

Global Raptor Migration “Bottlenecks” as a Parameter of Long-Term Variations in Raptor Populations

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INTRODUCTION

Despite its small size Israel is strategically located at the junction of three continents. As a result, Israel is a “bottleneck”, into which all or a large part of the world populations of certain raptor species concentrate, during spring and autumn.

Comparison of our results with data in the relevant literature, proves that our figures for species whose total population, or most of it, passes through “bottleneck” areas provides relatively reliable estimates of minimum population size. The numbers counted during migration are sometimes higher by an order of magnitude than the data from existing studies.

In order to examine long-term regularity in major migrating species’ appearance, the weighted average day of arrival was calculated for all the years of the study, as well as the date by which half of the population had passed over Israel, the average peak day, and the average arrival percentage for each species on the peak day. The results show that it is possible to predict the days of appearance of various raptor species with a precision of 1.35 to 3.12 days in autumn and 1.92 to 4.92 days in spring. In many of the species the arrival percentage on the peak day is higher in spring than in autumn.

METHODS

Five different data-gathering methods were used for this research:

1. *Ground Observer Network*: Dozens of studies have tracked migration with small numbers of observers at 2-3 key observation points. In this study, for the first time ever, ground observers were placed along a broad front: 25 observation points were placed across the country, along 75 kilometres, during several migration seasons. More than 150 experienced birdwatchers logged about 224,000 observation hours.

2. *Light Aircraft Tracking*: This method proved excellent for locating principal migration routes, their altitudes and counting flocks per time and distance units, and very efficient on “peak” migration days. Additional flights were carried out to confirm the radar distinction ability (see Method 5). Twenty-nine flights totalling 83.40 hours were carried out.

3. *Motorised Glider*: This method enabled continuous flying, up to 11.5 hours, with the same

flock, as well as exact mapping of the migration route, altitude, flock progress rate, climbing and gliding in thermals. One hundred and seventy-three flights totalling about 720 hours were carried out. This was the first time motorised glider migration tracking was used in the Middle East. No study using a motorised glider to systematically follow migrating flocks for such long periods of time had been done up to now, both in the number of flight hours and the number of tracking days.

4. *Unmanned Aircraft (Drones)*: This method enabled tracking single flocks for about 150 kilometres with constant documentation of the flock by video camera. Nineteen flights were carried out. To the best of our knowledge, this is the first biological study ever to make use of this military instrument for research.

5. *Radar*: A radar screen at the Ben-Gurion International Airport surveillance radar was permanently available during the migration seasons. This enabled constant tracking during all hours of the day. The cloud radar of the Shaham Company followed migration regularly only during one season. Its use was terminated due to technical problems. A total of 8,125 radar tracking hours was carried out. This is the first time radar was used to follow soaring bird migration in the Middle East in general, and in Israel specifically.

Most migration tracking research has been limited to one method, and only a minority combined two methods simultaneously, such as a combination of radar and ground observers (Evans & Lathbury 1973) or light aircraft and radar (Pennycuick, Alerstam & Larsson 1979). In our study, we have developed for the first time, to the best of our knowledge, research based on a combination of five methods for data gathering from one migration system, with each method complementing, at least partially, the deficiencies of one of the others. At the same time this enabled confirmation of data gathered by one method by one of the other methods. The development of several parallel research methods allowed for integration between the various methods. The radar could, for example, take over from the motorised glider for a short period of time, to enable refuelling and rest; it could then direct the glider to the exact position of the flock it had left to continue tracking.

The statistical analysis in this research is based on nine autumn migration seasons for raptors and four for storks and pelicans. During spring migration raptors were followed in Eilat for six years and storks for four in the western Negev.

RESULTS

Comparison of our results with data in the relevant literature proves that our figures for species whose total population or most of it passes through "bottleneck" areas provide relatively reliable estimates of minimum population size. The numbers counted during migration are sometimes higher by an order of magnitude than data from existing studies (Leshem 1991).

In order to examine long-term regularity in major migrating species' appearance, the weighted average day of arrival was calculated for all the years of the study, as well as the date by which half of the population had passed over Israel, the average peak day and the average arrival percentage for each species on the peak day. The results show that it is possible to predict the appearance days of various raptor species with a precision of 1.35 to 3.12 days in autumn and 1.92 to 4.92 days in spring ($P < 0.001$). The arrival of storks can be predicted with a precision of 3.78 days in autumn and 5.46 days in spring. The rest of the data examined were found to be statistically significant, but for some the time span was broader. The conclusion reached was that it is possible to predict appearance times of the various species.

Comparison of arrival percentages on the peak day for a number of raptor species shows that the passage percentages in autumn for flocking species are greater than for non-flocking species (17.1%-30.1% and 9.0%-15.6% respectively). In spring, the difference between flocking and non-flocking species is even greater: 27.7%-46.0% and 8.3%-12.0% respectively. Intra-specific comparison shows that for many of the species the arrival percentage on the peak day is higher in spring than in autumn. This is probably the adult population, hurrying to return to its breeding grounds in spring, therefore moving in more concentrated waves. Thus an inverse relation between the arrival percentage on the peak day and age of sexual maturity is found: 46% of the Levant Sparrowhawk population, which reaches sexual maturity in its first year, passes over during the peak day compared to 17.7% of the Steppe Eagle population, which reaches sexual maturity at five

Table 1. Summary of Soaring Bird Migration Surveys. Autumn 1982-1990.

Species	Kfar Kassem - Cross Samaria						Northern Valleys		
	1982	1983	1984	1985	1986	1987	1988	1989	1990
<i>C. gallicus</i>	7142	7697	7399	7005	8045	7288	3008	2492	3819
<i>P. haliaetus</i>	48	50	49	61	79	39	52	66	78
<i>A. pomarina</i>	89239	141868	88210	108873	114446	81429	74198	56533	83701
<i>A. nipalensis</i>	296	234	368	411	265	456	224	156	214
<i>A. heliaca</i>	24	9	22	37	13	37	9	18	3
<i>A. clanga</i>	33	41	67	79	74	85	42	50	30
<i>H. pennatus</i>	1176	1267	1127	1498	1973	1304	622	842	811
<i>B. rufinus</i>	18	20	57	32	13	24	43	62	25
<i>B. vulpinus</i>	80	303	139	352	517	461	934	2166	1952
<i>B. buteo</i>	16	13	22	29	30	42	5	6	3
<i>P. apivorus</i>	319660	133621	380576	390612	419164	379672	347397	300972	437432
<i>M. migrans</i>	313	293	447	759	1051	1195	1063	1131	1734
<i>N. percnopterus</i>	301	242	265	474	346	301	124	284	161
<i>G. fulvus</i>	16	52	39	32	73	27	76	39	62
<i>C. aeruginosus</i>	398	476	587	801	1237	1236	751	1534	1516
<i>C. cyaneus</i>	6	6	17	21	21	15	4	1	9
<i>C. pygargus</i>	12	16	20	51	12	34	47	103	55
<i>C. macrourus</i>	21	32	46	57	23	33	12	46	26
<i>C. pyg/macro</i>	340	341	287	469	496	642	215	661	446
Unidentified	2923	2677	2916	3377	3418	1974	1584	2495	1429
<i>A. brevipes</i>	21983	25316	29255	37896	44653	28708	40560	41237	41722
<i>A. nisus</i>	385	513	813	592	1761	1317	620	11508	68
<i>F. peregrinus</i>	15	12	8	20	18	2	15	12	17
<i>F. eleonorae</i>	44	37	15	34	17	22	17	8	15
<i>F. subbuteo</i>	29	29	42	59	55	40		15	19
<i>F. vespertinus</i>	631	1097	1514	2820	5752	1833	2836	4942	4200
<i>Falco</i> sp.	168	197	355	305	294	460		52	200
Total	445317	316459	514662	556756	603846	508676	474458	417073	580617
Double Count/									
Eliminated	32378	62714	62207	111294	147440	123112		102818	
Double Count (%)	7.3%	19.8%	12.1%	22.1%	24.4%	21.9		%24.7%	

years of age. In non-flocking species the situation is similar, although in less concentrated waves.

The regularity of passage time period length was examined for each of the species migrating over Israel. Analysis of the data shows that those species flying over in large numbers tend to flock and pass over during the shortest time periods. Thus, 90% of the populations of the five species which flock in autumn pass over during 13-20 days, compared to five non-flocking species which pass over during 24-35 days. The only exception to this rule is the White Pelican *Pelecanus onocrotalus* whose passage time period is long (114 days in autumn), despite its being a true flocker. The reason seems to be that this species flocks during the breeding season as well, populating very broad breeding grounds (between 22-85° longitude), with each breeding colony reaching its nesting site as independent units. Accordingly we find that this is the only flocking species that has no peak days on which more than 10% of the population fly over, and whose weighted average day of arrival is the least statistically significant of all flocking species (12.39 days).

Despite all the above, in non-flocking species, which have a longer passage time period, the weighted average arrival day is very exact, within a span of 1.8 to 2.85 days only, in the four non-flocking species analysed in this study (Booted Eagle *Hieraaetus pennatus* Short-toed Eagle *Circus gallicus*, Egyptian Vulture *Neophron percnopterus* and Marsh Harrier *Circus*

Table 2. Summary of Soaring Bird Migration Surveys, Eilat, Spring 1977, 1983, 1985-1988.

	1977*	1983**	1985	1986	1987	1988
<i>A. chrysaetos</i>		9			7	
<i>A. nipalensis</i>	19288	23318	75073	22762	17443	10922
<i>A. heliaca</i>	95	25	61	35	47	12
<i>A. pomarina</i>		40	74	58	67	21
<i>A. clanga</i>		11	5	6	4	5
<i>B. vulpinus</i>	315767	109493	225460	465827	380441	429139
<i>B. rufinus</i>		34	105	47	29	28
<i>M. migrans</i>	26770	27039	28834	24728	313363	31774
<i>A. nisus</i>	155	468	138	76	102	52
<i>A. brevipes</i>	5958	2556	905	17034	49836	21380
<i>C. gallicus</i>	220	183	345	151	59	67
<i>H. pennatus</i>	175	147	140	109	105	150
<i>H. fasciatus</i>		4	6	1	5	2
<i>P. haliaetus</i>	122	87	49	64	96	73
<i>N. percnopterus</i>	802	252	541	385	308	263
<i>C. aeruginosus</i>	125	371	242	93	171	71
<i>C. macrourus</i>		52	113	17	88	11
<i>C. pygargus</i>		44	41	13	14	10
<i>P. apivorus</i>	225952	265775	851598	341777	293658	188914
<i>Accipiter</i> sp.	1360		144	42	143	
<i>Buteo/Milvus</i>	149264		6460		3775	
<i>Aquila</i> sp.	9083		1111	17	31	
<i>Falco</i> sp.	8601		83		146	63
<i>Gyps fulvus</i>		3	17		2	4
<i>A. gentilis</i>		1	3		1	
<i>Circus</i> sp.		160	58		30	
<i>F. eleonorae</i>		1	16		9	
<i>F. naumanni</i>		54	13		34	
<i>F. biarmicus</i>		1	7	2	3	
<i>F. peregrinus</i>			4		4	
<i>F. subbuteo</i>		35	20	54		
<i>F. cherrug</i>			2			
Unidentified			2138		203	
Total	763,737	474127	1,193,751	873,388	778,224	688,659

*1977 - Christensen *et al.* (1982)

**1983-1988 - Shirihi, H. (1987)

aeruginosus). These four species also arrive with a high time overlap in autumn and spring, and there is a possibility that what we see here is inter-specific flocking of non-flocking species (they were also observed migrating in common thermals).

The spring migration wave is longer than the autumn one in most birds of prey and storks. In many of the species passage time in spring is almost double that in autumn.

Flocking and non-flocking species passing over Israel were compared according to their wintering grounds and type of food. The data show that all nine flocking species overflying Israel migrate south of the Sahara and some of them reach South Africa. They feed at least partially on exothermic prey. Three of the four commoner non-flocking species: Booted Eagle, Egyptian Vulture and Short-toed Eagle also feed on heterothermic prey and migrate south of the Sahara. Only the Marsh Harrier is an "intermediary species", wintering both north and south of the Sahara, and

feeding accordingly on birds and mammals. A number of species feeding on endothermic prey do not flock and accordingly do not migrate south of the Sahara. This phenomenon is paralleled in New World raptors (Mindell 1985).

Comparison of the weighted arrival day of different species according to their chronological order of appearance in autumn shows distinct regularity in the order of arrival according to the type of prey they feed on - from insect eaters to reptiles, fish and finally mammal eaters. During spring migration the picture is reversed, and the first to pass are those feeding on endothermic prey and the last the insect eaters. This phenomenon shows the close relation and dependence between migration times and the availability of prey, whose activity varies with changes in weather, with exotherms disappearing first in autumn and returning first in spring.

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Spectacled Owl *Pulsatrix perspicillata*