Addendum

An addendum to ‘Songbird migration across the Sahara: the non-stop hypothesis rejected!’

Keywords: songbird; migration; Sahara; quantification with radar

1. INTRODUCTION

In our article on songbird migration across the western Sahara (Schmaljohann *et al.* 2007), we refrained from citing Biebach *et al.*'s (2000) radar study on songbird migration across the eastern Sahara. Our intention was not to enter into details and problems of quantifying bird migration with radar. Understandably, some readers asked why the work of Biebach *et al.* (2000) was not cited and why we claimed to be the first to quantify songbird migration across the Sahara. We apologize for not having cited Biebach *et al.* (2000) being the first who attempted to answer the question whether songbirds cross the Sahara by a non-stop or intermittent flight strategy (Moreau 1961; Biebach *et al.* 1986; Bairlein 1988).

Biebach *et al.* (2000) estimated songbird migration in the Egyptian desert by using a modified marine radar. Their estimated densities are 10–20 and 20–40 times higher than those of moon-watch observations by Biebach *et al.* (1991) at the same and other sites in the eastern Sahara (Kiepenheuer & Linsenmair 1965), respectively. Density estimations of migrants derived from moon-watching and radar correspond well if migration occurs below 1500 m (Liechti *et al.* 1995). This precondition is optimally fulfilled during autumn migration as birds select the trade winds above the eastern Sahara (Bruderer *et al.* 1995b), which usually prevail below 1000 m (Klaassen & Biebach 2000). Furthermore, the songbird migration density estimates of Biebach *et al.* (2000) exceed by far the overall nocturnal migration density estimates in Israel, comprising the highest densities in the western Palaearctic (Bruderer & Liechti 1995). This extremely large difference in the migration densities detected by two methods in the same region raises the question of whether Biebach *et al.* (2000) might have detected targets other than songbirds.

2. MAJOR PITFALLS OF QUANTIFYING BIRD MIGRATION WITH RADAR

(a) Insect contamination

Insects, birds and weather phenomena are the most frequent radar targets (Eastwood 1967). Insects are several orders of magnitude more numerous than birds. Their high echo numbers are particularly annoying when using short-wavelength radar (Bruderer 1997), such as the X-band radar used in our (Schmaljohann *et al.* 2007) and Biebach *et al.*'s (2000) study. Since the strength of reflected energy of a given target increases dramatically with decreasing distance (roughly by $1/R^4$), most radars are equipped with a sensitivity time control (STC) to reduce the sensitivity of the receiver with decreasing

distance (Bruderer *et al.* 1995a). If the applied STC compensates reasonably for the effect of increasing echo sizes with decreasing distance, most echoes of small insects will fall below the detection threshold. Insects that cannot be eliminated according to their size can be distinguished from birds by their echo signature and air speed (Bruderer 1969; Riley 1973; Larkin 1991).

We applied an STC corresponding to the R^4 law to our radar data. Nevertheless, we still had to eliminate approximately 80% of the remaining echoes as insects (using echo signature), this even at the study sites in the bare sand desert with hardly any vegetation. The flight activity pattern of insects in the western Sahara was very similar to that of migrating birds and reached altitudes in autumn not far from those of birds (see also Riley & Reynolds 1979). Diurnal migration of insects occurred throughout the day, but was largely invisible from the ground.

Biebach *et al.* (2000) did not use a STC and recorded neither echo signatures nor air speed. Consequently, echoes could not be identified as birds or insects. They assumed that insect contamination had little effect on their results because they saw only few insects from the ground and vegetation was scarce. However, they did not study insect occurrence; thus, the proportion of insects in their data remained unknown.

(b) Songbird identification

Quantification of songbird migration must include echo identification at the songbird level. Only by using echo signature (wingbeat pattern), can birds be assigned to classes such as (i) waders and waterfowl (continuous flapping), (ii) songbirds (regular intermittent flapping), (iii) swifts (intermittent flapping with irregular long flapping and pause phases), or (iv) swallows (irregular flapping; Bruderer *et al.* 1972; Bruderer 1997; Liechti & Bruderer 2002).

With the method applied by Biebach *et al.* (2000), echo signatures were not available. Consequently, echoes could not be identified as songbirds. Waterbirds, waders and swifts, probably migrating non-stop over the area, were included in their study. Although they state that ‘visual observation for many years at potential stopover sites, such as small lakes, produced only very small numbers of the latter groups (waders and waterbirds)’, this is no proof of absence of non-stop migration overhead. Ephemeral ponds always attracted some waders in Mauritania (Salewski *et al.* 2005), but their number was low in comparison to the proportion of visually observed wader flocks passing our study site (a telescope mounted parallel to the radar beam). Furthermore, swifts and swallows represented more than 30% in our data. Swifts migrate solitarily during night, while

Figure 1. Empirically determined radar beam as beam width over distance for songbirds (solid lines) and waders (dotted lines) in a vertically looking position. Beam opening angle up to 3 km was 3.9 and 4.9° for songbirds and waders, respectively. According to the manufacturer, the opening angle has a value of 2.2°.

both aerial hunters fly mostly in flocks during daytime, but are rarely detected visually (B. Bruderer, F. Liechti & H. Schmaljohann 2003 and 2004, unpublished data). Therefore, Biebach *et al.* (2000) may have dealt (besides the insect problem) with an unknown mixture of migrants having different flight strategies.

(c) Quantification

As for all monitoring methods, proper quantification requires knowledge about the surveyed volume and the detection probability. The volume scanned by the radar beam is a function of beam width, detection range and shape of the radar beam (Eastwood 1967; Bruderer 1997). Since beam width and detection range vary with target size (in radar), the surveyed volume has to be determined empirically to obtain reliable estimates for beam width, detection range and shape of the radar beam.

Biebach *et al.* (2000) assumed their beam width to be 1.55° (manufacturer's information) and calculated the detection range from the calibrated radar used by Bruderer *et al.* (1995a). Based on the peak power output of their radar (25 versus 150 kW of our radar), they calculated a detection range of 3.2 km for small birds. They neglected the fact that both radar systems differ considerably, e.g. in receiver quality. Assuming the shape of the radar beam simply as a fixed cone and not a spindle (figure 1) is a violation of basic radar knowledge (Eastwood 1967; Bruderer 1997).

Radar observations in the western and the eastern Sahara may reveal differences in the composition of bird migration and the amount of insect movements, but to unravel this the applied methods must be adequate.

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