshore roads, power lines, buildings or oil platforms in the oil production areas. What is more, 96% of individuals in autumn 2011 and 100% in spring 2012 migrated below 200 m asl (Figure 2). At these heights, nearly all migrants, including all of the study species, can be expected to be affected by any future wind farms along the Caspian coast of Azerbaijan (Appendices S4 and S5).

Another parameter examined was the distance to the shoreline (Figure 3, Appendices S6–S7). Some species tended to migrate close to the coast (e.g. terns), whereas others (e.g. ducks, herons) preferred to maintain distances of 0.5–2 km. The diminishing accuracy of the observations with increasing distance produces results biased towards close-ranged migrants. Indeed, the difficulties of detection and identification of passing birds became so great at longer ranges that no useful data at all could be obtained beyond 5 km, where most oil constructions are situated. Nevertheless, as most of these are connected with each other by offshore roads or power lines, they are certain to be hazardous to migrants passing through these areas at whatever distances.

Despite several existing surveys dealing with oil pollution (e.g. Sultanov 1998, 2004), very little data on the mortality of migrants in the Caspian Sea is available. To date, the only indication of deleterious effects of constructions in the Caspian Sea is the observation by Casement and Howe (2005) of a number of bird cadavers seen from a safety vessel at an oil platform in the Azəri-Çıraq-Günəşli oilfield (120 km offshore).

Elsewhere in the world, however, a considerable amount of information on the offshore mortality of migrants has been brought together from studies and observations at oil platforms (Russell 2005), offshore research platforms (Hüppop *et al.* 2006) and offshore wind farms (Desholm and Kahlert 2005). Migrant casualties are due mainly to collisions, either directly or through concomitant starvation, often occurring at night in poor visibility and brought about by the birds' attraction towards artificial lights at these constructions (Russell 2005, Hüppop *et al.* 2006). There is no doubt whatever that the, for the most part, diurnal offshore migrants among the study species circumnavigate obstacles of all kinds (e.g. Desholm and Kahlert 2005), thus reducing the risk of a direct collision at least during the day. However, as far as the nocturnal migration behaviour of these study species is concerned, the same applies as for those in the coastal plain: no useful information can be obtained from the present observation data.

Dalmatian Pelican and Little Bustard

Two species occurred in outstanding numbers (Dalmatian Pelican and Little Bustard). Dalmatian Pelican is assessed as 'Vulnerable' (BirdLife International 2012a) and is estimated to have migrated in numbers representing 9–12% of the world and 14–20% of the flyway population in autumn 2011, and 33–57% of the world and 51–96% of the flyway population in spring 2012 (Heiss 2013). While in autumn 2011 only about 6% of pelicans migrated through the coastal plain at heights below the critical 50 m agl threshold, in spring 2012 the majority (68%) did so (Appendices S2–S3). The large body size of this species leads to a heavy dependence on thermal uplift and poor manoeuvrability on migration (Brown *et al.* 1992) which considerably increases its risk of collision with anthropogenic obstacles in the onshore region. Offshore migration in both observation periods was below the critical 50 m asl level (Appendices S4–S5), but as there are at present no constructions in the area, no hazards for the Dalmatian Pelican were identified within the study area.

The Little Bustard, considered 'Near Threatened' by BirdLife International (2012b), is estimated to have passed through the coastal plain in autumn 2011 in numbers representing 41–48% of the world and 71–82% of the flyway population (Heiss 2013).

Little Bustards migrated mainly at altitudes above 50 m (Appendix S2), heights which at the moment eliminate most collision risks. Frequent observations have, however, been made of individuals resting on the ground in the steppes at Besh Barmag during their migration period. During the approach and landing process the Little Bustard is especially at risk through power lines, which are known to claim many victims of this species in their wintering areas in central Azerbaijan (Gauger 2007). Little Bustards resting at Besh Barmag are also threatened by poaching. A number of individuals were shot in November 2011, when hunters drove through the steppes on board 4WD cars flushing birds and shooting at them. Poaching of Little Bustards was also reported from the same region in a previous study in autumn 2007 (Heiss and Gauger 2011), and is also known from the wintering grounds in Azerbaijan (Patrikeev 2004, Gauger 2007) and adjacent Iran (Sehhatisabet *et al.* 2012). The low number of victims notwithstanding, it is abundantly clear that a significant number of local people regard this species as fair game and ignore or are unaware of the fact that with the majority of its eastern population converging at Besh Barmag on migration, the life history of this species depends largely on a safe through passage.

Moreover, other observations made in November 2011 and March 2012 indicated that hunting is not confined to this one species, and that especially large prey, such as waterfowl resting along a coastal lagoon, are also targeted (observed shooting of Whooper Swan *Cygnus cygnus*, Northern Pintail *Anas acuta*, Eurasian Teal *Anas crecca*, Tufted Duck *Aythya fuligula*, Black-necked Grebe *Podiceps nigricollis*). Be that as it may, a certainly far greater impact on the migratory waterfowl populations is caused by the volume of hunting in the wintering grounds, for example in Gizil Agach Reserve (Patrikeev 2004, Sultanov 2008).

Raptors

Of all the study species, probably the most vulnerable on their passage through the bottleneck are the raptors. Although the number of individual casualties is relatively low, their excellent flight skills and high manoeuvrability enabling them to avoid direct collisions, for example with wind turbines (Barrios and Rodriguez 2004), any fatality at all has a disproportionally heavy impact on the population as a whole owing to their low fecundity rates (Saether and Bakke 2000, Marris and Fairless 2007).

This study shows that three raptor species (Steppe Eagle, Western Marsh Harrier and Pallid Harrier) migrate in critical numbers through the Besh Barmag bottleneck. The two harrier species passed through along the coastal plain (Heiss 2013) at low flight heights in both study seasons (Appendices S2–S3), making them vulnerable to existing and future anthropogenic obstacles. Nothing could be ascertained regarding the flight height of the Steppe Eagle, as this species migrated exclusively through the adjacent foothills of the coastal plain, where thermal uplifts supported their soaring migratory behaviour (Heiss 2013). Along their main migration route through the foothills anthropogenic obstacles are scarce, so that currently Steppe Eagles have a safe passage in the bottleneck area. Problems might arise in the future if wind turbines were to be erected along the Besh Barmag mountain ridge, an area where wind conditions and densities are likely to attract wind energy developers.

Supplementary Material

The supplementary material for this article can be found at journals.cambridge.org/bci

Acknowledgements

I wish to thank E. Sultanov for his support during the fieldwork and useful literature. A. Schmitz-Ornés gave useful comments on an earlier draft. Furthermore, I would like to thank the two reviewers for their suggestions and comments. K. Wilson checked the English. This study was financially supported by the German Academic Exchange Service (DAAD).

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Received 15 September 2014; revision accepted 2 April 2015;
Published online 29 September 2015