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New insights into fall passage ecology and behaviour of black storks (*Ciconia nigra*) at Dumbrăvița fishing complex (central Romania)

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Abstract. The Dumbrăvița Fishing Complex (Brașov, Romania) represents one of the most important Transylvanian stopovers for the black stork's (*Ciconia nigra*) fall passage. This study aims to prove the importance of adequate, species-synchronized drainage management of large ponds to maximize site potential as foraging area for black stork fall migrants, as well as to povide detailed recording of a new foraging pattern for this species. Throughout 4 consecutive fall passages (August-September; 2013-2016), black storks were monitored weekly, during evening foraging. Compared to bibliographical data (1995), the assessment of maximum numbers variation revealed a clear increase in numbers for the last 4 years, attributing highest values observed to passage-synchronized drainage of largest ponds. Pond focused analysis of fall passage peak numbers variation highlighted a positive impact of passage-timed water discharge on the occurrence of higher values for foraging groups. Regarding feeding ethology, foraging black storks were observed exclusively along the most vegetated shores, some groups displaying a new foraging pattern: repeated line feeding, deeper water dependent and potentially attributed to water currents. Foraging associations involved three Ardeidae species, with antagonistic behaviour only towards some *Ardea cinerea* individuals. Lastly, we propose the drainage of large ponds during the moments of maximum intensity for the black stork's fall passage.

Key words: black stork, fall passage, foraging ethology, drainage management.

The black stork, *Ciconia nigra* (Linnaeus, 1758), epitomizes the "umbrella species" concept (Lambeck 1997) through its cryptic ethology, extensive breeding/foraging areas (Jiguet & Villarubias 2004, Tamás 2012) and specific habitat requirements (Vlachos et al. 2008, Treinys et al. 2009). Listed SPEC2 and included in Annex I (EU Birds Directive) and Annex II (Migratory Species Convention), almost 50% of the world's black stork population breeds within Europe's Trans-Palearctic region, with relatively unknown Central-European population trends (BirdLife 2017). Hosting 5% of the European breeding population, Romania classified *Ciconia nigra* as Vulnerable, due to numbers decline (Botnariuc et al. 2005).

A major impacting factor on long-term avian population trends is natural foraging habitats loss and degradation (Newton 2004, Newton 2006), also applicable to the black stork (Lõhmus & Sellis 2001). As such, research on decreasing numbers switched perspective to migrational costs (Jadoul et al. 2003, Chevallier et al. 2010, Chevallier et al. 2011). The black stork's populations migrating eastwards require at least one stopover during the fall passage (Tamás 2012). Since black storks are partial to selecting anthropogenic ecosystems as stopovers during passages (Moreno-Opo et al. 2011), deepening the knowledge on the ethological and ecological basis of this selection is necessary.

This study assesses the importance of an anthropogenic habitat (Dumbrăvița Fishing Complex, Brașov, Romania), as stopover point for the black stork's fall passage, selected by 1% of the Central-European populations migrating southwards Europe (Management Plan for Nature2000 Site ROSPA0037 2016). Located on a major migratory route over Romania - the Vth Central-European-Bulgarian Bird Migration Route (Costică 2011) – this wetland (one reservoire and 12 fishing ponds) has gradually evolved into an important ornithological Nature2000 stopover site.

Considering the site's dualistic status (fishing complex and protected area), this study assesses several ecological aspects of the black stork's fall passage at Dumbrăvița ponds: (1) passage-synchronized drainage management and inter-annual variations in black stork numbers; (2) feeding ecology: patterns, feeding associations, foraging areas distribution; (3) origin of foraging groups.

Study area. The research was conducted at Dumbrăvița fishing ponds, a 191.1 ha wetland, within a Nature2000 site (ROSPA0037, Brașov county, Romania) (Ionescu 2002), comprising: 12 main fishing ponds, 3 secondary ponds, 8 basins (Fig. 1). Land usage for the surrounding area encompasses: pastures and farmlands (990.58 ha), woodlands (79,23 ha) and meadows (13,48 ha). (Management Plan for Nature2000 Site ROSPA0037 2016)

The area is subjected to fish farming practices and bird-watching activities for organized groups, from monitoring points only, in accordance with Nature2000 policies, all year round.

Data gathering. Throughout the fall passage (01.08.–30.09.) from 2013 to 2016, black storks were monitored weekly during the evening feeding period (16:00–18:00), through direct binocular observation (Auriol binoculars: 10x50). Counts were conducted on an irregular basis, depending on species presence and drainage process information from the keepers.

Numerical data was gathered through the point-counting method (Cătuneanu et al. 1978), establishing 2 monitoring points/pond, upon visibility criteria. The water surface was divided into imaginary, equally-sized sectors, to facilitate counting of larger groups (>25 individuals) and avoid double-counting errors. Foraging ethological patterns were video-recorded with a SonyDSC-H300 (20.1MP; 35x optical zoom).

Data were registered in fieldsheets with the following headers: date, hour, location, numbers, habitat, food, observations. Information on available food species was provided by the manager (aquacultured species; approximate fish size post-harvesting).

Data analysis. We used QGIS.2.18.2 to generate migration maps

Figure 1. Drained ponds size and distribution within Dumbrăvița Fishing Complex.

and Microsoft Excel for plot analysis. Given the intrinsic complexity and low predictability of the data, we chose histograms (similar to various studies presented in Tamás (2012)) to illustrate the inter-annual variations in maximum black stork numbers at Dumbrăvița, also including bibliographical data (Ionescu 2002) regarding the maximum numbers for 1995 (with no data on drainage for that year).

Graphic representation of the analysis between species synchronized water-level management and the inter-annual fluctuation in maximum numbers focused on 2 of the wider ponds (E9a,b; E7), bound to support larger black stork groups in terms of feeding resources. We considered: drainage starting date, species maximum numbers/pond/year and observation date. To overlap the results with the species' fall passage, in ordering drainage and observation date, chronology by year was replaced with a day-month order.

Inter-annual numbers variation. Throughout our study, the black stork's fall passage peak numbers (80 individuals recorded in 6-9.09.2013; 54 in 2-4.09.2014; 67 in 23.08.2015; 44 in 17.09.2016) were reached during the drainage of larger ponds (E9a,b; E7; E12) (Table 1). The transition of the migration peak period from the first decade of August (2015) up to the beginning of the autumnal aspect (2016) was highly influenced by the ponds' drainage succession. Drainage of large ponds (E9a, b) started earlier in 2015, while in 2016 water discharge from the largest basin (E12) was postponed un-

Table 1. Data on Black Stork maximum numbers observed at Dumbrăvița fishing ponds, drainage succesion and pond size, during 4 fall passages.

Pond	Area (ha)	Drainage starting date	Observation date	Maximum numbers observed
		2013		
E1	1.1	20.07	01.08	5
E2, E3	8.2	27.07	06.08	15
E9a,b	14	13.08	20.08	45
E7	9.5	20.08	06.09	80
E6	8.1	31.08	09.09	
I1	12.1	09.09	19.09	63
I2	4.9	16.09	25.09	13
		2014		
BR	3.9	18.07	10.08	15
I2	4.9	14.08	19.08	17
I1	12.1	20.08	22.08	23
E9a,b	14	27.08	02-04.08	54
E2	2.6	10.09	17.09	15
E3	5.6	17.09	24.09	32
E7	9.5	19.09	30.09	10
		2015		
BR2	1	20.07	13.08	10
E9a,b	14	18.08	23.08	67
E7	9.5	13.09	24.09	37
E6	8.5	20.09	27.09	30
		2016		
E9a,b	14	30.07	13.08	24
E7	9.5	10.08	13.08	24
E6	8.1	15.08	27.08	35
E3	5.6	01.09	02.09	33
E12	32.4	07.09	17.09	44
I3	5.8	27.09	28.09	5

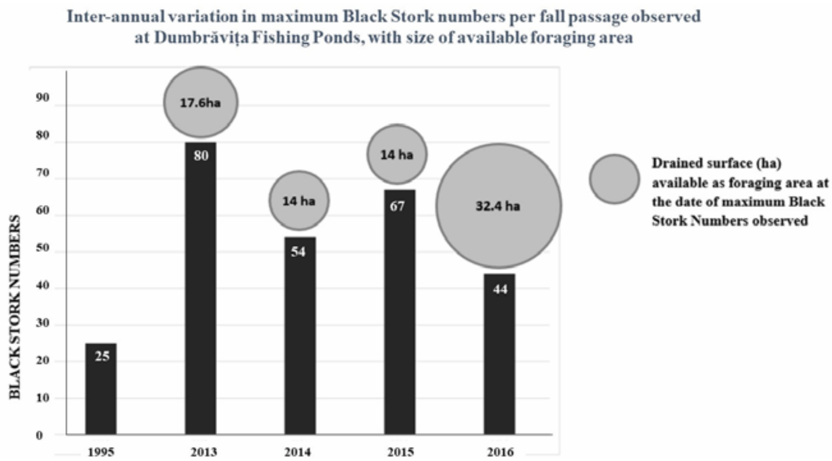

Figure 2. Inter-annual variation in maximum Black Stork numbers observed at Dumbrăvița Fishing Complex, with size of available foraging area.

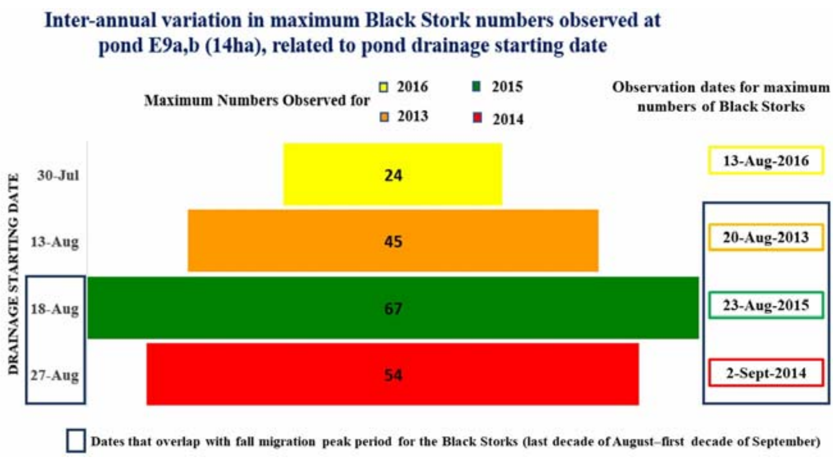

Figure 3. Inter-annual variation in maximum Black Stork numbers observed at pond E9a,b (14ha), related to pond drainage starting date.

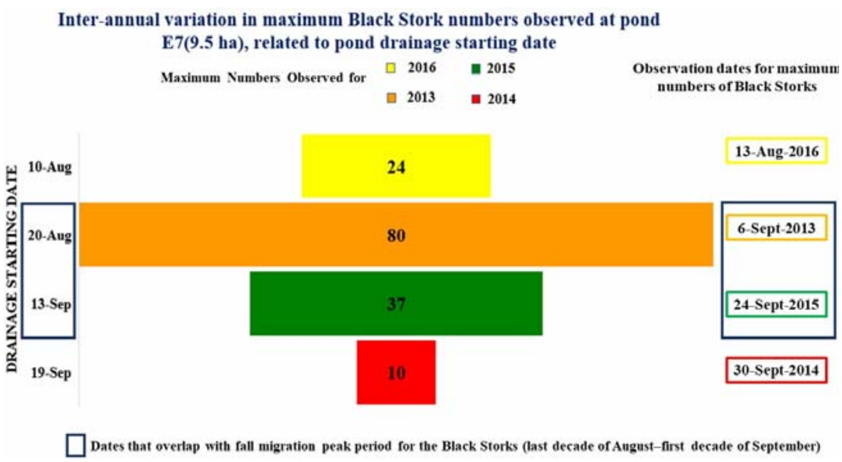

Figure 4. Inter-annual variation in maximum Black Stork numbers observed at pond E7 (9.5ha), related to pond drainage starting date.

til after mid-September. Regarding inter-annual dynamics (Fig. 2), we notice a sharp increase in maximum numbers recorded throughout our study (all >40 individuals) versus data from 1995 (25 storks/06.09.). While all fall passage peaks were reached during larger ponds drainage, when synchronizing water discharge with the migration peak interval for the black stork at Dumbrăvița (last decade of August - first decade of September; (Ionescu 2002)), numbers grow significantly higher (80 individuals/2013; exploiting 17.6 ha). In 2016, although the available foraging area when peak numbers were observed is the largest recorded and corresponds to the drainage of the largest basin (32.4 ha), the water discharge period overlapped with the end of the species fall passage, resulting in the lowest peak for our study.

Pond focused analysis of fall passage maximum numbers variation highlights the influence of drainage starting date on the black stork's passage dynamics at Dumbrăvița (Fig. 3). The lowest peak at E9a,b (14 ha) was recorded in 13.08.2016, when water discharge started in late July (30.07), two weeks outside fall migration peak interval for the black stork at Dumbrăvița. However, on dates overlapping with the fall passage peak period, significant numbers were recorded at E9a,b (groups >40 individuals). A similar pattern results at E7 (9.5 ha), only the lowest numbers are reached

Figure 5. Black Storks flock displaying line feeding at pond E7 (original photo Ciobotă Mihaela, 07.09.2015).

Figure 6. Black Storks in feeding associations with *Ardea alba*, *A. cinerea* and *Egretta garzetta* at pond E9b (original photo Ciobotă Mihaela, 21.08.2015).

Figure 7. Black Stork displaying antagonistic behaviour towards *Ardea cinerea*, during the evening feeding at pond E9b (original photo Ciobotă Mihaela, 21.08.2015).

when water discharge coincided with the end of the species fall passage (Fig. 4).

Foraging ethology. Correlated with the species foraging behaviour and cryptic ethology, black stork feeding groups were particular to partially drained ponds, with a preference for highly vegetated shores (*Typha-Phragmites* associations, *Salix* sp.). Thus, the species annual distribution within the fishing complex highly depends on water-level management decisions.

A new feeding pattern for the black stork was recorded, particular to waters about 50 cm deep, alongside the most vegetated shores. During a feeding session (i.e. uninterrupted foraging episode within the evening feeding period) the group aligned, one individual behind another, and moved forward, while feeding (Fig. 5). In between foraging episodes, they displayed stationary grooming activities (15-20 minutes). Before the next feeding session, the flock flew back to the previous starting point and repeated the same line pattern foraging.

Black storks were also observed sharing feeding areas with members of the Ardeidae family: *Ardea alba*, *A. cinerea* and *Egretta garzetta* (Fig. 6). Within these feeding associations (i.e. more/less compact groups exploiting the same foraging perimetres during evening feeding period: 4-6 P.M.), *A. cinerea* had the highest percentage (42%), followed by *Ardea alba* (20%), *Egretta garzetta* (19%), *Ciconia nigra* (19%). Antagonistic behaviour was ocasionally displayed towards *Ardea cinerea*, when competing for food (Fig. 7).

Ring recoveries. Five ringed individuals were observed (ringed as nestlings), from countries in Central and Northern Europe (Table 2), with the adult labeled 1N28 recorded two fall passages in a row, at the same feeding pond.

Importance of water level management

Increasing migrating numbers (with the highest value for Transylvania: 80 individuals/2013) could be explained through: (1) site location on the Vth Central-European-Bulgarian migratory corridor and black stork passage route fidelity, even when selecting stopovers (Tamás 2012); (2) water-level management focused on synchronizing large pond drainage to moments of maximum intensity for the species' fall migration; (3) aqua-cultured Cyprinidae species (*Carassius gibelio*, *Alburnus alburnus*), small-sized (100-120g fish brood/underdeveloped individuals, left post-harvesting) in accordance with black stork feeding preferences in Central Europe (Tamás 2012), and wintering areas (Bahat 2008, Chevallier et al. 2008, Li et al. 2011); (4) reduced anthropic impact (Ciobotă 2016).

Group size depends upon the presence of feeding areas on site, provided through periodical drainage. Constant pond drainage provides the species' characteristic shallow-water foraging areas (Ionescu 2002, Tamás 2012, Ciobotă 2016), numbers increasing significantly. Concerning black stork's preferences in semi-natural ecosystems, literature de-

Table 2. Ringing data for 5 Black Stork individuals recorded at Dumbrăvița during the fall passages of 3 consecutive migrating seasons (2013, 2014, 2015).

Black Stork - Ring no.	Ringing place	Ringing date	Recovery date	Approximate distance from ringing place to Dumbrăvița
1N28	Poland	2005	10.09.2013	648 km
			04-06.09.2014	
1V87	Poland	2008	10.09.2013	
V264	Lithuania	09.07.2010	28.08.2014	1056 km
63VW	Czech Republic	04.06.2014	02.09.2014	848 km
C4571	Slovakia	04.07.2015	23.08.2015	597 km

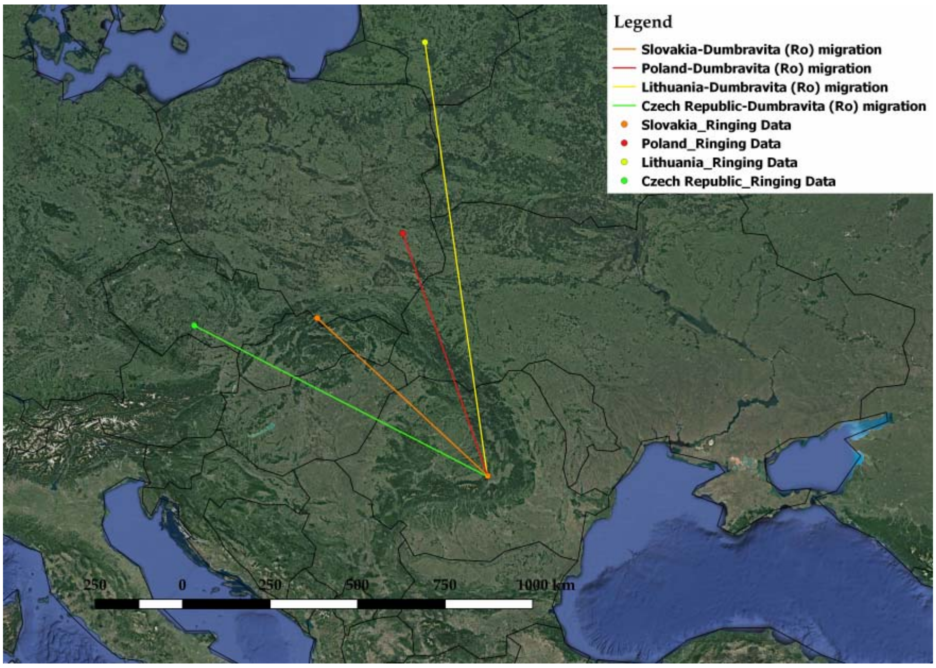

Figure 8. Migration routes for the Black Storks recorded at Dumbrăvița during the fall passages of 2013, 2014, 2015.

scribes a positive correlation between pond dimension and group size (Ionescu 2002, Moreno-Opo et al. 2011), attributed to: higher heterogeneity and diversity of food resources, prolonged water persistence in larger ponds (even during drainage), availability of wider feeding areas (Moreno-Opo et al. 2011). However, as revealed through our pond-focused analysis (at E9a,b; E7), the available feeding area needs to be passage-synchronized to support larger black stork groups. Resources availability outside the passage peak period results in either food depletion before the arrival of most black storks or food becoming available too late in the passage.

Foraging ethology

Preference for highly-vegetated pond shores could be attributed to high productivity values (wetland specific), with an increase in fish abundance (Moreno-Opo et al. 2011). Furthermore, nude shores represent pond access routes for fish harvesting, storks selecting vegetated perimeters to maintain distance from humans.

While forward-moving foraging behaviour is described in literature for herons (Kushlan 2011), repeating the same linear direction for different feeding sessions is a particular foraging display, which to our knowledge has not been mentioned in literature so far. This feeding pattern could potentially be attributed to water currents caused by drainage processes (that influence fish swimming direction) and black storks tending to choose routes that provide fish-catching with minimum effort and maximum visibility. However, further research needs to be done to establish a clear correlation between the new foraging pattern, fish mobility and hydrological parameters.

Ring recoveries

Linear distances between ringing places and Dumbrăvița (Fig. 8) did not exceed 1000 km (except the adult ringed in Lithuania) (Table 2). Given that black storks may travel 263.6 km/day (Chevallier et al. 2011), it is highly possible that Dumbrăvița was the first stopover for the 5 ringed individuals.

Ring recoveries help define migratory corridors and pinpoint intrinsic stopover selection mechanisms (Tamás 2012). Recording of individual 1N28 for two consecutive falls (2013, 2014) may suggest stopover site preference.

With the gradual degradation of natural wetlands, anthropogenic habitats (man-made ponds), can become real solutions for migratory avifauna conservation. (Moreno-Opo et al. 2011, Alexandrou et al. 2016). Therefore, knowledge on species ecology/ethology within these habitats is vital for long-term conservation plans. At Dumbrăvița, recent increases in black stork numbers are strongly related to water-level management. Thus, we suggest passage-synchronized large ponds drainage to improve site foraging value for this species.

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