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ABSTRACT

Capsule: Migration associations by Eurasian Curlews Numenius arquata are temporary and last for flight bouts between stopover sites

Aims: Migrant shorebirds are known to initiate migration communally, with groups of birds departing simultaneously from wintering or post-breeding fuelling sites, though the duration of such migratory associations is not known.
Methods: Wintering and breeding adult Eurasian Curlews, and some hand-reared juveniles, were equipped with GPS tags to record their migration.
Results: We describe four cases of joint migration by tagged Eurasian Curlews which provided the opportunity to study the duration of migration associations.
Conclusions: Migration associations lasted for one flight bout only, with separate departures from the subsequent stopover site. This implies that associations might involve individuals that are ready to leave at the same time but not those sharing a final destination. Our observations suggest that migratory groups are temporary associations, reminiscent of the dynamics of a fission-fusion society.

Social bonds during active migration are common in large migratory birds. The most obvious examples are geese and cranes, which perform autumn migration in family groups, with young birds remaining with their parents throughout their first winter (PrevettMacinnes 1980). In cranes, the dissociation of parents and young occurs late in the spring migration, after arrival on the breeding grounds (Howe 1989). Colonial birds can also associate closely during migration; for example, European Bee-eaters Merops apiaster from the same colony have been shown to migrate 14,000 km together (Dhanjal-Adams et al. 2018). Studying the group dynamics in space and time of a variety of migrating bird species will contribute to a better understanding of the causes and consequences of associations during migration. Developments and miniaturization of tracking devices should provide the opportunity to unravel such dynamics.

Migrant shorebirds are known to initiate migration communally, with groups of birds departing simultaneously from wintering or post-breeding fuelling sites. Within such groups, the temporal extent of migratory bonds is yet to be described. Reports of communal arrivals at stopover sites are common, but without individual surveys we cannot know if the same individuals depart together after resting or feeding. We might expect strong associations along the route for wader species engaged in long-lasting latitudinal ocean crossing, if they happen to migrate in groups, as do the Numeniini (MccAfferyGill 2020). As an example, large groups of Bar-tailed Godwits Limosa lapponica depart from the south Yukon–Kuskokwim delta in Alaska, to migrate to the South Pacific, flying non-stop for distances of approximately 10,000 km (Gill et al. 2009).

In winter and spring 2020, we deployed 61 global positioning system (GPS) tags on Eurasian Curlews Numenius arquata (hereafter Curlew) in France and Germany, with the aim of gaining a better understanding of their breeding ecology and migration connectivity. In Poland, four captive-bred juvenile Curlews were tagged and released in July 2020. Here we report four cases of joint migration bouts performed by two tagged Curlews. One case concerned two adults leaving their wintering ground for the prebreeding migration. Two other cases were birds leaving their breeding grounds by initiating the postbreeding migration. The last case concerns two juveniles initiating their first flight to the nonbreeding grounds. These are the first observations of joint migration bouts reported for any curlew species, and provide the opportunity to find out: (1) how long such associations last and (2) if they concern random individuals that are ready to leave at the same time, or individuals that share the same migration strategy and even the same final destination.

## Methods

In France and Germany, birds were fitted with Ornitrack-10 solar-powered backpack tags, with Global System for Mobile Communications (GSM) data transmission. In France, Ornitrack-E10 tags (weight 11 g; E means they had an elevated solar panel) with brown cases were used, fitted using legloop harnesses made of silicone analytical tube (external diameter 1.6 mm, internal diameter 0.8 mm) distributed by Reichelt Chemietechnik GmbH in Germany. In Germany, Ornitrack-10 tags (weight 10 g; similar to the E10 tags but with an integrated solar panel) with grey cases were used, fitted with wing-loop harnesses made from coated nylon string and metal clips. In Poland, birds were tagged with Milsar GSMRadioTAG-M9 tags, with solar panels and GSM data transmission (weight 16 g); these had brown cases and were attached with Teflon™ used as a wing harness. In all cases, the mass of the tag and harness remained less than 3% of the bird's body mass. As an example, in France, the lightest and heaviest tagged Curlews weighed 600 and 940 g respectively, so the tag and harness weight of 12 g was 1.3–2.0% of body mass.

All tags recorded locations at intervals of 5 min, and times of joint departure were estimated from the times of the last positions on the ground and the first position at some altitude of the two individuals involved (e.g. between 8:00 and 8:03 if bird 1 was grounded at 7:58 but in flight at 8:03, while bird 2 was grounded at 8:00 but in flight at 8:05). Data have been deposited on the Movebank platform (www. movebank.org), under the Movebank IDs 1077731101 (France) and 1126572166 (Germany).

Seven adult and three first-winter Curlews were captured with mist nets, ringed and tagged on 23 February 2020 at la Réserve Naturelle Nationale de Moëze-Oléron (45.90°N 1.08°W), where the previous day's high tide count was of approximately 600 Curlews. Five Curlews were captured with mist nets, ringed and tagged on 28 and 29 March 2020 on their breeding territories in the Département Deux-Sèvres, western France (46.25°N 0.03°E), where the local breeding population totals approximately 20 pairs. Some 45 breeding Curlews were ringed and tagged in spring 2020 at various sites in north-west Germany. In Poland, four

captive-bred juveniles were tagged and released into the wild on 1 July 2020 in the Wolsztyn Powiat, Greater Poland Voivodeship (52.01°N 16.24°E). These individuals were part of an active conservation plan for the Curlew at Wielki Łęg Obrzański, a Natura 2000 site from which eggs were taken from wild nests to be incubated artificially. Hatched chicks were raised in aviaries and released into the wild after fledging. Due to the strong decline in the numbers of Curlews in the Obrzański Łęgi valley and the high rate of predation, the main goal was to increase the breeding success through head-starting.

## Results

Of the 61 tagged Curlews, 4 dyads were recorded migrating together. These dyads were:

(1) Two females (200185 and 200187) tagged on 23 February 2020 at Moëze-Oléron National Nature Reserve; both were sexed as females based on biometrics (bill lengths 154 and 161 mm respectively; body masses 940 and 850 g respectively; Summers et al. 2012).
(2) A female (200201) and a male (200204) tagged on 28 March 2020 on different breeding territories in Deux-Sèvres Department, France. Though they belonged to the same local breeding population, they were not a pair, having bred 2 km apart.
(3) A male (201072) and female (201075) captured while nesting on their breeding territories. 201072 was tagged on 27 April 2020 in the Leda-Jümme lowlands (53.22°N 7.65°E) east of Leer, Germany, 201075 was tagged on 21 April 2020 near Rheiderland, west of Leer (52.22°N 7.34°E). They bred 17 km apart.
(4) Two Curlews (B2392 and 02382) from the captivereared Polish study.

Figures 1–4 show the mapped tracks, flight altitudes, and changes in latitude and longitude for each dyad of birds that initiated their migration together. These plots reveal how these birds associated and dissociated during migration.

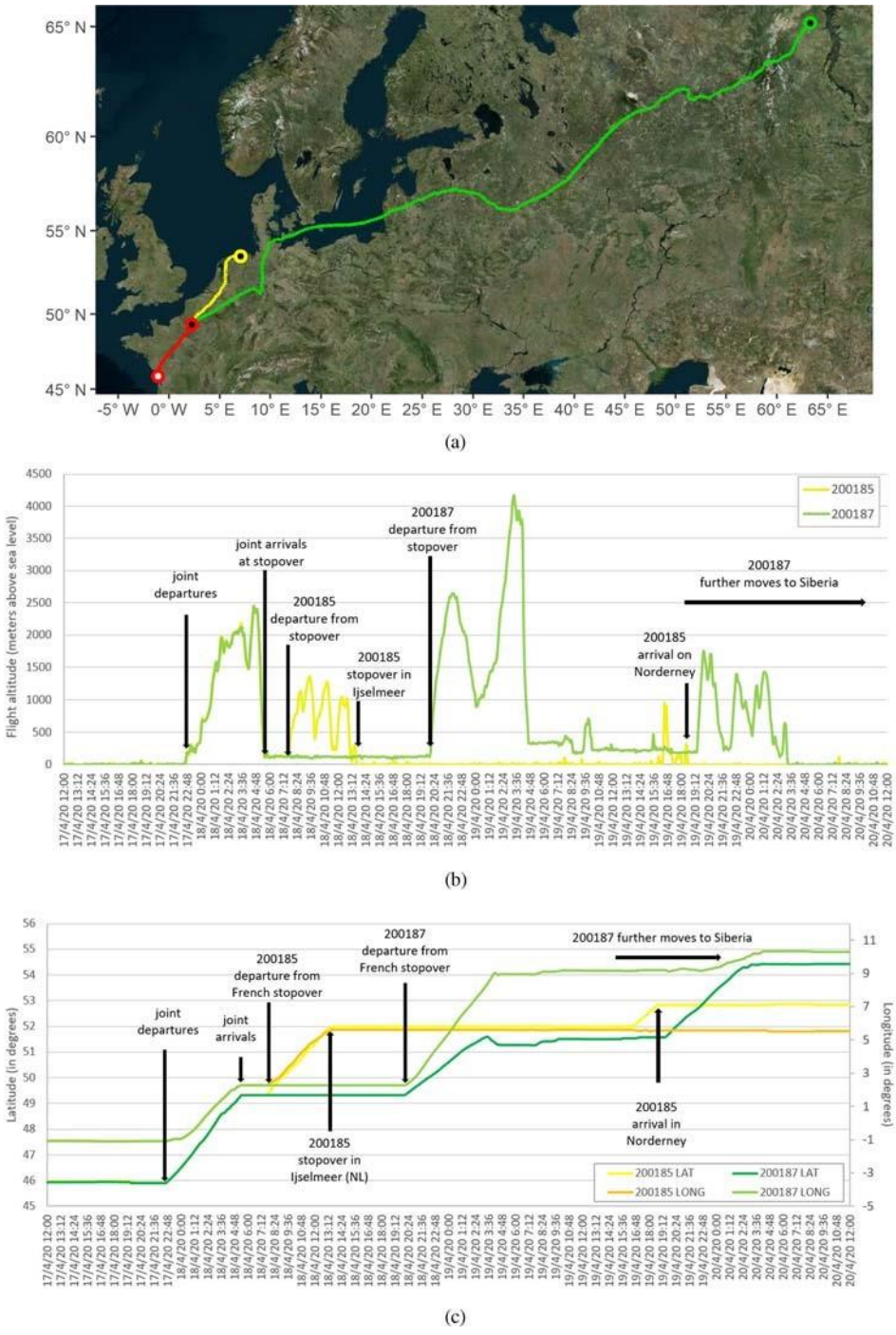


Figure 1. Migration tracks of two adult Curlews (200185 in yellow and 200187 in green) leaving their wintering site (Réserve Naturelle Nationale de Moëze-Oléron, western France) together. Upper panel: overall tracks from 17 April to 15 May 2020 (joint bout in red). Middle panel: altitude (above sea level) recorded by the GPS tags; annotated to mark the migration steps. Lower panel: latitudes and longitudes as recorded by the GPS tags; annotated to mark the migration steps.

## Joint flight by 200185 and 200187

On 17 April 2020, individuals 200185 and 200187 left their French wintering site together at sunset, between 22:37 and 22:40. They joined just 10 min prior to the start of migration, after standing 100 m apart during the previous hour. They made a stopover north of Paris, between Creil and Beauvais (49.35°N 2.28°E) (Figure 1). On 18 April at 07:48, 200185 departed and stopped again close to Veenendaal, the Netherlands, at 13:37. Its final move to Norderney, one of the East Frisian Islands located off the North Sea coast of Germany on the northern edge of the Wadden Sea, began on 19 April at 16:29 and ended with its arrival

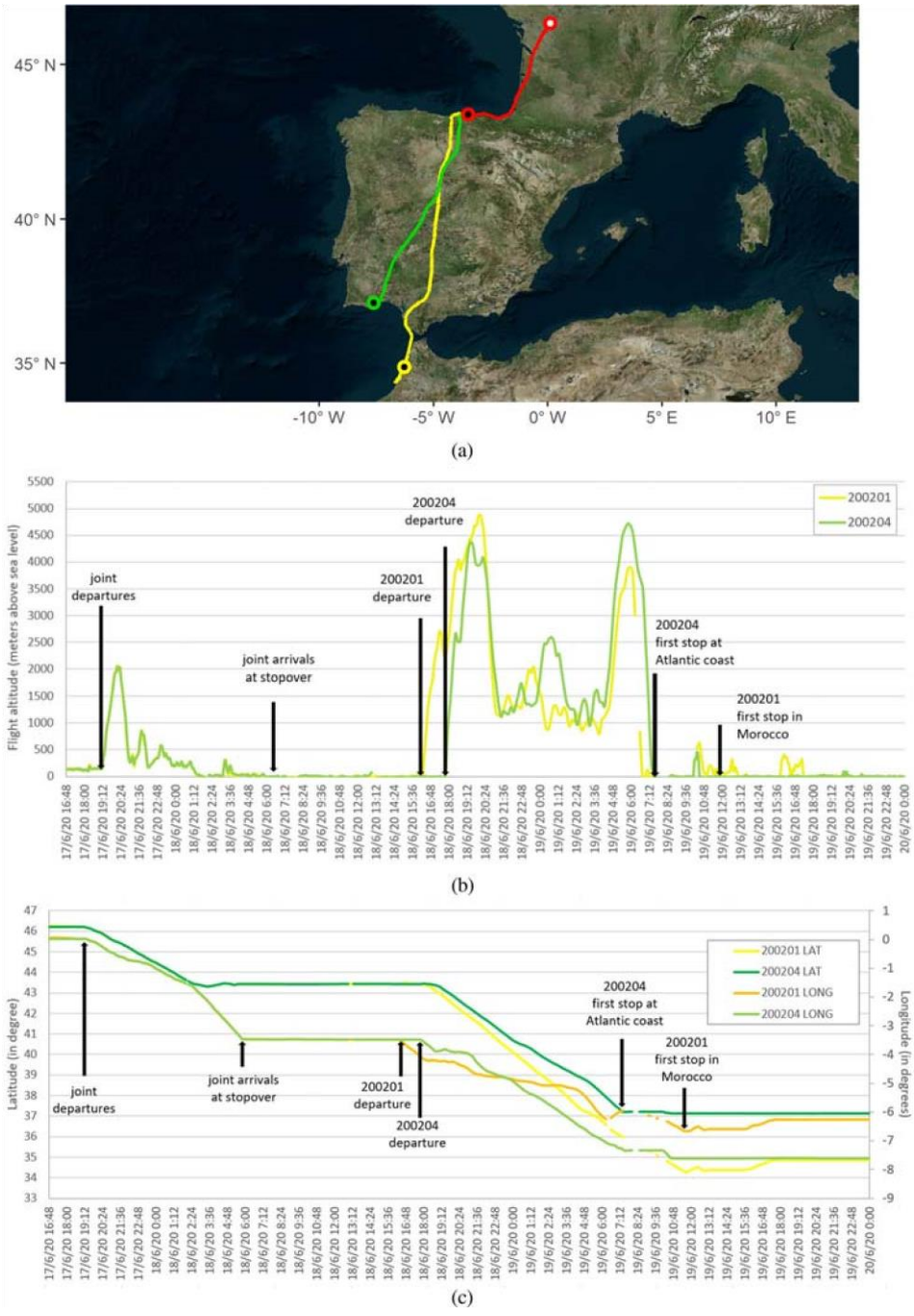


Figure 2. Migration tracks of two adult Curlews (200201 in yellow and 200204 in green) leaving their breeding site (Deux-Sèvres, western France) together. Upper panel: overall tracks from 17 to 20 June 2020 (joint bout in red). Middle panel: altitude (above sea level) recorded by the GPS tags; annotated to mark the migration steps. Lower panel: latitudes and longitudes as recorded by
the GPS tags; annotated to mark the migration steps.

at 18:39. On 18 April at 20:05, 200187 departed from the common stopover site more than 12 h after 200185. On 19 April at 04:32 200187 landed near Korbach in central Germany, moved again twice in the morning, then departed further north on 19 April from 19:27, landing near Kiel in Germany at 03:17 on 20 April. Further moves towards the north-east occurred until the end of May, the bird even crossing the Ural Mountains to reach Yamalia in central northern Russia (approximately 68°N 73°E).

## Joint flight by 200201 and 200204

On 17 June 2020, individuals 200201 and 200204 departed simultaneously from Deux-Sèvres between 19:16 and 19:17 for a non-stop southward flight,

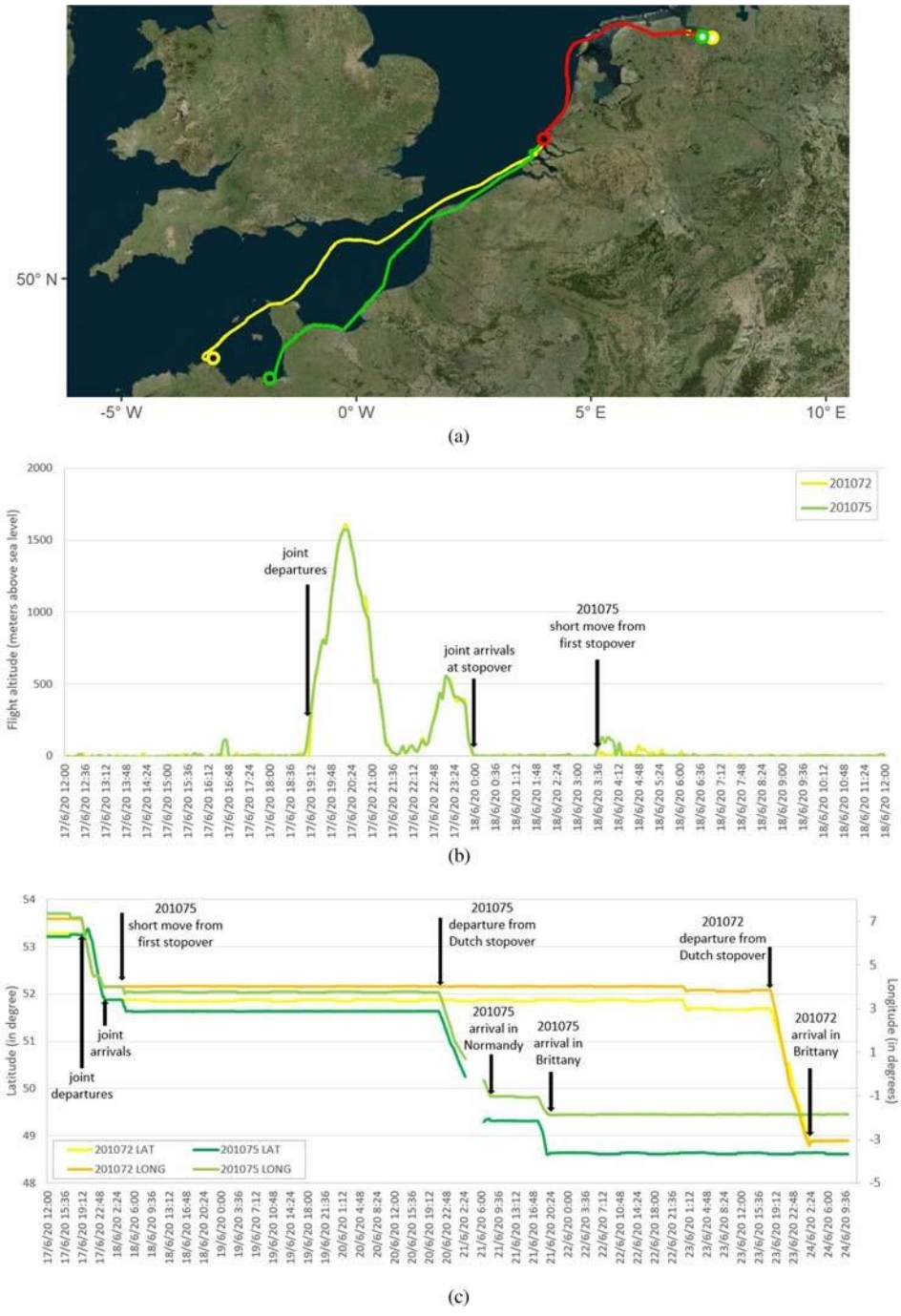


Figure 3. Migration tracks of two adult Curlews (201072 in yellow and 201075 in green) leaving their breeding site (Leer, northern Germany) together. Upper panel: overall tracks from 17 to 24 June 2020 (joint bout in red). Middle panel: altitude (above sea level) recorded by the GPS tags; annotated to mark the migration steps. Lower panel: latitudes and longitudes as recorded by the GPS tags;
annotated to mark the migration steps.

arriving together on the Ria de Treto estuary, in Laredo Bay, northern Spain on 18 June at 05:49. The two birds departed separately from this stopover site in the late afternoon of 18 June (Figure 2). Individual 200201 departed at 18:18, making a non-stop flight south to Kenitra, Morocco, where it made a stopover on 19 June from 15:11 to 17:40, before moving north to Merja Zerga, a tidal lagoon on the Atlantic coast of Morocco, reaching its final destination on 19 June at 19:31. Individual 200204 departed 90 min later than 200201, at 19:46, making a non-stop flight to Isla Cristina, on the Atlantic coast of Spain, arriving at 09:31 on 19 June. The bird made a short stop here until, departing at 12:06 the same day, before reaching

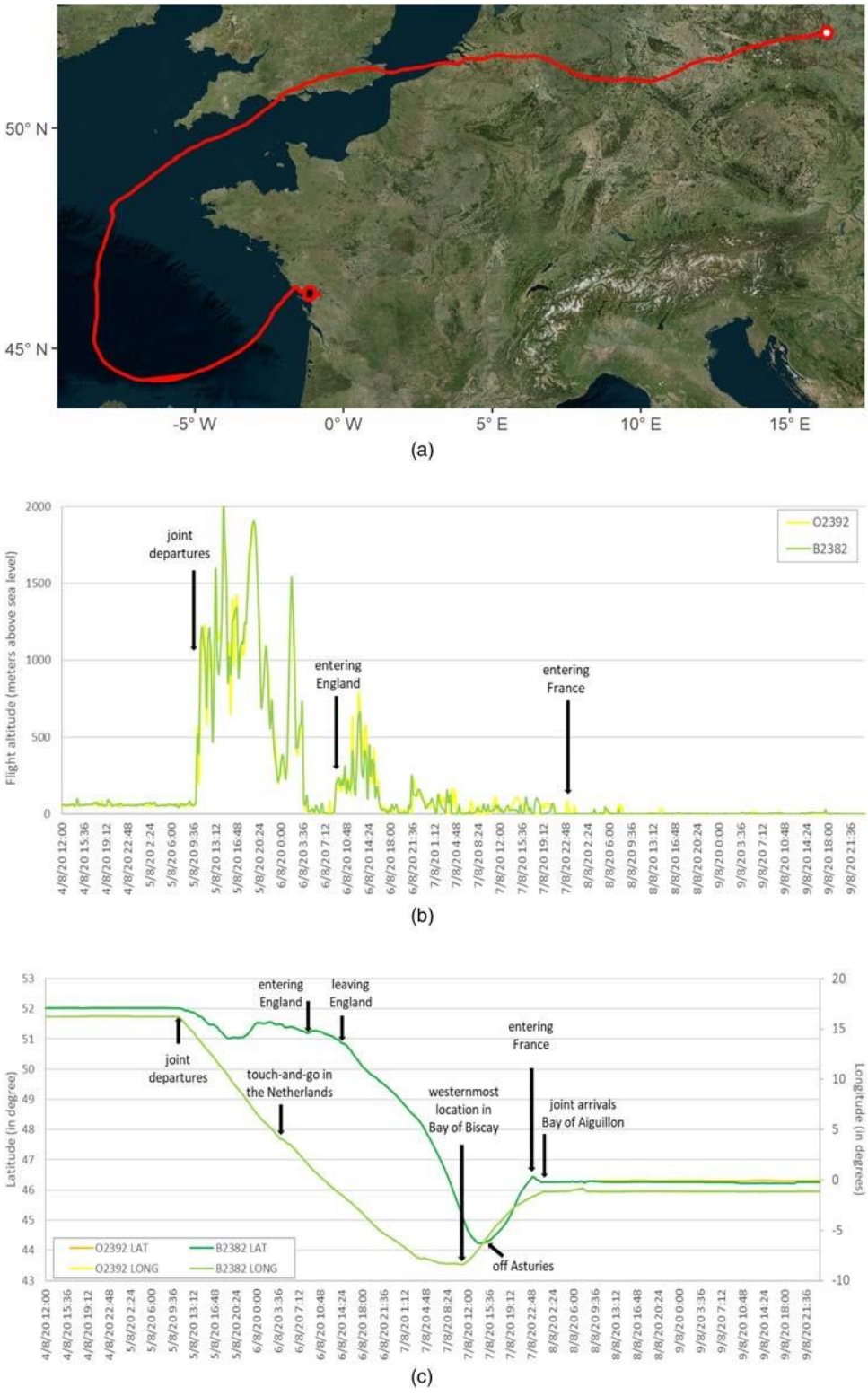


Figure 4. Migration tracks of two juvenile Curlews (B2392 and 02382, tracked superimposed) leaving their release site in Poland (Wolsztyn Powiat, Greater Poland Voivodeship) together. Upper panel: overall tracks from 5 to 8 August 2020. Middle panel: altitude (above sea level) recorded by the GPS tags; annotated to mark the migration steps. Lower panel: latitudes and longitudes as recorded by the GPS tags; annotated to mark the migration steps.

its final destination at Ilha de Tavira, Portugal, at 12:41 the same day. After separation, the two birds travelled across Spain on the same day but at different times, although they followed quite similar routes and even flew at similar altitudes.

### Joint flight by 201072 and 201075

On 17 June 2020 between 19:08 and 19:12, individuals 201072 and 201075 departed simultaneously from the mouth of Ems Estuary in Dollart Bay, part of the Lower Saxony Wadden Sea National Park (Figure 3). To be more precise, 201075 was located approximately 5 km further east and began migration between 18:58 and 19:03. Curlew 201072 was roosting or feeding in the Dollard Bay when 201075 flew over at an altitude of 190 m above sea level, at which time 201072 took off and joined 201075 in flight. They both landed between 23:53 and 23:57 south of Maasvlakte, the Netherlands, on Havenhoofd shore in the RhineMeuse delta. Both birds stayed in the delta for a few days. Bird 201072 stayed until 18:07 on 23 June, then departed for a non-stop flight to its final destination, at Sillon de Talbert, near Bréhat Island on the French Atlantic coast, where the bird arrived on 24 June at 02:22. Bird 201075 departed from the Rhine-Meuse delta on 20 June at 21:19 for a non-stop flight to Isigny-sur-Mer, Normandy, France, where it arrived on 21 June at 08:03. After a stopover of almost 10 h the bird departed again at 17:53 for its final destination, the bay of Cancale in Brittany, where it landed at 19:48 the same day.

### Joint flight by B2392 and 02382

Individuals B2392 and 02382 were captive-bred juveniles released on 1 July 2020 in Poland. For B2382, the first location recorded in active migration was on 5 August 2020 at 10:04, near to the release site, while the next definite landing was recorded on 8 August 2020 at 02:39 in the Bay of Aiguillon, France (46.27°N 1.15°W) (Figure 4). For bird 02392, migration was initiated at 10:02 on 5 August, and the bird landed at the same place as B2382 in the Bay of Aiguillon at 02:32 on 8 August. During their joint migration bout, the two birds slowed down at two places over Zeeland, the Netherlands, though apparently without landing (no similar locations recorded for both individuals at 15 min intervals), or at most with a brief touchdown. These slowdowns occurred on 6 August around 04:00–04:15 at 51.48°N 4.04°E, and around 05:15–05:30 at 51.39°N 3.62°E. Both birds entered England north of Dover on 6 August at 09:00, and left England the same day at 15:45 southeast of Poole. They then performed a large loop over the Bay of Biscay, reaching the westernmost point of the tracks (45.25°N 8.39°W) on 7 August at 10:50. Then they flew towards Galicia, Spain, turned progressively to the west off Asturias and then moved north-east towards the French coast. The two birds entered France on 7 August between 22:49 and 23:04 but did not stop when they reached the coast; instead they made a few brief touchdown stops and stayed together until they reached La baie de l'Aiguillon where they finally settled. Overall, the migration bout lasted approximately 64.5 h. The two birds separated around 09:00 on 8 August, and later spent August and September at La baie de l'Aiguillon, but not together.

## Discussion

We report here four cases where dyads of Curlew individuals performed a common first migration flight bout. This is not necessarily surprising, as Curlews are known to leave their wintering grounds or stopover sites in groups (pers. obs.). A common sighting at both the Réserve Naturelle Nationale de MoëzeOléron and the Réserve Naturelle Nationale de la baie de l'Aiguillon is to see groups of Curlews rising high in the sky at sunset during migration periods in early April. It is, however, the first time that such joint departures of tagged birds have been reported for shorebirds, providing the opportunity to study the strength of such associations during migration. We report the short duration of the observed migratory bonds, and the fact that joint migrants generally had different final destinations.

In all three observed joint migrations of adults, the two individuals associated for the first flight bout, lasting between 5 and 11 h, at the start of the seasonal migratory journey. They migrated together during a single bout and always at night, and dissociated afterwards. The joint nocturnal flights always ended with a landing together for a first stopover. In all three cases, the duration of the stopover differed between the two birds, leading to one bird starting a second migration bout earlier than the other. The final destination of the birds of each dyad also differed, sometimes slightly (as for the two German breeders going to Brittany), but in other cases dramatically so. The two Curlews that initiated their pre-breeding migration together finished at very different destinations: one spent the spring on Norderney, northern Germany, while the other travelled to the Asian slopes of the Ural Mountains. These three dyads of birds were known to be not mated pairs, either because they

migrated to very distant breeding grounds, or because we ringed them as breeders involved with other individuals. The case of the two captive-bred juveniles is somehow different, as the birds made a single but long flight bout, so stayed together during the complete migration journey. During their flight to reach their wintering area in western Europe, we do not know if these two birds benefited from the company of experienced adults (Currie et al. 2001); but if they were on their own it could explain the non-optimal and potentially hazardous track over the Atlantic. As there was only one continuous flight, with no intermediate stopover between the breeding site and the final destination, we cannot interpret these data any further in terms of migration bond.

Despite the small sample size, given the patterns they share, we hypothesize that those Curlews initiating their migration together are strongly associated only in the short term, and engage in opportunistic temporary bonds that generally do not last longer than one migration bout, with a redistribution of associations probably after each stopover. This also seems to be confirmed by the two birds breeding in northern Germany, as one flew off to join the other bird as it was flying over; we speculate that there might be some vocal activities during the start of a bout to invite other conspecifics to join the group. We also acknowledge that the probability of recording joint flights was higher for the first migratory bout, as the tagged birds were spatially close to each other before initiating migration. Migration initiation depends on multiple factors, including photoperiod, weather, local food availability, and physiological status (Rappole 2013). The first three factors are equal for birds lingering together or close-by for weeks or months before migration, e.g. birds from the same breeding population or wintering at a same site, so that their probability of initiating migration jointly is higher. Having more tagged birds across the European range might reveal similar temporary associations during the next flight bouts too. With the deployment of more tags on Curlews across Europe in future years, we expect to document further cases of joint migration, which may allow us to determine the frequency of such events.

Sustained migratory associations have been reported within families (Scheiber et al. 2013) or in social birds originating from the same colony (Dhanjal-Adams et al. 2018), so involving individuals with, at least initially, strong existing social bonds. In Curlews, early offspring desertion by females (Currie et al. 2001) and late offspring desertion by males disrupt family associations during the post-breeding migration. Here we only detected temporary associations, which are reminiscent of the dynamics of a fission-fusion society, as observed in non-breeding corvids (Loretto et al. 2017). In such instances, group size typically fluctuates over time and space, with individuals coming together and separating (Sueur et al. 2011) as they trade off the different benefits and costs of cooperation. Flocking during migration should increase navigational accuracy (Mueller et al. 2013), either through social learning, where experienced individuals guide less-experienced individuals (Teitelbaum et al. 2016), or through collective learning, where groups pool their knowledge to generate better migratory decisions than solitary individuals (SasakiBiro 2017). However, it seems that even inexperienced birds can migrate together, so this might not be the major benefit in Curlews. Flocking during migration might also reduce predation risk (CreswellQuinn 2011) and, most importantly, should provide energetic advantages if flying in formation (Weimerskirch et al. 2001). In Curlews, flocks might be simply anonymous crowds of birds initiating migration simultaneously because of a similar physiological state of readiness (Gwinner 1990), that aggregate to move to the next stopover site, before forming new, anonymous associations from that stopover to the next depending on the ability of the birds to continue the journey or the need to first restore body reserves.

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