SPRINGTIME MOVEMENTS OF TRANSIENT NOCTURNALLY MIGRATING LANDBIRDS IN THE GULF COASTAL BEND REGION OF TEXAS

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Studies of bird migration on the coast of the Gulf of Mexico are important because they provide information about the influence of the Gulf on the patterns of migration. Because of the complex nature of the over-all problem, the findings at different localities around the Gulf contribute uniquely to an understanding of the whole situation. The total picture of migration in the Gulf region will be understood fully only after many Gulf areas in diverse geographical locations are thoroughly investigated at different seasons. The main purpose of the present investigation, conducted in 1963 and 1964, was to determine the character of the nocturnal spring migration of transient landbirds in the Coastal Bend region of south Texas near Corpus Christi.

Although a local study of this type primarily can provide information only about spring migration in the specific locality concerned, the findings can enjoy wider ramifications through an appraisal of the unique geographical position of the study area. The Coastal Bend area is crucial in that the western shoreline of the Gulf of Mexico bends from a north-south orientation south of Corpus Christi to a northeast orientation north of that city. The area is ideally situated for determining the existence and extent of the overland and circum-Gulf spring migration believed by Williams (1945, 1947, 1950a, b, 1952) to occur over the western perimeter of the Gulf of Mexico. Also, an appreciation of the influence of the shoreline on the direction of migration could result from the findings in this region where the trend of the coastline changes direction. Conversely, the study area is not well situated for documenting the existence of the massive overwater or trans-Gulf spring migrations postulated by Cooke (1888, 1915), Lowery (1945, 1946, 1951), Lowery and Newman (1966), and Gauthreaux (1965). Yet such a proposed massive movement of birds northward across the Gulf might be discernible to some extent in the Corpus Christi area.

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The term overland migration is used in the present study to denote migration over land or along the shore of the Coastal Bend region of Texas and does not imply that the migrants followed a similar path throughout their northward journey from points south, as the term circum-Gulf implies. That is, it does not preclude the possibility that some of the birds observed flying over land and along the coast were migrants that previously had arrived from overwater routes south of the study area and then turned northeastward after arrival over land. The term overwater migration refers to those migrants that arrived in the Coastal Bend region from the direction of the open Gulf and does not imply that the flight northward was entirely over water.

METHODS

Bird movements were studied in March, April, and May of the two years by periodically counting populations of grounded migrants on the coast and inland, by observing through a telescope the passage of birds seen against the lunar disc, and by making telescopic observations of the passage of migrants seen at the zenith by day. Also, grounded migrants were collected and their general condition determined by appraising fat deposits. Species of transient landbirds were regularly counted in three 20-acre census areas (fig. 1). The Nueces Area was located 17 mi. W of Corpus Christi Bay along the Nueces River, approximately 1 mi. W of Calallen, Nueces County, Texas. The Welder Area was located along the Aransas River on the Welder Wildlife Refuge, approximately 8 mi. NE of Sinton, San Patricio County, Texas. The conspicuous vegetation of both of these areas was hackberry (*Celtis laevigata* and *C. reticulata*), cedar elm (*Ulmus crassifolia*), green ash (*Fraxinus pennsylvania*), and mesquite (*Prosopis glandulosa*). The Rockport Area consisted of two 10-acre plots. One plot was located along Highway 881 1 mi. W of Rockport, Aransas County, Texas. This area was bordered on the north by a small wet weather lake and the vegetation was comprised mostly of live oak (*Quercus virginiana*) interspersed with mesquite (*Prosopis glandulosa*) and huisache (*Acacia farnesiana*). The other plot was situated 1 mi. N of Rockport along Highway 35. It was predominantly live oak with some mesquite.

The species counted in the census areas and those collected for lipid analysis were transient landbirds that typically winter in México, Central America, and

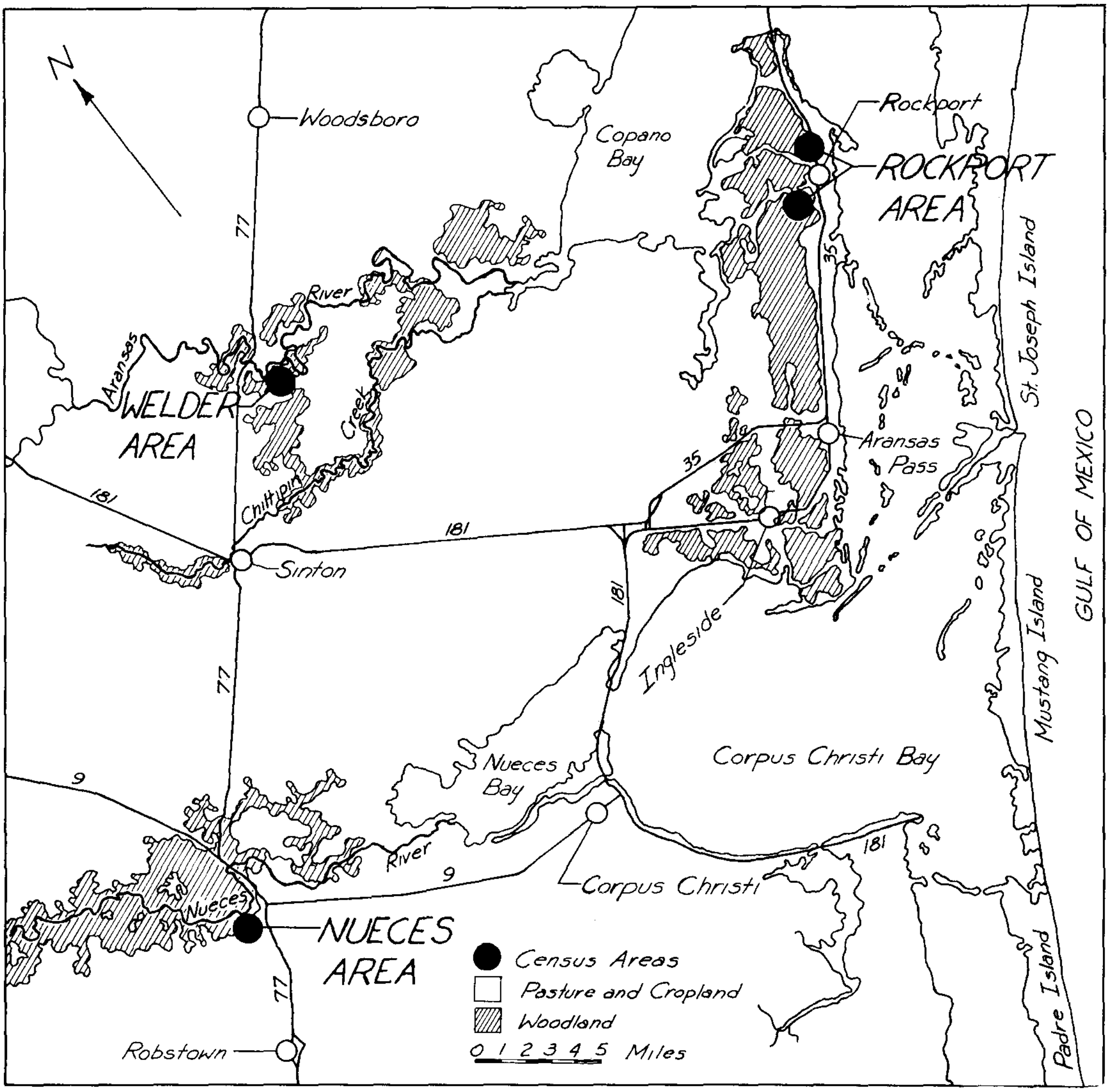

FIGURE 1. Location of study areas and distribution of woodland vegetation in the Coastal Bend region of Texas.

South America, and pass through Texas, primarily at night, in the northward spring migration.

The procedures of Lowery (1951) and Lowery and Newman (1963, 1966) were employed, using a 20 × Bausch & Lomb Balscope, Sr., telescope. Thus, passing migrants were observed overhead by day and in silhouette against the moon at night during the springs of 1963 and 1964 at the Welder Wildlife Refuge (28° 10′ N, 97° 28′ W) and at Rockport (28° 00′ N, 97° 10′ W). In 1963, additional nighttime stations were utilized at Padre Island (27° 37′ N, 97° 13′ W) and at the Nueces Area (27° 48′ N, 97° 32′ W).

It is unavoidable that some of the migrants counted passing the lunar disc were not landbirds since it is impossible to identify the species of birds observed. However, it was possible to recognize some silhouettes of ducks, geese, and certain shorebirds, and these were eliminated from the analysis. Another factor that might have produced some error in the transient-migrant lunar data is that some winter resident migrant species winter in the study area and south of it in Texas and northern México and migrate northward during the spring. However, this factor does not appear to be critical, because Hagar (1952) showed that the majority of these species move northward prior to the date the present observations were conducted. These same problems are inherent in the telescopic observations of diurnal migration, plus the added presence of many birds that are strictly diurnal migrants, and not simply habitual night migrants found aloft by day. Thus, every effort was made to discount shorebirds, gulls, terns, swallows, hawks, and other birds that were not part of this study.

Since radar studies (Harper 1958; Nisbet 1963; Gauthreaux 1965) indicate that most migration occurs at approximately 2500 and 3000 ft (762 and 914 m), winds aloft at 3000 ft were used in interpreting the various data. The winds-aloft data were obtained from the United States Weather Station in Corpus Christi, Texas, for 21:00 CST, the most appropriate hour available during nocturnal migration. This information was supplemented by appraisal of cold-front passage from daily weather forecasts and from United States Daily Weather Maps, which was important

TABLE 1. Number of transient migrants per 20 acres per day in the Gulf Coastal Bend region of Texas, 1963–64.

1963		Census area			1964		Census area		
Date[a]	Upper winds	Nueces	Welder	Rockport	Date[a]	Upper winds	Nueces	Welder	Rockport
March					March				
					11	SSE	13		1
					*12	NNE	65	21	
					13	SSE	15	14	
14	SE		49		14	S	2		0
15	NE			0	*15	W	3	21	
16	S			6	**16	N	19	11	
17	SSW	7	34		**17	SE	32		4
18	S			0	18	E	22	17	
19	S	8	10		19	SSE		29	
*20	N	31	37		*20	WNW			3
**21	ENE			3	**21	SSW		37	
**22	E	17	26		**22	N	35		5
23	SSE		17		23	SSE	35	28	
24	SSE			0	***24	S		82	
25	SSE		9		***25	S	21		0
26	S		6		*26	W	37	46	
*27	NNE	49		0	**27	NNE	22		0
28	SSE		4		**28	S	45	66	
29	S		9		**29	NNE			0
30	S			1	**30	E	34	16	
31	SSE		6		**31	E	31		0
April					April				
1	SSE	13	17		1	SSE	16	14	
2	SSE			0	2	S	9		3
3	SSE	10	3	2	3	SSW			
4	SE	19	2		4	S		33	
*5	ESE		108	6	*5	S	22	81	13
**6	E	59	40		**6	N	13	32	
**7	NNW	105	69		*7	SSE	36	9	
8	E	22		2	**8	N			1
9	S		10		**9	N	17	9	
10	WSW	4	8		**10	E	5		
11	S	3		0	**11	SSE			24
12	S	2	1		**12	S	69	64	
*13	NE			32	*13	SSW	14	44	
**14	ESE	97	118		**14	S	121		99
15	SSE	20	41		**15	E		20	
16	S		16	22	16	SE			
17	S	9	24		17	SSE	51		11
18	S			5	18	S	63	61	
19	S	5	19		19	SSE		15	15
20	SSW				20	S	22	30	
21	SSE	59	29		21	S	9		4
22	S			24	22	S	12		
23	SSE		39		23	S		21	
24	SE	65	29		24	S			0
25	S			5	25	S	11	3	
***26	SSE		156		26	SSE			12
***27	SSE		59		*27	NNW	63		6
28	SSE			6	**28	NW	35	2	
29	S		56		**29	WSW	65	69	
30	S	43	51		**30	ENE	162		56
May					May				
*1	E	206		61	**1	S	174	145	
**2	ENE		242		**2	SW	90		60
**3	SE	209		140	3	SSE			
**4	ESE	133	62		**4	ESE		64	
**5	SE	169			***5	ESE			43
6	SE			28	***6	SSE	102	189	
**7	ESE		40		7	SSE	21		
**8	E	94			8	S			9
9	SSE			16	9	SSE	17	22	
10	S		21		10	SSE		23	
11	S		32		11	SSE	51		8
12	SSE	72		4	*12	S	79	33	
13	S		34		**13	W	41		86
14	SE		57		**14	N	86	115	
15	SSE			16	**15	E	133		
16	SSE				16	SSE			13
17	S		17	1	17	ESE	73	39	
18	S				18	SE	61		9
19	SSE		22		19	SE		13	
20	SSE		21		20	E			

[a] * Indicates passage of cold front; **, days following frontal passage when fronts still exerted unfavorable conditions for migration; ***, unfavorable migratory conditions such as heavy overcast or rain not associated with cold fronts.

TABLE 2. Total numbers of grounded transient migrants and numbers per census in spring 1963 and 1964 in association with different weather conditions.

Year	Location	Frontal and stormy weather			Fair weather		
		Total birds	No. censuses	Birds/census	Total birds	No. censuses	Birds/census
1963	Nueces	1169	11	106	361	16	23
	Welder	957	11	87	693	31	22
	Rockport	242	6	40	138	19	7
1964	Nueces	1671	30	56	503	18	28
	Welder	1176	22	54	362	15	24
	Rockport	400	16	25	85	12	7

during fronts that moved too rapidly to be reflected in the once-daily winds-aloft reading.

All the specimens obtained for lipid analysis were collected on the Welder Wildlife Refuge, weighed and frozen immediately, and later prepared for lipid extraction using a method modified from that described by Odum and Connell (1956). Each frozen specimen was milled to an emulsion with acetone and then dried over a water bath at 65°C. After the dehydrated residue was weighed, the fat was extracted in petroleum ether for 6–8 hr using a Soxhlet extractor. The vehicle was evaporated from the extract over a steam bath and the remaining lipid residue was weighed.

The specimens, regardless of species, were separated into eight groups according to the direction of the winds aloft. The average lipid index (g fat/g nonfat dry weight) for each group was computed following the procedure of Odum, Rogers, and Hicks (1964).

POPULATIONS OF GROUNDED MIGRANTS

The 3560 birds observed in the three census areas 14 March–20 May 1963 (table 1) included 60 species of transient migrants, and the total of 4531 birds counted in the same census areas 11 March–19 May 1964 (table 1) included 57 transient species.

The population peaks of grounded migrants in both years were usually associated with the passage of cold fronts and accompanying northerly winds (table 1). In some instances the peak occurred a day or two after frontal passage. This was evidenced by the increase of grounded migrants following the passage of such frontal systems. The rapid decline of grounded migrants following a frontal passage when the winds shifted back to a southerly direction indicated that they continued their northward flight under the first favorable conditions, and were not immediately replaced locally. This agrees with the findings of Bagg (1956, 1957), Dennis (1954), Imhof (1953), and Lowery (1945).

On 7 April 1964 the passage of a cold front did not result in an increase in grounded transient landbirds (table 1), probably because this frontal system reached the study area only two days after the preceding front. The northerly winds associated with the front of 5 April shifted to a southerly direction the night of 6–7 April, and with the advance of the following front, the winds shifted back to the north on the afternoon of 7 April providing a brief one-night interval of favorable winds allowing the previously grounded migrants to resume their flight. The front of 7 April then passed during the daylight hours when relatively few birds were migrating.

Sometimes migrants were precipitated in the absence of the passage of cold fronts and northerly winds. The grounded transients noted at Welder on 26 April 1963 were associated with warm temperatures, southeasterly winds, and heavily overcast skies (table 1). This phenomenon also occurred at the Rockport Area on 5 May 1964 and at the Nueces and Welder Areas on 6 May 1964 when the winds were from the ESE and SE, respectively, skies were heavily overcast, and intermittent light rain and warm temperature prevailed (table 1). It appears that this influx of grounded migrants in 1963 was due to the heavy overcast and that the precipitation of transients in 1964 was due to the combined effects of heavily overcast skies and light rain. Williams (1947) states that rain, regardless of wind, will precipitate birds, and the cessation of migration during periods of rain or mist has been demonstrated by Svardson (1947), Ball (1947), Mascher (1955), and others. Sutter (1957) found that migration in Switzerland did not normally occur during periods of high fog, and Lack (1960) reported that migration was reduced or halted in association with rain and overcast.

Each year in the study areas the average numbers of grounded migrants were higher during periods of stormy weather and cold front activity than during fair weather (table 2). In fact, during both years of the study the separate monthly averages in each census area were, without exception, higher during frontal and stormy weather than during the fair weather in the same month. According

TABLE 3. The number of grounded migrants by species per census in each of three census areas, spring 1963 and 1964.

Selected transient species	Nueces (75 censuses) Birds/census	Welder (79 censuses) Birds/census	Rockport (53 censuses) Birds/census
Yellow-billed Cuckoo (*Coccyzus americanus*)	1.27	.50	.41
Black-billed Cuckoo (*Coccyzus erythropthalmus*)	.01	.05	.00
Ruby-throated Hummingbird (*Archilochus colubris*)	.20	.01	.05
Black-chinned Hummingbird (*Archilochus alexandri*)	.08	.01	.07
Eastern Kingbird (*Tyrannus tyrannus*)	.78	.10	.77
Great Crested Flycatcher (*Myiarchus crinitus*)	1.33	1.17	.30
Empidonax spp.	2.97	.95	.41
Eastern Wood Pewee (*Contopus virens*)	.88	1.23	.58
Olive-sided Flycatcher (*Nuttallornis borealis*)	.28	.02	.05
Catbird (*Dumetella carolinensis*)	1.38	.41	.30
Wood Thrush (*Hylocichla mustelina*)	.25	.87	.05
Swainson's Thrush (*Hylocichla ustulata*)	1.50	1.52	.15
Gray-cheeked Thrush (*Hylocichla minima*)	.33	.47	.00
Veery (*Hylocichla fuscescens*)	.26	.38	.02
Blue-gray Gnatcatcher (*Polioptila caerulea*)	4.05	4.79	.32
Yellow-throated Vireo (*Vireo flavifrons*)	.09	.07	.00
Solitary Vireo (*Vireo solitarius*)	.24	.23	.04
Red-eyed Vireo (*Vireo olivaceus*)	1.21	1.10	.71
Warbling Vireo (*Vireo gilvus*)	.92	.09	.24
Black-and-white Warbler (*Mniotilta varia*)	2.54	3.22	.62
Prothonotary Warbler (*Protonotaria citrea*)	.14	.09	.24
Swainson's Warbler (*Limnothlypis swainsonii*)	.00	.04	.00
Worm-eating Warbler (*Helmitheros vermivorus*)	.44	1.27	.11
Golden-winged Warbler (*Vermivora chrysoptera*)	.09	.27	.04
Blue-winged Warbler (*Vermivora pinus*)	.08	.13	.04
Tennessee Warbler (*Vermivora peregrina*)	.76	1.51	.73
Nashville Warbler (*Vermivora ruficapilla*)	2.10	1.41	.09
Parula Warbler (*Parula americana*)	.89	1.15	.07
Yellow Warbler (*Dendroica petechia*)	.88	.09	.30
Magnolia Warbler (*Dendroica magnolia*)	2.36	1.65	.47
Black-throated Blue Warbler (*Dendroica caerulescens*)	.00	.01	.02
Black-throated Gray Warbler (*Dendroica nigrescens*)	.00	.00	.02
Black-throated Green Warbler (*Dendroica virens*)	.97	.86	.26
Cerulean Warbler (*Dendroica cerulea*)	.04	.07	.05
Blackburnian Warbler (*Dendroica fusca*)	.34	.33	.39
Yellow-throated Warbler (*Dendroica dominica*)	.28	.18	.02
Chestnut-sided Warbler (*Dendroica pensylvanica*)	1.17	.83	.41
Bay-breasted Warbler (*Dendroica castanea*)	1.08	.54	.58
Blackpoll Warbler (*Dendroica striata*)	.03	.00	.00
Ovenbird (*Seiurus aurocapillus*)	.41	.95	.19
Northern Waterthrush (*Seiurus noveboracensis*)	1.01	.07	.02
Louisiana Waterthrush (*Seiurus motacilla*)	.16	.06	.00
Kentucky Warbler (*Oporornis formosus*)	.33	.48	.09
Connecticut Warbler (*Oporornis agilis*)	.00	.01	.00
Mourning Warbler (*Oporornis philadelphia*)	.42	.05	.02
Yellow-breasted Chat (*Icteria virens*)	1.49	.28	.15
Hooded Warbler (*Wilsonia citrina*)	.68	1.36	.09
Wilson's Warbler (*Wilsonia pusilla*)	.30	.19	.19
Canada Warbler (*Wilsonia canadensis*)	1.38	2.60	.28
American Redstart (*Setophaga ruticilla*)	1.54	1.46	.81
Orchard Oriole (*Icterus spurius*)	1.46	1.40	.73
Baltimore Oriole (*Icterus galbula*)	1.58	.69	.56
Scarlet Tanager (*Piranga olivacea*)	.01	.22	.05
Summer Tanager (*Piranga rubra*)	.56	.27	.51
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	.33	.32	.13
Blue Grosbeak (*Guiraca caerulea*)	.74	.13	.19
Indigo Bunting (*Passerina cyanea*)	3.14	1.27	2.32
Lazuli Bunting (*Passerina amoena*)	.00	.00	.02
Dickcissel (*Spiza americana*)	1.45	1.24	.90

to the one-tailed sign test (Siegel 1956), this difference is highly significant ($N = 8$, $x = 0$, $P < 0.001$). The one-tailed alternative was appropriate because the nature of the difference was anticipated. The literature reports convey the expectation that grounded migrants will attain peak densities during unfavorable weather.

The total number of grounded migrants in 1963 and 1964 was consistently higher, regardless of weather conditions, in the Nueces and Welder Areas than in the Rockport Area (table 1). An F test showed that these differences were significant at the 0.01 confidence level, yet there was no significant difference between the Nueces and Welder Areas (table 1). Also, the number of the various species of grounded migrants per census was consistently greater in the Nueces and Welder areas than in the Rockport area (table 3). The one-tailed sign test (Siegel 1956) showed that the differences between the Nueces Area and Rockport Area, and between the Welder Area and Rockport Area were significant at the 0.05 confidence level, but there was no significant difference between the Nueces and Welder Areas.

TABLE 4. Migration traffic rates of birds observed by telescope passing the lunar disc in 1963 and 1964 in the Coastal Bend region of Texas.

Station and dates	Starting time	Duration (hr)	Winds aloft	% migration traffic rate in individual sectors														Migration traffic rate (birds/hr)[a]
				SSW–SW	SW–WSW	WSW–W	W–WNW	WNW–NW	NW–NNW	NNW–N	N–NNE	NNE–NE	NE–ENE	ENE–E	E–ESE	ESE–SE	SSE–S	
Rockport 1963																		
April 7	21:00	2	E							9	18	36	24	13				5303
8	20:00	3	S	1					2		19	44	20	10		4		2876
9–10	20:00	4	WSW								17	49	29	5				533
10	21:00	2	S						60	20		12		8				155
11–12	22:00	3	S				2		15		26	30	22	5				774
May 5	21:00	2	SE				4		8	16	41	14	17					3040
6–7	19:00	6	ESE						6	10	38	36	9	1				6982
7–8	20:00	6	E							8	39	35	16	1	1			24,498
Total		28							2	8	36	35	16	2	1			7823
Padre Island 1963																		
May 3–4	19:00	7	ESE					9	25	34	27	3		2				1780
4	19:00	2	SE						45		15	23				17		540
5–6	20:00	5	SE	4					2	4	24	41	20	4		1		5510
Total		14		2				3	9	14	25	30	13	3		1		2935
Welder 1963																		
April 6	20:00	3	NNW									19	69		12			410
8–9	20:00	5	S		1				2	6	30	43	11	6	1			2883
9	20:00	3	WSW		2						42	56						806
10	21:00	2	S					13			17	70						174
11–12	1:00	2	S						28	14	16	16		26				1467
May 3	20:00	3	ESE					1	16	29	34	10	9	1				13,294
5	20:00	2	SE		1				2	2	31	18	32	12	2			6817
6	20:00	2	ESE						6	31	27	25	11					6741
7	19:00	3	E					2	5	24	31	36	2					3809
8	20:00	3	SSE						2	12	29	50	7					1677
9–10	21:00	3	S						3	5	28	54	10					1940
Total		31						1	8	18	29	29	11	3	1			3773
Nueces 1963																		
April 6–7	22:00	2	NNW							13		25	36				26	750
8	20:00	2	S							5	45	40	10					776
9	20:00	2	WSW						17	13	18	42	10					320
10	21:00	1	S					19	31			26			24			177
May 3	22:00	1	ESE						15	43	14	20	4	4				10,732
5	19:00	3	SE							39	27	26	8					1383
7	20:00	2	E		4				8	18	23	40	7					3259
8	20:00	3	SSE						2	6	38	39	12		3			1441
10	22:00	1	S					55				45						443
Total		17						2	8	27	22	31	8	1			1	1767
Welder 1964																		
March 30–31	22:00	2	E						38		28	34						162
April 24–25	19:00	5	S						17	10	43	25	5					1000
26–27	20:00	4	NNW						3	4	23	49	17	3	1			2263
27–28	21:00	4	NW							5	42	47	4	2				4583
28–29	22:00	2	WSW	4		6	10			47		33						283
Total		17							3	7	37	43	8	2				1957
Rockport 1964																		
April 26–27	19:00	5	NNW	1	1	1	8	23	6	15	22	6	11	6				956
28–29	21:00	3	WSW			14		86										51
Total		8				1	8	26	6	14	22	6	11	6				617

[a] No. birds/hr migrating at right angles to a line one mile long.

The major forest vegetation type at the Nueces and Welder Areas was alike and differed from that in the Rockport Area. This suggests that the differences in bird numbers between the Rockport Area and the Nueces and Welder Areas were due to actual habitat differences. Downwind migratory drift also might be involved in producing the consistently higher densities of grounded transients in the Nueces and Welder Areas. The prevailing winds in the Coastal Bend region are southeasterly and would be conducive to overland or coastal migrations since they not only would prevent the migrants from being blown out to sea but would have a tendency to drift the migrants inland away from the coast.

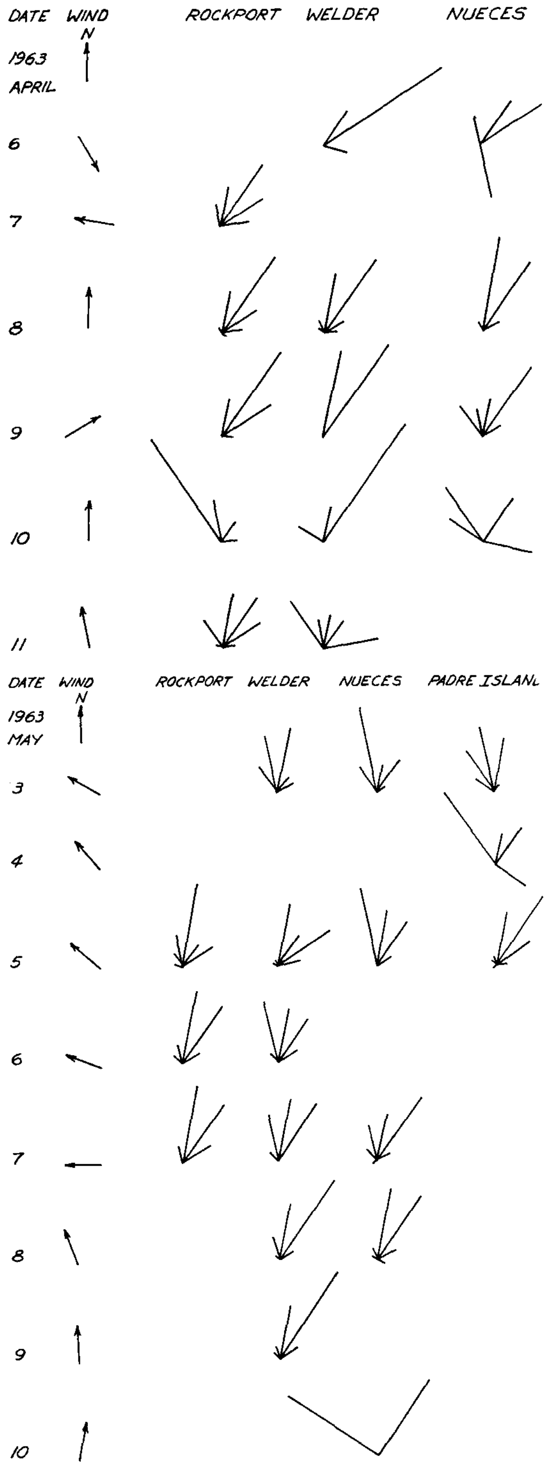

FIGURE 2. Flight directions of nocturnal migrants seen by telescope against the moon in 1963. Each line is proportional to the percentage of birds flying in that direction (see table 4).

Downwind migratory drift has been noted on the New England coast during fall migration. Trowbridge (1902), Allen and Peterson (1936), Griscom (1949), Baird and Nisbet (1960), and others found that the largest concentrations of migrants on the New England coast were correlated with northwest winds, and suggested that the birds were drifted eastward from an inland migration route.

NOCTURNAL MIGRATION

In 1963 the lunar observations at all stations showed consistently that most migrants were flying courses somewhat east of north (table 4, fig. 2). Although there were nights at all stations when northwestward flights were as great or greater than those heading northeasterly, the over-all migration traffic rate of birds flying in a northeasterly direction was considerably the larger (fig. 3). Similar directions of migration have been reported during the spring for the Houston, Texas, area (Williams 1950b) and for Rockport and inland at College Station, Texas (Lowery 1951). When the winds aloft were from a southwesterly or southerly direction, the northeasterly flights more or less followed the trajectory of the winds, but when the winds were from a southeasterly to easterly direction, the migrants flew across the winds. Since the prevailing winds in the Coastal Bend region of Texas are southeasterly, it is evident that the migrants were deliberately flying northeasterly, with or without assistance of tail winds (table 4). The prevailing southeast winds may even assist overland or coastal migration since these cross winds would tend to prevent the migrants from being blown out over the Gulf. Lowery and Newman (1966) found that during fall migration, migrants tended to follow the trend of the Texas coast regardless of the wind direction, but elsewhere in the United States the birds tended to follow the trajectory of the winds. James (1955), studying fall migration in the Mississippi River Basin and adjacent areas, also found that nocturnal migrants tended to follow the winds.

It appears that the northeastward flights observed at all four stations were mostly overland migrants flying along the coast (figs. 2, 3). It is possible that a portion of these northeast flights represents reorientation of overwater migrants after westward displacement by southeasterly winds over the Gulf. Although the present study does not provide the kind of evidence necessary for determining whether or not this is true, such findings have been reported by Lack (1960) and Gauthreaux (1965).

The spread of the vector pattern, showing large median vectors with successively smaller vectors in the sectors on either side, could represent simple sampling error or variation in

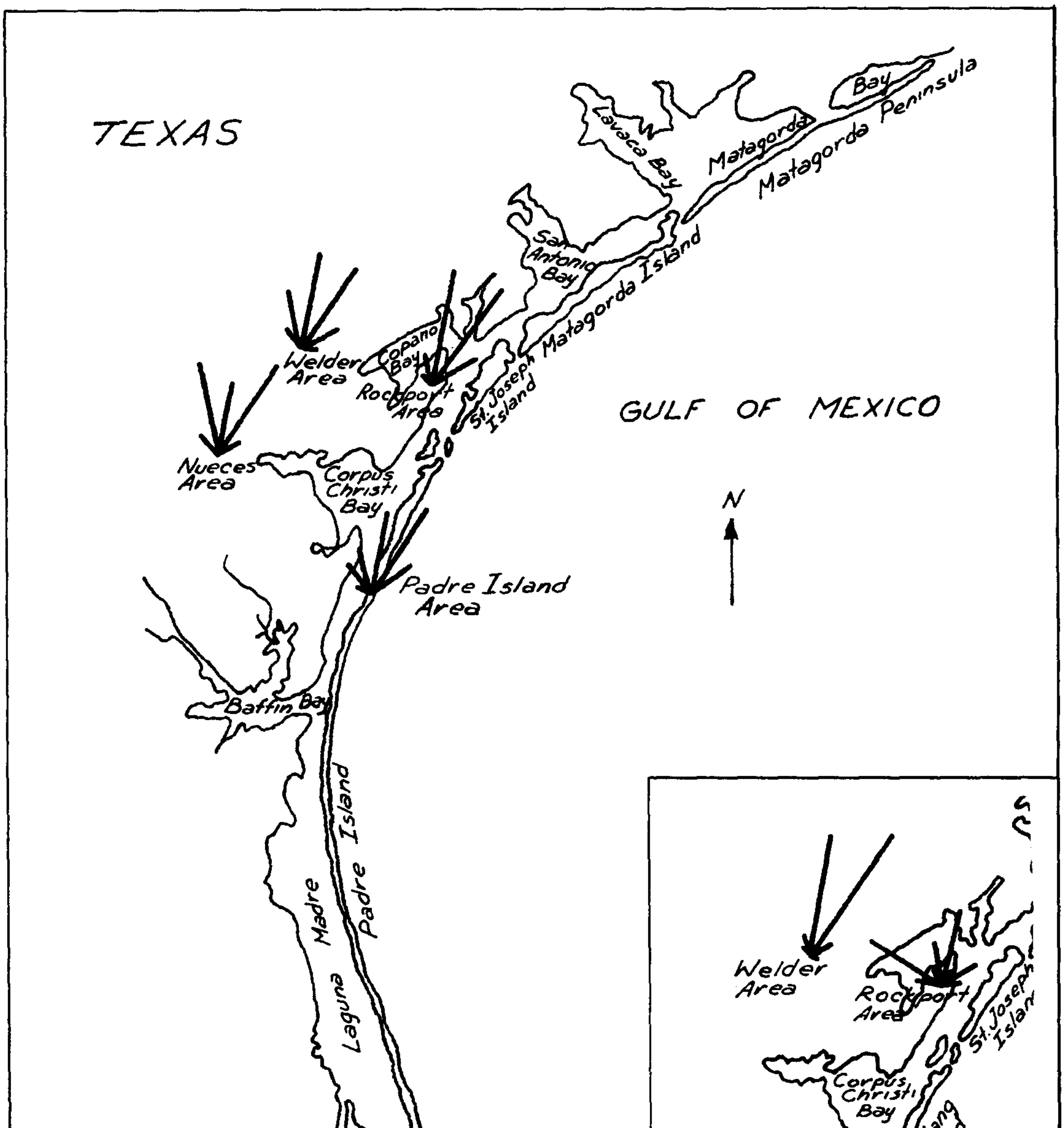

FIGURE 3. Over-all flight directions of nocturnal migrants observed passing the lunar disc in 1963 and in 1964 (insert, lower right). Each line is proportional to the percentage of birds flying in that direction (see table 4).

a normal distribution pattern of bird migration that is essentially overland (figs. 2, 3). However, the very small vectors representing flight directions northwestward off the Gulf could be real directions per se, and as such represent overwater migrants following the prevailing southeasterly winds (figs. 2, 3). If the wind directions over the Gulf were similar to those along the Texas Coast, the flight of these migrants could have originated in the Yucatán-Campeche-Tabasco region of México or points south. In fact, large numbers of nocturnal spring migrants are known to initiate northwestward flights from Yucatán at night (Lowery 1951). This study does not provide the critical evidence needed to determine whether or not the northwestward flights actually represented overwater migrants, but if the northwest flights were overwater migrants, the apparent magnitude of migration sampled passing the lunar disc was quite small.

The consistently large flight of presumed overland nocturnal migrants flying northeasterly is just what one would expect, because it has been shown by Lowery (1951) and Gauthreaux (1965), and is suggested later in the present study, that trans-Gulf night migrants arrive in greatest numbers over the Gulf Coast during the daylight hours. The nocturnal telescopic studies therefore were conducted during the period in which the fewest migrants arrive from over the Gulf, and thus these studies do not independently indicate that most landbird migrants arrive overland on the western Gulf coast of Texas. However, they do indicate that a tremendous number of transients flying northward at night from eastern and southern México arrive in Texas via overland routes. This is supported by the lunar observations conducted on the eastern coast of México, at Tampico, which showed a relatively large number of migrants flying northward along the coast (Lowery 1951).

In 1964 lunar observations were conducted only at the Rockport and Welder stations and the migratory patterns differed somewhat from those exhibited in 1963 (table 4, fig. 4). The flight pattern at Rockport indicates two directional flight trends of almost equal magnitude, one west of north and the other east of north (fig. 3). However, the over-all flight trend at the Welder station was east of north, resembling the patterns of 1963. The greatest migration traffic rates were observed on nights associated with the passage of a cold front when the winds were from the NNW and NW (table 4). On the night of 26 April, lunar observations at both stations were conducted

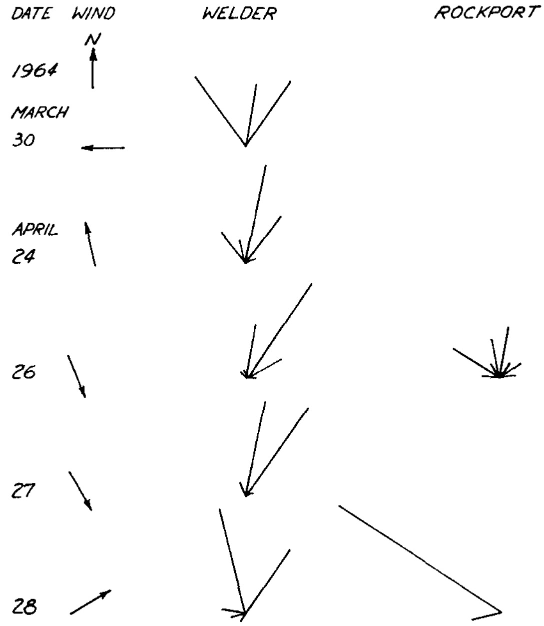

FIGURE 4. Flight directions of nocturnal migrants seen by telescope against the moon in 1964. Each line is proportional to the percentage of birds flying in that direction (see table 4).

simultaneously for 4 hr (table 4). A comparison of these data shows two distinct differences. The migration traffic rate at Welder during this period was twice as great as that recorded at Rockport, and the magnitudes of the northwestward and northeastward flights were approximately equal at Rockport, whereas 93 per cent of the migrants observed at Welder were flying northeasterly (table 4). This suggests that the northwesterly flight observed at Rockport represented either overwater migrants flying into the winds toward land, or migrants that had been blown out to sea by the northwest winds and were flying into the wind to reach land again. This type of reorientation after drift has been reported in New England during fall migration (Baird and Nisbet 1960, and others). However, reorientation of trans-Gulf migrants does not appear to be the case here, since the magnitude of reverse or seaward migration observed at both stations as a result of the northwesterly winds was not sufficiently high to account for the magnitude of the northwest flight. Therefore the majority of these birds flying northwesterly probably were overwater migrants, which would be contrary to the ideas of Williams (1950a) concerning the source of birds arriving from off the Gulf during north winds.

The difference in the relative magnitudes of the northwest flights observed at Rockport and Welder in 1964 during periods of northwesterly winds suggests that the majority of

TABLE 5. Birds observed by telescope flying across the zenith in daylight in 1963 and 1964 in the Coastal Bend region of Texas.

Station and date	Time	Duration[a] (hr:min)	Winds aloft	No. birds and flight directions: WSW–W	WNW–NW	NW–NNW	NNW–N	N–NNE	NNE–NE	NE–ENE	ENE–E	SE–SSE	Birds/hr
Rockport 1963													
March 18	16:30–17:40	1:00	S										0.0
30	15:00–17:00	1:50	SSE				1	1					1.1
April 2	16:15–18:30	2:00	SSE										0.0
10	16:00–19:15	2:45	S						2				0.7
11	16:30–16:45	2:10	S				1	3					1.8
16	9:10–10:45	1:15	S				1						0.8
16	14:10–16:00	1:50	S				1						0.5
18	8:15–10:20	2:05	S										0.0
25	15:30–18:00	2:10	SSE	1	1	4	18	12	5	7	1		22.6
28	15:45–17:45	1:45	S				1						0.6
May 3	13:00–15:00	2:00	ESE		1		2	2					2.5
6	15:00–18:30	2:05	ESE			1	31	27	14				35.0
9	18:15–19:15	1:00	S			1	4	1	3				9.0
12	16:30–18:45	1:45	S				2	2					2.3
15	17:30–18:30	1:00	SSE										0.0
Total		26:40		1	2	6	62	48	24	7	1		5.7
Per cent					1	4	41	33	16	5			
Welder 1964													
March 19	16:30–18:00	1:30	WNW										0.0
24	15:30–17:30	1:45	S										0.0
April 13	18:20–19:00	40	S										0.0
21	16:30–18:00	1:30	S				2	1	1				2.9
25	17:00–18:30	1:30	SSE				1			3			2.9
28	16:30–18:15	1:30	WSW			1	3						2.9
May 7	15:30–18:00	2:00	SSE			8	59	74	17				79.0
10	9:30–12:00	2:00	SSE										0.0
15	15:30–16:45	1:30	SSE			3	9	2					9.3
Total		13:55				12	74	77	18	3			13.1
Per cent						7	40	42	9	2			
Rockport 1964													
March 20	8:30–10:30	1:45	SSW										0.0
26	16:00–17:30	1:30	NNE										0.0
April 8	16:00–18:30	2:15	N										0.0
14	16:00–17:30	1:30	E							2	4	2	5.3
19	15:30–17:00	1:30	S				1	1		2			2.7
26	17:00–18:30	1:25	SSE				9						6.4
27	10:00–11:45	1:45	NNW										0.0
May 2	16:15–18:00	1:30	SSE			8	3	8	6				16.7
8	14:45–17:00	1:45	S				1	3					2.3
16	14:30–16:30	1:45	SSE					2					1.1
Total		16:40				8	14	14	6	4	4	2	3.1
Per cent						15	27	27	11	8	8	4	

[a] The time from the beginning to the end of observation minus any time-out rest periods.

overwater migrants landed because of the adverse winds soon after their arrival over land, and thus were not recorded at the inland station.

The smallness of the northwestward flight of birds from the open Gulf is apparent from the lunar data. Yet, since the land mass between the lunar station and the coast was so narrow, these data do not necessarily discount the possible presence of a large northwestward flight taken by grounded migrants. If the station were farther inland, the numbers of grounded birds to the east would be large enough to produce a big flight if they flew toward the northwest. Therefore, the relative largeness of the northeastward flight could be biased by this factor at near-coast observation stations. Considering that the flight directions at an inland station in Texas (Lowery 1951) were similar to the ones in the present study, we feel that this bias is merely theoretical, not real.

Despite variations, peak migration traffic rates occurred during the first of May both years.

DIURNAL MIGRATION

Observations were conducted with the telescope trained at the zenith in 1963 along the coast at Rockport (table 5). Observations were made during both the morning and the afternoon but most observations unavoidably were restricted to the afternoon. Peak numbers of migrants were noted during the afternoon when the winds were from SSE and ESE. Relatively fewer birds were seen during south winds. The majority of the observed migrants were flying courses between NNW and NNE (table 5). Diurnal telescopic observations were made at the inland Welder Station on four days in 1963, but no migrants were observed.

The greatest percentages of migrants observed at Welder and Rockport in 1964 were on headings between NNW and NNE, and again peak numbers occurred when winds were east of south (table 5).

In general there were only a few dates in 1963 and 1964 when any significant daytime flights were noted, and the numbers of daytime migrants were highly variable, with maximum flight densities usually occurring in early May (table 5). One exception, a peak density in April, was noted at Rockport in 1963. All flights at both stations showed the same directional trends with the exception of one small aberrant flight at Rockport in 1963 when the migrants were flying more east of north than usual.

The afternoon telescopic observations in both years indicated that the highest recorded flight densities occurred during a 2–3-hr period before sunset when the winds aloft were from a southeasterly direction (table 5). The paucity or absence of migrants observed passing the zenith during the morning was primarily due to the relatively few hours of observations and provides no critical evidence as to whether or not migration (other than swallow migration) occurs during this time period in the Coastal Bend region (table 5).

The flight patterns exhibited in both 1963 and 1964 at Rockport and Welder indicate that the majority of the migrants observed passing the zenith in the afternoon were flying courses between NNW and NNE regardless of the upper wind direction. The bulk of flight was in a northerly direction and consisted of components of equal magnitude to the east and west of north (table 5). The migrants following courses west of north could have been flying more or less with the southeasterly winds. Those with headings east of north could have been quartering across the winds. On the other hand, the spread of flight directions could represent patterns resulting from sampling error inherent in the method used or even could be normal variation in a migration pattern that was essentially northward overland migration. Yet, it appears quite likely that the northwesterly headings, at least in part, represent real flights off the open Gulf made by overwater migrants that had begun the migration the preceding night. The fact that the average direction of flight by day was shifted well to the west of the average nocturnal flight trajectory supports this idea. Even more support is evident in the coincidence of the only peak numbers of day migrants with winds blowing from east of south off the open Gulf (table 5), while overland winds brought few day migrants. Evidently the off-Gulf winds contributed overwater migrants to the flight of diurnal migrants.

Assuming that the wind directions over the Gulf of Mexico were similar to those along the Texas coast and that the migrants followed approximately the same course from the beginning of their flight until reaching the coast of Texas, it is evident that their last possible contact with land would have been in the Yucatán-Campeche-Tabasco-Veracruz areas of México. Graber (1965), using radio telemetry, established that a Gray-cheeked Thrush migrating northward followed the winds and maintained a constant heading throughout the entire flight. Migrants departing from western Tabasco or southeastern Veracruz would arrive over water in the Coastal Bend region if they flew a course only 11 degrees west of north, which is well within the data. The arrival of overwater migrants in the Coastal Bend region may also have been due to westward displacement by prevailing southeasterly winds of migrants heading toward the northern Gulf coast. The importance of overseas drift has been reported by Lack (1962). Lowery (1951) at Progreso, Yucatán, found that relatively large numbers of nocturnal spring migrants initiated a northwestward trans-Gulf migration from there, and suggested that southerly and southeasterly winds would tend to displace much of the trans-Gulf flights to the western part of the Gulf. He calculated that the majority of migrants leaving Yucatán in the hours of heaviest flight, before midnight, flying at an average speed of 33 mph would traverse the 580 miles to the northern Gulf coast in about 17 hr and arrive there during the daylight hours. Gauthreaux (1965), using both the telescope and radar, found that the majority of birds arriving on the coast of Louisiana from over the Gulf tended to follow the winds and thus were flying northwesterly courses. These migrations were recorded first in the morning, peaked in the afternoon, diminished near nightfall, and occasionally trans-Gulf migrants continued to arrive after dark. Presumably all these birds left the land masses at the south rim of the Gulf on the preceding night. If the greatest density of overwater migrants during the day in the present study actually did occur in the late afternoon, as suggested by the skywatch data, the somewhat later arrival in the Coastal Bend region than on the northern Gulf Coast could be due to the fact that the overwater distance between land masses on the southern rim of the Gulf and the Coastal Bend region is 100–200 miles greater than the distance between these land masses and the northern Gulf Coast.

If indeed the birds observed at both Welder and Rockport in 1963 and 1964 with northwesterly headings were migrants arriving from over the open Gulf, there is no evidence that they were blown out to sea by advancing cold fronts or any similar meteorological condition, as was suggested by Williams (1947, 1950a).

The birds flying courses north to east of north were diurnal overland migrants moving northeastwardly from México. Some overwater migrants that redirected flight directions to follow the coast probably were included. The northeasterly headings of these migrants indicate that they were deliberately flying overland and along the coast, quartering across the prevailing southeasterly winds (table 5). Winds blowing from this direction would be advantageous to birds migrating along or near the coast, since these winds would have a tendency to drift the migrants inland and prevent drift out to sea. It is possible that some of the birds composing the northeast flights were diurnal migrants that typically winter in southern Texas and northern México. Considering that many of the birds in the N to NNW sector would be flying near north, this overland segment of the flight probably comprised the bulk of the daytime migration.

If the daywatch data were computed on a basis similar to the lunar data, a rough comparison of the directional magnitudes might be justified. The major error introduced when this method is applied to diurnal migration is that birds migrating during the day apparently tend to fly in flocks, whereas birds migrating at night tend to be more evenly distributed throughout the sky with little tendency to fly in flocks (Lowery 1951). When conducting the zenith-directed skywatch, the telescope remains vertical in a stationary position. The flight directions observed are true directions, and the cone of visibility at a given altitude remains constant and is approximately five times as great in diameter as the moon-watching cone (Lowery and Newman 1963). The telescope used had a field diameter of 112 ft (34 m) at 3000 ft (914 m). This means that the diameter of the field at 3000 ft is 1/47 of a mile. To convert the daywatch data to birds/mile of front, the number of birds observed is multiplied by 47. For example, the largest number of birds observed passing the zenith in 1963 was recorded at Rockport on 6 May when 73 migrants were observed during a 2-hr, 5-min period, thus averaging 35 birds/hr (table 5). Multiplying 35 by 47 gives the average number of birds per hr per mile of front, which in this case was 1645 birds. Similarly, the largest avian movement recorded at Welder in 1964 was on 7 May (table 5), averaging 3713 birds per hr per mile of front, and the greatest passage recorded at Rockport in 1964 (table 5) averaged 785 birds per hour per mile of front on 2 May. However, there were only a few dates in both years when flights approaching these magnitudes were noted. The day-to-day diurnal migration traffic rates thus appear to be lower in magnitude than the rates noted for the lunar observations. The peak migration traffic rate of migrants observed both at the zenith by day and passing the lunar disc at night occurred during the first part of May.

In view of the lunar observations and diurnal skywatch, it appears that the amount of overwater migration actually observed in the Coastal Bend region was somewhat less than the magnitude of overland migration. However, this should not be interpreted to mean that the majority of transient landbirds arriving on the entire Gulf coast or even the Texas coast are overland migrants. The apparent greater numbers of overland migrants moving northward from eastern México and points south may be due to a channeling effect produced by the corridor between the Sierra Madre Oriental and the Gulf, concentrating the migrants in a flight lane approximately 100 miles wide (Lowery 1951). However, Lowery (ibid.) points out that no restrictions of this nature can be discerned in relation to trans-Gulf migration and if the trans-Gulf flights cannot be assumed to be as wide as the Gulf itself, they at least have the breadth of the entire 260-mile northern coast of the Yucatán Peninsula.

MIGRATORY STRESS

Since there were no general differences in the lipid data of 1963 and 1964, the two years were combined. The indices for the combined total were lowest when the winds were from a northerly direction, highest when the winds were southeasterly, and somewhat intermediate when the winds were southwesterly (table 6).

TABLE 6. Mean lipid indices of grounded transient migrants with respect to winds aloft at the Welder Refuge.

Winds aloft	1963		1964		Combined total	
	No. specimens	$\bar{x}$ lipid index	No. specimens	$\bar{x}$ lipid index	No. specimens	$\bar{x}$ lipid index
0°–45°	6	.338	40	.356	46	.354
46°–90°	48	.356	0	—	48	.356
91°–135°	43	.422	36	.447	79	.434
136°–180°	78	.407	86	.473	164	.442
181°–225°	0	—	7	.361	7	.361
226°–270°	0	—	47	.388	47	.388
271°–315°	0	—	0	—	0	—
316°–359°	11	.377	0	—	11	.377

The main disadvantage in the analysis of fat deposits of grounded migrants is the inability to determine how many days the individual birds have been grounded when collected. This factor could introduce a considerable error when attempting to correlate the fat deposits of grounded birds colllected on a given day with the wind directions the preceding night (table 6). It is reasonable to expect that the error introduced by the day-to-day carry-over of grounded migrants redepositing fat before migrating again is fairly constant through the migratory season. Thus all collections, regardless of wind direction, probably were biased to the same degree by this carry-over of birds that had arrived earlier than the preceding night. Therefore, the lipid indices at best represent trends provided by the condition of recent arrivals associated with immediate weather conditions superimposed on this background carry-over. This probably explains why the differences shown in table 6 are not striking.

On the other hand, the low average lipid indices in table 6 suggest that migrants do not tarry long in the Gulf Coastal Bend region. These values correspond to those of lean spring migrants reported by Odum et al. (1964), but are not quite as low as those of birds that have exhausted all their energy reserves. If migrants stayed long enough in the area to replenish fat stores, one would expect the average lipid values to be higher than these minimal ones. Probably the carry-over of grounded migrants is slight and thus the fat condition of the collected birds represents more closely than would be expected the result of wind conditions the previous night. The rapid change in populations in the census areas supports this idea of quick migratory interchange.

Because of the two imponderables discussed above, and in view of the fact that the average lipid values in table 6 are not statistically different, the lipid findings cannot be used to shape major principles of migration in the Coastal Bend region. Mention can be made only of trends in fat differences as indications of relative migratory stress, supplying added support to the basic findings documented by the other methods used to determine patterns of migration. For example, it is tempting to suggest that the low average lipid indices (table 6) support the existence of a considerable overwater migration in the Coastal Bend region because trans-Gulf migrants, unlike circum-Gulf migrants, cannot stop in route and would be expected to expend considerable fat energy during the long overwater flight. Yet, the telescopic observations showed that the overland migrants apparently outnumber overwater migrants. Furthermore, the birds were heaviest when the winds were off the Gulf (table 6). The diurnal telescopic observations (table 5) showed that these wind directions carried most of the overwater migrants into the region. This situation conflicts with the assumption that overland migrants need not expend as much energy as the trans-Gulf migrants. Everything considered, then, the lipid data must be treated as an indication of relative physiological stresses in overland migrants in the Coastal Bend region. The birds apparently arrive in a lean condition and depart soon afterwards, still in a comparatively low fat state.

Whenever winds were in directions that would tend to drift overland migrants off shore, the fat indices were lower than during winds blowing in directions that would keep them over land (table 6). This suggests the existence of a compensation for offshore migratory drift and a resulting increased expenditure of energy in the process. Such a compensation for drift was observed by Baird and Nisbet (1960) during fall migration.

Obviously headwinds cause migrants to expend a great amount of energy since the lowest mean fat values followed nights when there were headwinds opposing spring migration (table 6). The birds in the first and last groups of table 6 met both a headwind and offshore drift, while the birds in the second group experienced some winds that were still headwinds but did not involve offshore drift.

SUMMARY

In March, April, and May of 1963 and 1964 in the Gulf Coastal Bend region of south Texas bird movements were studied by periodically counting populations of grounded migrants on the coast and inland, by observing through a telescope the passage of birds seen against the lunar disc, and by making telescopic observations of the passage of migrants seen at the zenith by day. In addition, grounded migrants were collected to determine their general condition by appraising fat deposits.

Transient species were grounded following the passage of most cold fronts, and occasionally they were grounded by heavily overcast skies and/or light rain not associated with a frontal passage. Although the same species were present on the coast and inland, the numbers of each species of grounded migrants, and total populations in general, were higher in the inland areas than on the coast. This condition probably was due to the better habitat present in the inland areas. Even so, the densities of grounded migrants were relatively higher in both inland and coastal areas during and after frontal weather and similar weather conditions than during fair weather.

The relatively high densities of the northeastward migratory flights, evidenced by the lunar observations, indicate that the bulk of nocturnal spring migration moving through the Coastal Bend region was composed primarily of overland migrants flying northward from eastern México across the prevailing southeasterly winds. These prevailing onshore cross winds are advantageous because they prevent offshore drift. Conversely, northwest flights observed were in part overwater migrants, flying with the prevailing southeasterly winds, and apparently were of smaller magnitude than the overland flights. When the winds were from a northerly direction, the majority of overwater migrants apparently landed soon after their arrival over land, but many overland migrations were not halted nor were they drifted out to sea by cold fronts and the accompanying northerly winds.

At least a portion of the northwesterly flights observed during the afternoon at the zenith were overwater migrants that had departed the preceding night from the land masses at the south rim of the Gulf. The birds flying courses north to east of north were mostly diurnal migrants moving northeastwardly from México, but probably also included some redirected overwater migrants. This coastwise movement composed the bulk of the diurnal flights.

In view of the lunar observations and diurnal skywatch, it appears that in the Coastal Bend region the amount of overwater migration was small in relation to the magnitude of overland migration. These data also indicate that the northwestward overwater flights were moving more or less with the wind and the northeastward overland flights were deliberately quartering across the prevailing southeasterly winds. The peak migration traffic rates of birds observed both at night and by day occurred during the first part of May.

The lipid indices were lowest in migrants collected following nights when there were headwinds and/or offshore winds that exert a migratory stress on the birds, apparently because the birds have to adjust to maintain an overland position and/or forward progress. Conversely, the lipid indices were highest when the winds were off the Gulf.

Even though the magnitude of overland migration through the Gulf Coastal Bend region of Texas apparently is greater than the amount of overwater migration, observation at this one location cannot decide the pattern for the Gulf as a whole. This is especially true considering that the study area is not well positioned for receiving overwater migration, whereas it is in the main stream of a concentrated overland migration.

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