INFLUENCE OF WEATHER CONDITIONS ON THE AUTUMN MIGRATION OF DUNLIN (*CALIDRIS ALPINA*) AT THE SOUTHERN BALTIC COAST*

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ABSTRACT

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Results of five seasons of counts of Dunlins resting at the Reda mouth (Gulf of Gdańsk, Poland) during autumn migration were compared with local weather conditions and synoptic situation along the southern coast of the Baltic to check Dunlin preferences to the weather in days of take-off to continue the passage. Leaving the Gulf of Gdańsk region Dunlins fly in three directions – along the southern coast of the Baltic towards the Atlantic coast, to the Mediterranean and to the Black Sea. The distribution of each of the 24 studied weather parameters were compared between days of Dunlins departures and stays by the chi-square test of independence. A statistically significant dependencies of birds take-offs were found to the 24-hour change in temperature in Świnoujście (see Fig. 1) ($p < 0.001$), wind sector ($p < 0.01$) and kind of air masses ($p < 0.05$) in juveniles and to the air pressure value ($p < 0.1$) in adults. In the case of adult birds also the 24-hour change in temperature in Gdańsk and Świnoujście was taken into account as possibly affecting their departures as the significance level was $0.05 < p < 0.1$. For the above weather parameters the significance of deviation of their distribution in days of take-offs from the distribution of the expected values was checked by the chi-square test and the direction of this deviation was determined. The obtained pattern of the relations of birds departures to weather conditions was analysed with respect to the probable synoptic situations over the study area favourable for the flight of groups of Dunlins to south-east, south-west and west and compared with the literature data. Generally, for the birds choosing the south-eastern flyway the most convenient situation is created by the western edge of the cyclone passing over the Gulf of Gdańsk. For the group flying to south-west the western part of the low or the eastern part of the high pressure system are the best conditions to depart and for Dunlins flying west from the Gulf of Gdańsk the most favourable situation occurs when the centre of the high is situated north to the stopover site or the centre of the low is localised south to it. Also unfavourable zones of the air pressure systems were defined on the basis of the existing publications and the results of the study. Such situation occurs when the "transition zone" between low and high pressure systems moves over the study area, and also when the site is under the influence of the north-western edge of the anticyclone or south-eastern part of the cyclone. Additionally, the old polar air masses over the study area are avoided by Dunlins while taking-off. The weather conditions on each day between the ringing and recapture for five short-term controls of Dunlins ringed at the Reda mouth and retrapped in Langerwerder (Gulf of Mecklemburg, Germany) were analysed regarding the above results. In cases of 4 out of these birds at least one day with the situation favourable for crossing the distance was found and in the last bird occurrence of the convenient weather was not so distinct. All the relation of Dunlins' departures to the weather found during the analysis are not so evident as in the existing literature data. This could be explained by mixing at the study area of three groups of birds heading in different directions. It is also possible that along parts of all three migration routes next to the Reda mouth Dunlins are not forced to take into account weather conditions when flying as good roosts can be found there in case of exhaustion or unfavourable weather conditions. The

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analyse of wind directions and speed in relation to each of the three migration directions of Dunlins from the studied region, according to the Alerstam's method (1978), showed that during the autumn season strong winds which would make Dunlins' departures impossible practically do not occur. This could explain the weak correspondence of Dunlins take-offs to the wind conditions, regarded by many authors as a decisive factor for birds migration.

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INTRODUCTION

It is generally known from many papers that weather conditions en route influence the timing of waders migration and its course (Alerstam 1978, 1990; Elkins 1983, Richardson 1978, 1990; Gautheraux 1991; Zalakevicius *et al.* 1995). Some papers on the relation between the migration and the weather conditions showed relations between numbers of migrating waders and convenient air pressure zones, air masses movements, wind speed and direction, and also visibility (cloud cover, rain) (Alerstam 1978, 1990; Elkins 1983; Richardson 1978, 1990). The assistance of tail wind and good visibility along some parts of the migrating route probably enable birds to reach the next resting place on their way (i.e. Piersma and van de Sant 1992).

Waders migrating in autumn from breeding grounds in Siberia and Scandinavia pass through the southern coast of the Baltic. Among them Dunlin is one of the most numerous species observed every autumn at the Gulf of Gdańsk, where it can find resting and feeding places. The term of adult birds passage at this region is mainly July and August while juvenile birds arrive in high numbers in mid-August and pass through till the end of October (Gromadzka 1983, 1987). On the basis of the results of many years of ringing carried out at the Vistula mouth (Gulf of Gdańsk, Poland) it is known that Dunlins leave this region heading in three directions. The majority of recoveries come from areas western to the Gulf of Gdańsk situated along the East Atlantic Coastal Flyway – these birds will be called "W group" in the paper. The next resting site after the Gulf of Gdańsk on this route seems to be the region of the Gulf of Mecklemburg (Germany). Some birds fly also over the mainland to the Mediterranean (SW group) and to the Black Sea (SE group), although recoveries from these two ways are less numerous (Gromadzka 1987).

The aim of the study was to find the relation between the weather conditions and take-off of Dunlins from the region of Gulf of Gdańsk to continue their autumn migration.

METHODS

The study was carried out in the Reda mouth, the Gulf of Gdańsk, Poland (Fig. 1). The research area is a 3 km long section of a sandy beach and includes also the electric power station ashes dumping place situated near the coast. The Reda mouth is one of two main resting places of Dunlins (the other one is the Vistula mouth) and other waders

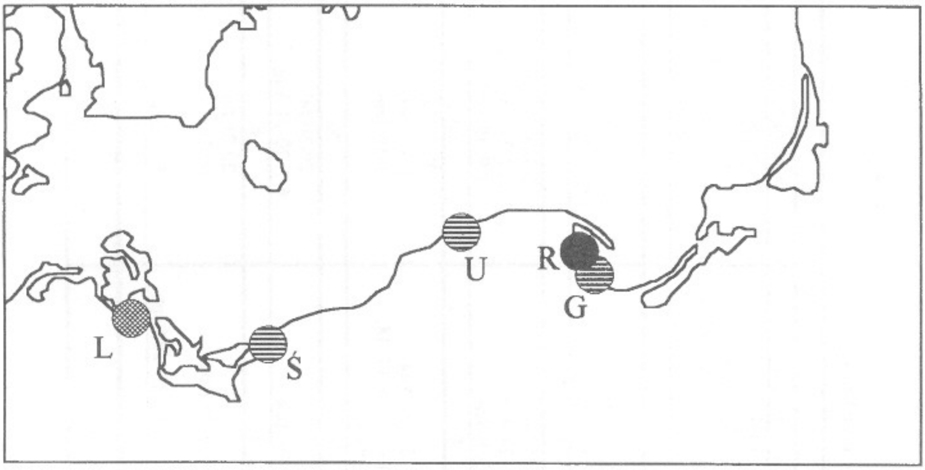

Fig. 1. Southern Baltic coast with the study area (solid circle), meteorological stations (lined circles) and the site from where the analysed short-term controls come (hatched circle) marked. R – Reda mouth, G – Gdańsk, U – Ustka, S – Świnoujście, L – Langerwerder.

migrating through the Gulf of Gdańsk in autumn. Research on the autumn migration of waders at this site has been carried out since 1983 by Waterbird Research Group KULING (Brewka *et al.* 1987). Material used in the study was collected by KULING in years 1988-1993. Three times a day between 15 June and 30 September Dunlins observed at the site were counted and aged according to the plumage. The daily maximal count was taken to further study. Both age categories – adults and juveniles were analysed separately. Day to day percent changes of birds number was calculated. Only days with at least 10 individuals of a given age category were considered as days of Dunlins' presence at the study area (Table 1). This allowed to eliminate the possible influence of natural breaks between migration waves (which can last up till 17 days) on the results. Out of this period days with the decrease not less than 10% of Dunlins number of a given age category observed the previous day were considered as expected dates of leaving the site by birds. There were 105 such days for adults and 59 for juveniles in all seasons (Table 1).The remaining days of the period of Dunlins presence at the area were treated as days when birds stayed at the roost.

For all days of Dunlins presence at the area plus the days directly following each case of their departure weather conditions were checked. Meteorological data were taken from Daily Meteorological Bulletin published by Polish Meteorology and Water Management Institute (IMGW). First group of parameters as:

– general wind direction sector according to air pressure systems,

– air pressure,

Table 1

Dates of take-offs and standard periods for adult and juvenile Dunlins in studied seasons

Year	AD		JUV	
	Dates of take-offs	Standard period	Dates of take-offs	Standard period
1988	20, 22, 27, 29, 31 Jul. 3, 10, 12, 13, 15, 18, 20, 21, 23, 25, 26 Aug. 1, 11, 18 Sept.	18-22, 25-31 Jul. 1-26 Aug. 1, 10-11, 17-18 Sept.	25 Jul. 7, 16, 19, 22, 27, 30 Aug. 5, 6, 7, 8, 11, 12, 17, 18, 19, 29 Sept.	20-25 Jul. 6-7, 12, 16-30 Aug. 1-8, 10-12, 14-15, 17-19, 27-30 Sept.
Number of days	19	42	17	44
1989	18, 19, 24, 25, 28, 31 Jul. 1, 4, 6, 12, 13, 16, 19, 22, 28 Aug.	15-19, 21-26, 28-31 Jul. 1-22, 26-27 Aug.	22, 23, 29 Aug. 18, 30 Sept.	6-7, 22-29 Aug. 14-20, 24-30 Sept.
Number of days	15	39	5	23
1990	16, 18, 23, 24 Jul. 16, 22 Aug.	15-25, 28, 30-31 Jul. 15-16, 21-23 Aug.	21 Jul. 16, 24 Aug. 2, 3, 9 Sept.	21-25, 28 Jul 15-16, 21-24, 28-31 Aug. 1-9, 19 Sept.
Number of days	6	13	6	26
1991	17, 18, 19, 25, 27, 28, 29,31 Jul. 3, 10, 15, 18, 20, 22, 23, 28, 30 Aug. 1, 2, 4, 7, 9, 11, 12, 13, 14, 19, 21, 24 Sept.	15-31 Jul. 1-3, 9-10, 13-31 Aug. 1-21, 23-24 Sept.	12, 25, 26, 28 Aug. 2, 3, 4, 7, 10, 11, 14, 17, 18, 20, 24 Sept.	20-21 Jul. 12-31 Aug. 1-30 Sept.
Number of days	6	13	6	26
1992	16, 18, 26, 27, 30 Jul. 1, 2, 4, 6, 10, 16, 19 Aug.	15-18, 23-31 Jul. 1-6, 9-10, 15-20 Aug.	7, 20 Aug.	29-30 Jul. 6-7, 20-21 Aug.
Number of days	12	27	2	6
1993	17, 19, 20, 21, 22, 23, 26, 28, 31 Jul. 3, 7, 9, 14, 15, 17, 22, 26, 29 Aug. 3, 4, 10, 18, 28, 29 Sept.	15-31 Jul. 1-3, 6-9, 12-17, 21-23, 25-31 Aug. 9-10, 14-18, 27-29 Sept.	21 Jul. 17, 19, 20, 26 Aug. 1, 5, 7, 10, 13, 21, 25, 27, 29 Sept.	20-21 Jul. 14-31 Aug. 1-30 Sept.
Number of days	24	54	14	19
Total number of days	**105**	**208**	**59**	**138**

– atmospheric front,

– kind of coming air masses,

were read from maps of synoptic situation at 02.00 h of local time (01.00 h GMT) for the southern coast of the Baltic between the Gulf of Gdańsk and the Gulf of Mecklemburg. In the case of such weather conditions like:

– wind direction,

– wind speed,

– cloud cover,

– atmospheric phenomena (e.g. fog, rain, storm),

– air temperature,

daily measurements from 08.00 h (07.00 h GMT) taken at three meteorological stations (Gdańsk, Ustka, Świnoujście) situated on the Polish Baltic coast (Fig. 1) were used. 24-hour change in barometric pressure and in local air temperature were calculated from the respective data taken from the Meteorological Bulletin. Generally, 24 meteorological parameters were used for the analyses.

Distribution of each weather variable in days of take-off and days when birds stayed at the roost were compared by the chi-square test of independence considering Yates correction when necessary. In cases of the statistically significant dependence of birds take-off on a given weather factor, the significance of the deviation of the number of days when birds stayed and took-off from the expected value was also tested by the chi-square test. The expected value was calculated according to the standard procedure of the chi-square test.

In addition, wind speed and direction were compared with Alerstam's model (1978) showing the combined effect of wind speed and direction on the possibility of the birds flight. Wind direction was calculated according to Alerstam's method in relation to each of three migration directions of Dunlins departures from the studied part of the Baltic coast.

Five short-term controls (within five days from the date of ringing) of Dunlins ringed at the Reda mouth and retraped in Langerwerder (Gulf of Mecklemburg, Germany) were also used. Weather conditions on all days between ringing and recapture of these birds were treated separately.

RESULTS AND DISCUSSION

Results of the chi-square tests are shown in Table 2. As it can be seen from there, only a few weather parameters seemed to have influence on Dunlins' take-off and taking into account each weather variable the pattern of correlations looks complicated.

Richardson (1978) presented general synoptic situations favourable for birds migration. He also suggested that birds directly respond mainly to the favourable winds connected with the air pressure systems and that dependence of birds take-off upon other weather factors is rather the effect of the occurrence of given weather conditions within the specified synoptic situation favourable for the passage.

Groups of Dunlins following each of the three flyways would prefer different conditions for the departure from the Gulf of Gdańsk region. Distribution of these weather variables on which Dunlins' take-offs were dependent and the significance level are presented in Table 3. The table includes also cases when p was higher than usually accepted level, but lower than 0.1 (Table 2). These weather parameters can be grouped according to the occurrence within the favourable and unfavourable synoptic situation for one of the three migratory groups of Dunlins.

Table 2

Results of the chi-square test of distribution of weather variables in days of Dunlin's take-offs and stays at Reda mouth (italic – $p < 0.1$, * – $p < 0.05$, ** – $p < 0.01$, *** – $p < 0.001$)

Age class	AD				JUV			
Meteorological parameter	*d.f*	*p*			*d.f*	*p*		
Wind sector	5	0.2198			5	0.0020**		
Air pressure	2	0.0310*			2	0.1427		
24-change in air pressure	5	*0.0836*			5	0.5451		
Front	3	0.9643			3	0.6752		
Kind of air masses	5	0.7093			3	0.0482*		
Atm. phenomena	1	0.3315			1	0.1688		
Meteorological stations		Gdańsk	Ustka	Świnoujście		Gdańsk	Ustka	Świnoujście
Wind direction	5	0.4375	0.2130	0.9303	6	0.6153	0.8926	0.1895
Wind speed	6	0.2311	0.1198	0.7547	6	0.5380	0.9737	0.1875
Cloud cover	4	0.1021	0.3767	0.6123	4	0.8636	0.2009	0.8736
Local atm. phenomena	1	0.5863	1.0000	1.0000	1	0.8356	0.1921	0.6340
Temperature	8	0.6498	0.7435	0.7722	8	0.3264	0.3380	0.4790
24-hour change in temp.	7	0.1488	0.1612	*0.0559*	7	0.8462	0.6784	0.0004***
24-hour change in temp.- grouped	3	*0.0752*	0.9746	0.1378	3	0.4380	0.6926	0.0002***

SE group

The most convenient pattern of air pressure systems for this group of birds is marked at Figure 2. According to Richardson (1978) and Elkins (1983) birds flying in this direction moved at the western edge of the low pressure system (cyclone), shortly after passage of the cold front when the high (anticyclone) came towards the stopover site. Such a situation is in autumn often connected with occurrence of polar-sea air masses coming from north-west. These air masses are usually relatively cold and wet so the air temperature decreases. This would be the case of the dependence of Dunlins take-off to the fresh polar-sea air masses occurrence over the study area and to 24-hour temperature fall in points situated along the coast (Table 3). Described weather situation occurs firstly in Świnoujście as the high approaches from north-west. This could explain the dependence of take-offs of young

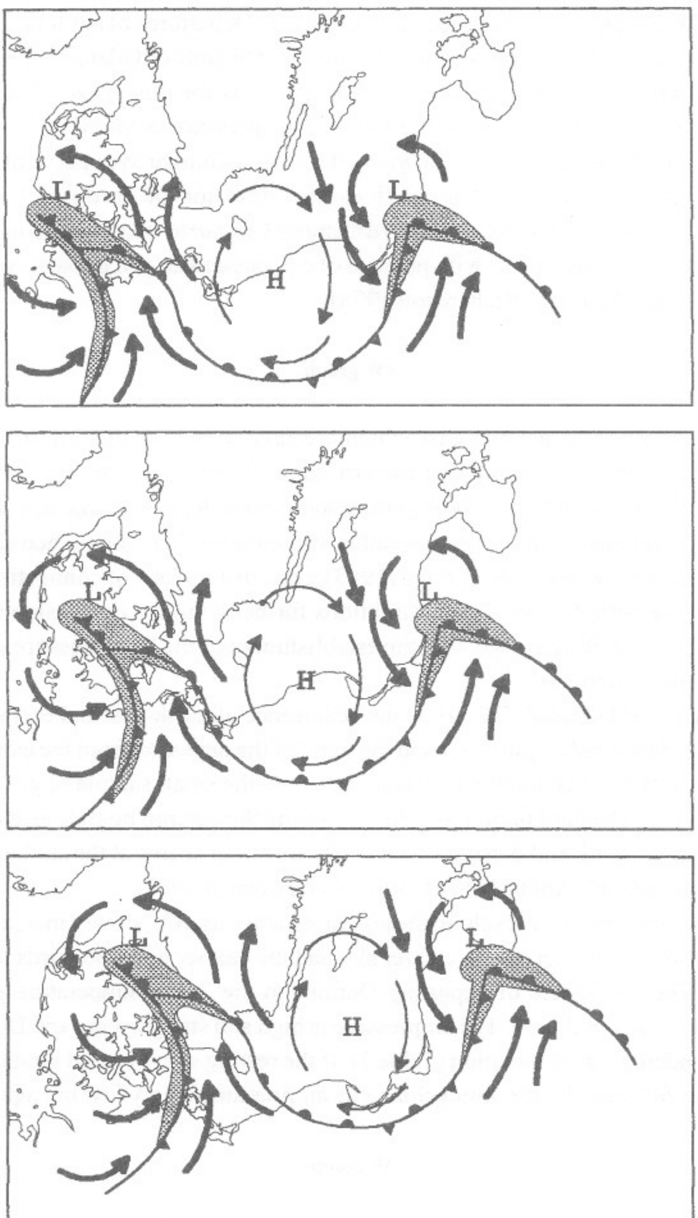

Fig. 2. Synoptic situations favourable for autumn migration of groups of Dunlins from the Gulf of Gdańsk region: SE group – top figure, SW group – middle figure, W group – bottom figure L, H – centres of low and high; thick arrows – strong winds, thin arrows – moderate winds; semi – cirdes mark warm front, triangles – cold front, both signs – occluded front. (after Richardson 1978, changed).

birds upon the 24-hour air temperature changes there. Departures of adult birds are dependent on to the same temperature change, but only in the Gulf of Gdańsk region (Table 3). The general wind sector is north-west giving tailwinds for this group of birds. As this situation is localised at the edge of the low, the air pressure is low but growing, which correspond to Dunlins preferences shown by the results. Similar synoptic situation is connected with intensive migration in south-eastern direction of northeast Canadian and Greenland Knots (*Calidris canutus*) and Turnstones (*Arenaria interpres*) to north-western Europe (Elkins 1983) as well as with passage of e.g. passerines and geese in south-eastern direction in North America (Richardson 1978).

SW group

Wind sectors north-east and east which are favourable for this group occur at the western edge of the low or/and the eastern edge of the high pressure zone (Fig. 2). Richardson (1978) stated that birds migrating south-west departed some time after groups flying south-east because the optimal weather situation for them took place usually a day after north-westerly winds. Also Elkins (1983) gave an evidence of connection of migration in south-western direction with conditions further behind a depression and even of the closer relation of the passage with the establishment of the high pressure system after cold front than with the low.

Dependence of Dunlins' take-off on the occurrence of north-east and east winds in the study was not statistically significant and the trend of the deviation from the expected value was rather negative. This could have been caused by the small sample (e.g. 15 days with such winds within standard period for adults). During the autumn migration and especially later in the season north and north-eastern winds are rather scarce at the studied part of the Baltic coast giving only about 11% of all winds (Kwiecień 1987).

At the eastern part of anticyclone the air temperature usually slowly increases because the high pressure system gives the clearer sky and the calmer winds towards the centre of the system. The preference of departing Dunlins to the 2-3°C temperature growth was shown by the results (Table 3). The air pressure is high and still growing and Dunlins' take-offs are dependent on such situation (Table 3). If the resting site is placed west to the centre of the low not followed by the anticyclone, the air pressure is very low but again growing.

W group

Weather conditions favourable for this group are created by the centre of the high situated north and/or center of the low south to the stopover site (Fig. 2). In such a situation the sectors of wind direction are from east to south-east. Similarly as for the SW group, there was no statistically significant preference of these wind sectors showed by Dunlins, for the reasons explained earlier. The air temperature at the stopover site in the case of the cyclone placed north to the locality is rather high but falling. When the edge of the anticyclone is situated southerly to the site the temperature there is low but slowly increasing, which would agree with the results shown in Table 2.

Table 3

Distributions of weather variables correlated with Dunlins take-offs. *P* – result of chi-square test of weather variables distributions in days of take-offs and stays; tr – trend of the deviation from the expected value; *p* - significance of deviation from the expected value (italic – $p < 0.1$; * – $p < 0.05$; ** – $p < 0.01$; *** – $p < 0.001$); AOAM – arctic old air masses, PSAM – polar-sea air masses, PSWAM – polar-sea warm air masses, PSOAM – polar – sea old air masses.

Age class	AD				JUV			
Parameter	*P*	class	tr	*p*	*P*	class	tr	*p*
24-hour trend in temperature – Świnoujście (°C)	*0.0559*	<–2	–	0.2070	0.0004***	<–2	+	0.4541
		–2	+	*0.0586*		–2	+	0.0247*
		–1	–	0.0475*		–1	–	*0.0807*
		0	+	0.8332		0	–	0.2310
		1	+	0.9381		1	–	0.0972
		2	+	0.2070		2	+	*0.0528*
		3	+	0.1986		3	+	0.0222*
		>3	–	0.2577		>3	–	0.0490*
24-hour trend in temperature – grouped	*0.0752*	<–1	–	0.2390	0.0002***	<–1	+	0.0342*
		–1, 0, 1	+	0.8909		–1, 0, 1	+	0.0076*
AD – in Gdańsk		2, 3	+	0.0440*		2, 3	–	0.0020**
JUV – in Świnoujście		>3	–	0.2570		>3	–	0.0490**
Air pressure (hPa)	0.0310*	992.5-997.5	+	0.0062*				
		1002.5-1012.5	–	0.0491*				
		1017.5-1032.5	+	0.8403				
24-change in air pressure (°C)	*0.0836*	–15	+	0.3948				
		–10	+	0.6625				
		–5	+	0.6029				
		0	–	0.1928				
		5	+	0.0258*				
		>5	–	0.1693				
Wind sector					0.0020**	E, NE	+	0.4420
						N	-	0.0414*
						NW	+	0.0134*
						W, SW	–	0.0142*
						S	+	0.1713
						SE	–	0.7324
Kind of air masses					0.0482*	AOAM	+	0.8345
						PSAM	+	*0.0778*
						PSWAM	–	0.5449
						PSOAM	–	0.0350*

For the short-term controls of birds recovered west to the study area the set of weather variables on which Dunlins' take-offs are dependent and additionally local wind directions are presented in Table 4. The synoptic situations described above as favourable for the migration of the W group can be identified within days of passage of individuals shown in

Table 4. As the distance between the Reda mouth and Langerwerder (about 450 km) can be crossed by Dunlin in 7-8 hours, only one night with a favourable weather conditions would be enough for the bird to complete it.

Table 4

Weather conditions for the short-term controls of Dunlins ringed at Reda mouth and retraped in Langerwerder (Mecklemburg Bay, Germany) for each day between ringing and recapture. 1 – wind directions sector, 2 – air pressure (hPa), 3 – 24-hour air pressure change (hPa), 4 – kind of coming air masses (POAM – polar old air masses, PSWAM – polar-sea warm air masses, AOAM – arctic old air masses), 5 – wind direction in Gdańsk, 6 – 24-hour temperature change in Gdańsk (°C), 7 – 24-hour temperature change in Świnoujście (°C)

No.	Age	Date	1	2	3	4	5	6	7
1	AD	05.08.89	NW	1002.5	0		SW	–1	–1
		06.08.89	W	1007.5	5	POAM	SW	1	1
		07.08.89	NW	1007.5	0		SW	1	0
		08.08.89	SW	1012.5	5		NW	0	4
2	JUV	08.09.89	W	1022.5	0		–	–6	–2
		09.09.89	SE	1017.5	–5	PSWAM	–	1	2
		10.09.89	E	1017.5	0	PSWAM	NE	6	3
3	JUV	18.09.89	SW	1012.5	0	PSWAM	SW	3	0
		19.09.89	SW	1022.5	10		–	–2	1
		20.09.89	NW	1017.5	–5		W	4	–1
4	JUV	24.08.90	SE	1022.5	5		W	–2	–4
		25.08.90	W	1017.5	–5		–	–1	2
		26.08.90	NW	1012.5	–5	PSWAM	NW	4	1
5	JUV	08.09.91	NW	1017.5	5	AOAM	W	–1	–2
		09.09.81	NW	1017.5	0		W	6	2
		10.09.81	W	1017.5	0		SW	–1	1
		11.09.81	W	1012.5	–5	PSWAM	–	–1	–1
		12.09.81	NW	1007.5	–5		NW	–1	–4

For two of the five individuals shown in Table 4 (no. 2, 4) easterly wind sectors occurred during the probable time of the birds flight. For the remaining Dunlins western wind sectors were dominating but winds were probably very calm at least in two cases (no. 3, 5), when locally in Gdańsk the still was noted. For Dunlin no. 2 together with easterly wind sectors at the second and the third day high but falling air pressure was noted. The air temperature in Świnoujście was raising by 2-3°C probably because of coming polar-sea warm air masses. Similar conditions can be seen for bird no. 4 on the first and the second day. Such conditions would be characteristic for the high pressure system situated north to the Reda mouth and the passage route. In the case of the individual no. 5 the weather pattern is not so clear and this is probably caused by the old arctic air masses and centre of the high stagnating over the study area. As all the time western and north-western headwinds blew, the bird could take-off at the first as well as at the last days of the period between ringing and control, not waiting for the favourable winds. However, the occurrence of polar-sea warm air masses and local still on the fourth day may be worth noting as the potential better conditions for flight.

For the only adult bird shown in the Table 4 the preferences were also not so well pronounced. The synoptic situation was created by old polar air masses slowly moving west. This can be considered as unfavourable conditions for Dunlins departures according to the results shown in Table 3. The winds were generally western and south-western – unfavourable for the migration. Also other weather conditions showed values generally avoided by Dunlins during take-offs. However, birds have a limited time for the migration and they cannot wait for the favourable weather for a long period of time so if the lasting inconvenient situation does not make the flight impossible at all, they fly under suboptimal conditions (Elkins 1983).

The evidence in literature of the passage in western direction was not found, probably because this direction does not occur in western Europe and North America. Passage in western direction of the group of Dunlins following the East Atlantic Coastal Flyway is affected by the latitudinal course of the studied part of southern Baltic coast.

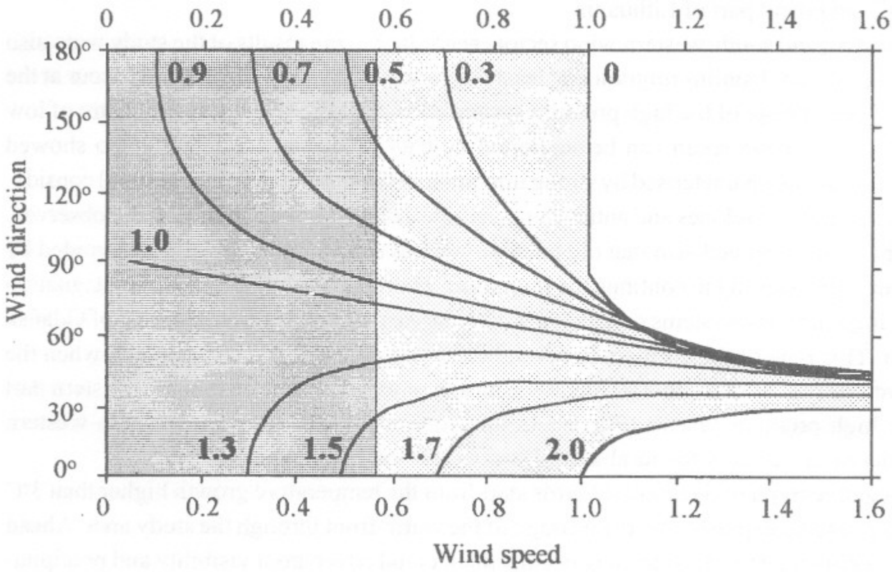

Fig. 3. Comparison of the Alerstam's model of bird ground speed in relation to wind direction and speed with the wind conditions met by Dunlin in the Gulf of Gdańsk region. Wind direction is presented in relation to birds migration direction – 0° corresponds to the tailwinds and 180° to headwinds. Wind speed is expressed as the ratio of the birds air speed. Whole dotted area marks the wind directions and speeds where birds flight is possible. Densely dotted area show the field corresponding to wind speed and directions met by Dunlins at the Gulf of Gdańsk. (After Alerstam 1978, changed).

Weather conditions unfavourable for the migration

Opposite to the positive influence of good weather on the intensity of birds migration the unfavourable synoptic situation can be the reason that birds remain at the staging site (Elkins 1983). From the results shown in Table 3 for some weather conditions negative trends of deviation from the expected values of bird numbers can be seen. These conditions can be grouped by their occurrence within specific air pressure systems positioned over southern Baltic coast showing the weather situation avoided by Dunlins taking-off from the Reda mouth.

Among weather conditions convenient for birds flying to south-east and to south-west a short period of unfavourable situation for Dunlins migration occur. In this "transition zone" between low and high pressure system (see Fig. 2) or two low pressure systems the air pressure is medium (1002.5 hPa – 1012.5 hPa) and the wind sector changes to north. In days of such weather conditions the number of days when Dunlins departed from the Reda mouth was significantly lower then expected (Table 3). The above zone was also shown as characterised by lack of the migration as in the results of Zalakevicius *et al.* (1995) for the coastal and inland part of Lithuania.

Western and south-western wind sectors according to the results of the study were also unfavourable for Dunlins migration at least for young individuals. Such winds occur at the north-western edge of the high pressure system or/and south-westerly to the centre of low (Fig. 2). The above result can be supported by data of Richardson (1978) who showed these areas as not characterised by strong migration. Also Zalakevicius *et al.* (1995) considered these parts of cyclones and anticyclones as zones of a weak migration activity observed.

The results showed also that old polar air masses over the study area were avoided by Dunlins while starting to continue the migration. This could be explained by the stagnation of the high pressure systems connected with polar-sea air masses over the Gulf of Gdańsk region. This type of the air mass in several days turns to polar old air mass and when the anticyclone moves to south-east, the Reda mouth remains in western to north-western part of the high pressure system (Fig. 2). In this zone winds are southern to south-western considered earlier as unfavourable for Dunlins take-off.

Negative trend of deviation of birds start from the temperature growth higher than 3°C (Table 3) can be explained by the passage of the warm front through the study area. Ahead of and within the frontal zone there occur a thick cloud cover, poor visibility and precipitation. Winds are strong, south-eastern to southern. These sectors did not influence Dunlins take-off or stay, but as warm front moves east the winds soon change to south-western which were avoided by young birds (Table 3).

General comments

The pattern of convenient and inconvenient weather conditions shown by the study generally agrees with the literature data (cf. cited above). However, the statistical significance of wind vectors influence, shown only by young birds and not to all sectors, extremely high significance in case of the air temperature changes both locally and west to the stopover site as well as lack of the dependence of Dunlins' take-off upon such weather variables as e.g. wind speed, passage of the front, cloudiness and precipitation of the front, needs a comment.

Elkins (1983) stated that generally waders migration is more difficult to correlate with the weather because of their strong, fast and often long-distance flight. This could be the reason of generally weak or lack of dependence of Dunlins' departures on the weather conditions shown by many authors as strongly related to birds migration.

Wind is the weather factor considered by many authors (i.e. Alerstam 1978, 1990; Elkins 1983; Richardson 1978, 1990; Gautheraux 1991; Piersma and van de Sant 1992; Zalakevicius *et al.* 1995) as a decisive one for birds migration. In the study the statistically significant dependence of the start for the migration to wind sector was shown only by young birds and there was no connection shown to four wind sectors of which north-eastern and eastern are considered as especially convenient for the SW group migration (Richardson 1978; Elkins 1983). There was also no dependence upon local winds at the starting place as well as along the route of the W group flying along the southern Baltic coast. According to Elkins (1983) more intensive migration of waders was observed in the same optimal conditions as for other groups of birds but waders seem to be less prone to adverse wind drift than others. This could explain the weak dependence of this factor on the take-offs shown by study related to a certain wader species in comparison with the results of studies on the other groups of birds.

Another reason of this weak correlation can be the fact that the three groups of Dunlins rest at the Gulf of Gdańsk region in the same period of time and are mixed. This could cause the difficulties in obtaining the clear pattern of relations from statistic tests as each group prefers different starting conditions. The particular dates of arrivals and departures of each group were impossible to define because they are indistinguishable by biometrics or moulting stage (Gromadzka 1989) and number of recoveries from south-west and south-east were very low. Finally the weather conditions favourable for each group replace each other very quickly, especially in the case of optimal situation for SW and SE groups migration. In the cases of very quickly moving air pressure systems the connections of birds take-off and the weather changes could have been omitted to some extent. This could be the effect of the time span between the probable hour of birds start and the time of weather measurements control which could have been longer than the time of the air pressure zones passage over the study area. This time difference in the case of measurements taken at local meteorological stations could reach 15 hours.

The lack of the connection between some weather variables, especially of some wind sectors, and Dunlins take-off, could also be explained by a hypothesis that along the studied part of the migration route Dunlins do not have to take the advantage of a good weather to reach the next resting place on their way. Birds flying along the Baltic coast have to cioss the distance of ca. 450 km to reach the Gulf of Mecklemburg. The closest to the Reda mouth records from SW and SE flyways come from distances of ca. 670 km (Mediterranean direction) and ca. 680 km (Black Sea route) (KULING, unpubl. data). Such distances can be covered by Dunlins migrating with the average flight speed of 65km/h in 7.5-10.5 hours so it could be done in one "jump". All three ways of migration from the Gulf of Gdańsk are "safe" in case of facing unfavourable weather conditions. Birds can find good resting places along each of them. Also the risk of being drifted by wind towards the open sea is minimal in the studied region. The idea that Dunlins do not have to reduce the energetic cost of flight by choosing favourable weather while leaving the Gulf of Gdańsk is suggested by the results of Meissner (1993). This study showed that birds caught at the Reda mouth were fat enough to fly directly to Langerwerder even without resting in the investigated area.

Because of the vast evidence of influence of the wind conditions on birds migration cited above, a special attention was given to a connection of wind speed and direction and Dunlins' departures in each of the three directions. The comparison of Dunlins air speed, being the bird ground speed corrected by the effect of every possible combination of wind directions and wind speeds noted at the meteorological stations on birds flight ability in each of possible flyways, with Alerstam's model (1978) was made. The results showed that on the coast of the Gulf of Gdańsk during the studied seasons Dunlins did not meet wind conditions which would make the flight in any of the three main migration directions impossible (Fig. 3).

The passage of atmospheric fronts was also not related to Dunlins' start to continue the passage. Some authors (i.e. Richardson 1978, Elkins 1983, Alerstam 1990) stated that birds flying to south-east started just after passage of the cold front because the wind direction was favourable then, and avoided starting before and just after warm front had crossed. The connection of Dunlins' start with the passage of the front was probably not shown by the study for methodological reasons. For each day only the fronts actually remaining over the southern coast of the Baltic were noted, so the fronts which have just passed this area were omitted.

In the study the impact of atmospheric phenomena such as storm, fog and precipitation and also of cloudiness on Dunlins take-off was not shown. All these factors are considered by different authors (Elkins 1983, Alerstam 1990) as influencing birds orientation. However, Elkins (1983) gave examples of regular migration of passerine birds in the fog and of waders during heavy rains. At the study area the negative influence of the above factors could also be compensated by the effect of the leading line helping to orientate (Elkins 1983) – Dunlins flying west follow the Baltic coastline and the SE group can probably fly along the Vistula river valley.

Differences in adult and young Dunlins' preferences

The pattern of dependencies of take-offs upon weather parameters differ between both age categories. As it can be seen from Table 2 adult birds react on air pressure and also the correspondence of their departures with 24-hour trend in air pressure can be suspected. This kind of reaction was not found in juvenile Dunlins. Departures of young birds were significantly connected with the kind of coming air masses. The above differences between age categories could be explained by the change in dominating types of atmospheric circulation along the southern Baltic coast between periods of migration of adult and young Dunlins through this region. In July/early August when adult birds stay in the Gulf of Gdańsk region (Gromadzka 1987) cyclonal circulation is more frequent than later in the season (Kwiecień 1987). As the western part of the cyclone provides good migration conditions for both SE and SW group (see above) the correlation of the departures with low air pressure occurred in adult birds. In the second half of August and in September when high pressure systems dominate, but cyclones are still frequent, the dependence on the air pressure values was probably more difficult to show by statistic tests. Favourable flight conditions for SE and SW groups are also connected with coming polar-sea air masses occurring behind a cyclone and creating cold front. Such situation is more frequent in late August/ September than earlier and this could cause the occurrence of connection of young birds departures with this weather parameter despite not finding it for adult birds. Also the dependence and negative trend of deviation from the expected values of take-offs of youngs on old polar sea air masses can be explained by more frequent occurrence of high pressure systems during their migration through the Gulf of Gdańsk than during the period of adults' passage. When polar – sea air masses stagnate over the area they turn to polar – sea old air masses and the high is filling out and move to south east. Such situation giving south-western to southern winds is unfavourable for Dunlins migration.

Young birds are generally more prone to the weather conditions during migration than adult birds (Elkins 1983). This could explain the connection of their take-off with wind sector not found for adult Dunlins. It is possible that adult birds which know the migratory route and recognise the landmarks due to the experience of previous passages can compensate the possible wind drift while juveniles must be more "careful" choosing the conditions for flight.

Similar pattern of deviation from expected values in the case of 24-hour change in air temperature in Świnoujście was shown by both age categories with much higher level of statistical significance of this relation for young birds then for adults (Table 3). Also preferences to a given temperature change intervals are better pronounced in young Dunlins. Taking into account grouped trends in air temperature the reaction of adult birds could be presumed only to local conditions in Gdańsk region, while youngs' take-offs are strongly connected with changes of temperature in Świnoujście – about 350 km to the west from the resting area. Naturally, they rather don't react directly to the 24-hour temperature amplitudes in Świnoujście, but trends in temperature there can be connected with change of synoptic situation approaching the Gulf of Gdańsk region from the west. Young birds as more sensitive could react stronger to such changes than adult Dunlins. However, there is very little literature evidence of differences between young and adult birds' reaction to weather so that the above explanations are rather presumptions than statements.

The results presented above show only some aspects of relation of Dunlins migration to the weather. Further investigations based on short-term controls of ringed birds could shade more light on the pattern of dependence of birds migration on weather condition. It would especially allow to expose and make more clear the differences of adult and young birds sensitivity to the weather parameters during the passage.

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