OCS Study
MMS 2005-009

Coastal Marine Institute

Interactions Between Migrating Birds and Offshore Oil and Gas Platforms in the Northern Gulf of Mexico

Final Report

U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

Cooperative Agreement
Coastal Marine Institute
Louisiana State University

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Final Report

Editor

Robert W. Russell

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ABOUT THE COVER

The cover art depicts a fallout of migrating birds and insects on a platform in the northern Gulf of Mexico and is the work of Brian P. Gibbons, a field biologist from Texas who spent nearly a year living offshore during this study.

PREFACE

This study entitled “Interactions Between Migrating Birds and Offshore Oil and Gas Platforms in the Northern Gulf of Mexico,” also known informally as the “Migration Over the Gulf Project” (MOGP), provides data and analyses of trans-Gulf bird migration from three years of intensive study on 13 platforms located in offshore waters in the northern Gulf of Mexico. The study was sponsored by the Minerals Management Service (MMS) to provide environmental information to the MMS concerning the possible influence of platforms on migrating birds. This volume focuses on broad-scale patterns of migration and presents general findings concerning the ecology of migrants on platforms and the influences of platforms on trans-Gulf migration.

ACKNOWLEDGMENTS

This report would not have been possible without the contributions of hundreds of people.

First and foremost, thanks are due to the many dedicated field biologists who lived offshore for weeks or months at a time to conduct this study, listed here in descending order of time spent offshore: Rick Knight, Brian Gibbons, Mac Myers, Robert Russell, Jon King, Stacy Peterson, Mike Nelson, Karl Bardon, Alan Wormington, Dave Patton, Jeff Birdsley, Cameron Cox, Marshall Iliff, Brian Sullivan, Brian O'Shea, Dan Christian, John Arvin, Aaron Brees, Rick West, Matthew Holder, Arvind Panjabi, Jim Tietz, Laurence Binford, Paul Dickson, Richard Gibbons, Byron Stone, David Muth, Don Norman, and Dan Purrington. Thanks are also due to Diane Russell for providing logistical support to the project while Robert Russell was offshore. The collective pronouns "we," "us," and "our" are used throughout the text to acknowledge the important contributions of time, energy, and insight provided by the entire field team.

A study of this magnitude could never have been conducted without the enthusiastic cooperation of the petroleum industry, and we were fortunate to have enjoyed extensive logistical support from British Petroleum, ChevronTexaco, ConocoPhillips, ExxonMobil, Newfield Exploration, and Shell Offshore. These companies provided long-term housing and large quantities of food to our offshore field personnel, as well as regular helicopter transportation to and from shore and administrative support on shore. Hundreds of people involved in many facets of the industry provided assistance with all aspects of the study, but special thanks go to Russell Putt (British Petroleum), Phil Smith (Shell Offshore), and Vince Cottone (ChevronTexaco) for securing access to critical platforms during the expanded phase of the study. Although they are too numerous to name individually, we thank the many crewmen on the platforms where we worked for their interest, support, and camaraderie.

Thanks go to Mac Myers for devising the framework for the habitat classification scheme, and to Dave Patton, Mac Myers, and Stacy Peterson for assisting with synoptic weather classification. Dave Patton went well beyond the call of duty and invested a great deal of his own time downloading NEXRAD images for the radar component of the study. Many of the observers contributed photographs from their time offshore, and special thanks go to Dave Patton for contributing a large volume of outstanding material. Brian Gibbons assisted with enumeration and identification of insects in the light trap samples, and Lisa Peri completed the bulk of this laborious work. Victoria M. Bayless kindly made available facilities for storing and analyzing the insect samples at the Louisiana State Arthropod Museum. Alexis Lugo-Fernandez provided a copy of the Yocke et al. (2000) study, and Mark Yocke granted permission to reproduce the diagrammatic weather maps in Figure 5.1. Radar images and weather maps in Chapters 7-9 are included here courtesy of WSI Corporation, TAP Publishing Company, and Unisys Corporation. Special thanks to Brian Gibbons for creating the spectacular artwork that graces the cover of this report.

This study was originally housed at the LSU Museum of Natural Science, where much of the administrative groundwork for the study was completed by Donald Norman, who negotiated access to the original platforms used in the study. Special thanks go to Russell Chapman and the staff of the LSU School of the Coast and Environment, who agreed to support the study after facilities at the museum became unavailable.

Sidney Gauthreaux wishes to thank Alan Cunningham, Andrew Farnsworth, Steve Lohr, and David Mizrahi, who did most of the radar image quantification under his supervision and assisted in the preparation of the final subcontractor's report. Sidney Gauthreaux also thanks Villere Reggio, Jr., who was responsible for his involvement in this project, and Carroll Belser, who provided valuable support throughout the project.

This study was funded by the Minerals Management Service through the Louisiana State University Coastal Marine Institute (CMI) program under contracts 14-35-0001-30660 and 1435-01-99-CA-30951. Many thanks are due to the Minerals Management Service for its exceptional support of the study and for its patience during the delays while this report was being completed. We are grateful to Larry Rouse for his encouragement and support as Director of the LSU CMI. The Contracting Officer's Technical Representatives (COTRs) for this study were Bob Rogers, Sam Holder, Jeff Childs, and Dave Moran. All of the COTRs provided valuable advice and support.

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Chapter 1

Executive Summary

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The Gulf of Mexico is a major ecological barrier confronted by hundreds of millions of migrating birds each spring and fall. Trans-Gulf migrations evolved in the absence of natural islands that could serve as stopover sites; thus, the installation of an artificial archipelago of nearly 4000 oil and gas production platforms in the northern Gulf over the past five decades has introduced a novel and potentially important component into the en route environment of trans-Gulf bird migrants. From 1998-2000, my research group at LSU studied the ecology of trans-Gulf migration and the influence of platforms on migrants using a team of field biologists stationed on an array of platforms across the northern Gulf. This study was funded by the Minerals Management Service (MMS) through a cooperative agreement with the Louisiana State University Coastal Marine Institute, with extensive support provided by British Petroleum, ChevronTexaco, ConocoPhillips, ExxonMobil, Newfield Exploration, and Shell Offshore. The objectives of this study were to quantify spring and fall trans-Gulf migrations and to evaluate the influence of offshore platforms on trans-Gulf migrating birds. In particular, this study sought to address the following questions: 1) Which species are trans-Gulf migrants? 2) Are there specific migration routes across the Gulf of Mexico? 3) When do migrants use platforms for stopovers, and how does the timing of platform use relate to the seasonal and diel timing of trans-Gulf migration as well as weather? 4) How many individual migrants use platforms for stopovers, and how are the numbers of migrants using platforms related to total trans-Gulf migration traffic aloft? 5) What is the condition of migrating birds that stop on platforms, and what factors determine how long they stay? 6) During stopovers, do migrants use platforms in predictable ways? 7) How many migrants that stop on platforms depart successfully versus die there, and why do some birds die?

We sought to select platforms for study that were representative of the population of platforms at large, with respect to both structure and geography. We staffed as many as 10 platforms in a given season, stretching from North Padre Island 975 in the extreme western end of the Gulf to Viosca Knoll 786 at the eastern boundary of the Central Planning Area. All platforms used in this study were major fixed-leg platforms, with the exception of one compliant tower. Standardized field work was conducted on five platforms from mid-March to mid-May in spring 1998 and 1999 and from mid-August to mid-November in fall 1998. The study was subsequently expanded considerably in temporal and geographical scope; ten platforms were staffed from early August through mid-November in fall 1999, and nine platforms were staffed from early March to late May in spring 2000. In addition to the standard spring and fall field programs, one platform was staffed year-round in 1999-2000.

The basic field protocol consisted of a standardized, time-designated "platform census" conducted by an observer while walking around the platform on a prescribed route, with the goal of locating, counting, and identifying all living birds on the platform at different times throughout the day. When a migrant was detected, it was identified to species and (when possible) age and sex, and details of its behavior and apparent physiological condition were recorded. This repetitive and highly standardized monitoring scheme permitted us to develop detailed longitudinal case histories for individuals that undertook extended stopovers on the study platforms. In addition to the censuses of birds stopping over on the platforms, visual surveys of the airspace around platforms were used to assess the volume of flyby migration traffic and to quantify the flight behavior of trans-Gulf migrants.

An important adjunct to our field work on the platforms was the remote observation of migration over the Gulf using land-based radars. Radar operates by emitting a beam of radio waves into the atmosphere and measuring the amount of energy reflected back to the radar unit by any "targets" in the beam's path. The strength of the radar reflection is partly a function of the targets' size and density, and theoretical and empirical models of radar cross section are available which permit one to estimate the density of migrants based on radar reflectivity. The National Weather Service currently operates a national network of S-band Doppler weather surveillance radars known as NEXRAD (Next Generation Radar), including 10 radar sites that provide a nearly complete observational network around the northern Gulf Coast from Brownsville, Texas, to Key West, Florida. Radar reflectivity can be converted into migration traffic rates using theoretical and empirical models of radar cross section provided that one has information concerning the approximate size distribution of the radar scatterers, such as is available from the platform observations.

Migration is profoundly influenced by the weather. To understand the influence of weather on trans-Gulf migration and platform use, we developed a synoptic climatology to relate large-scale weather patterns over the Gulf to variability in trans-Gulf migration and platform use. Our synoptic typecasting scheme was a slight modification of systems previously developed for the northern Gulf Coast, and recognized the following eight synoptic-scale weather types, which are hereafter indicated by their abbreviations in boldface for easy recognition: 1) Gulf Front (**GF**); 2) East Coast Low (**ELOW**); 3) Midwest Continental High (**MCH**); 4) Eastern Continental High (**ECH**); 5) Bermuda High (**BH**); 6) Gulf High (**GH**); 7) Tropical Low (**TLOW**); and 8) Not Determined (**ND**). Weather over the Gulf during this study usually followed a predictable cycle: As the center of an anticyclone drifted eastward across the continent and out over the Atlantic Ocean, winds over the northern Gulf veered from NE (**MCH**) to E (**ECH**) and eventually to SE (**BH**). Eventually a cyclone moved eastward and a front passed over the Gulf (**GF**) bringing winds from the NW. Following frontal passage, winds over the Gulf were dominated by the departing cyclone (**ELOW**) until a new anticyclone approached and the cycle repeated. Occasionally the cycle was interrupted when the anticyclone drifted out over the Gulf (**GH**), usually resulting in light winds over the northern Gulf. During the summer and fall, tropical weather systems (**TLOW**) often developed in the Gulf or entered the Gulf from the east, usually bringing strong winds and foul weather.

Prior to this study, the conventional wisdom had been that spring trans-Gulf migration involves a roughly straight-line, shortest-distance flight from the Yucatan Peninsula to the upper Gulf Coast. Our results support parts of this scenario but also indicate that the situation is considerably more complex. Backtracking from radar images and arrival times on platforms indicates that most spring migrants initiate their flights from the Yucatan Peninsula and/or the northern coast of the Isthmus of Tehuantepec. Radar and direct observational evidence indicates that most trans-Gulf migration takes place over the western Gulf and suggests that the route of migrants is curvilinear and divergent, veering from a probable mean heading of northwest at points of origin, to north off the south Texas coast, to northeast off the Upper Texas Coast and Louisiana. Large flights are usually associated with Eastern Continental High (**ECH**) or Bermuda High (**BH**) synoptic weather patterns, in which winds similarly veer clockwise around the western Gulf. We therefore suggest that the route of trans-Gulf migrants is influenced by the availability of tailwinds, with migrants attempting to minimize the time or energy expenditure required for crossing.

This hypothesis is strengthened by the finding that centers of offshore abundance as well as areas of eventual landfall varied in concert with synoptic weather. On **ECH** days when winds typically had a stronger westward component over the southern Gulf and often maintained a westward component over the northern Gulf, migrants were most abundant on platforms in the far western Gulf and landfall was usually along the Texas coast. In contrast, on **BH** days, when winds had a weaker westerly component over the southern Gulf and usually an eastward component over the northern Gulf, peak offshore abundance shifted eastward and landfall was more likely to take place farther east along the northern Gulf

Coast, occasionally as far as the Florida Panhandle. All available evidence indicates that the main migration stream is at least partially "steered" by synoptic-scale winds.

In addition to being subject to geographic displacement via steering by synoptic winds, the migration stream itself showed evidence of having a complex geographic structure. In at least several species of warblers, females apparently take a more direct route across the Gulf, and males tend to take a more westerly route. Species with different goals prefer to depart under different synoptic weather types.

The diel timing of spring trans-Gulf migration followed a predictable pattern that was evident both in radar imagery and from direct visual observations on the platforms. Spring migration over the northern Gulf began between early morning and early afternoon, peaked 3-4 h after first detection, and continued until 7-12 h after first detection. Patterns of diel timing varied geographically and were related to weather, again consistent with a strong synoptic steering influence on migration routes across the Gulf.

The bulk of spring trans-Gulf migration detected by radar occurred between March 25 and May 24, but very large flights (>25 million migrants) occurred only in the 3-week period from April 22 to May 13. Waterfowl and herons peaked by early April. Shorebirds had widely varying migration schedules, with different species peaking as early as mid-March and as late as the end of May. Landbird migrants showed peaks throughout the season, but a majority of species peaked in the second half of April. Theoretical analyses of radar data yielded estimated total seasonal estimates of 316 million trans-Gulf migrants in spring 1998 and 147 million trans-Gulf migrants in spring 1999. In both years, about two thirds of all migrants made landfall west of South Marsh Island.

Radar-observed spring migration was characterized by a series of pulses and tended to be "all-or-nothing", i.e., either significant trans-Gulf migration was evident on radar or else it was essentially entirely absent. Dramatic hiatuses in radar-observed migration were always associated with strong cold fronts that penetrated deep into Mexico and set up persistent northerly winds over most of the Gulf. Conversely, radar-observed migration peaks were almost strictly associated with **ECH** and **BH** days.

Fall trans-Gulf migration was more difficult to study because the extensive presence of aerial insects precluded quantitative interpretation of radar imagery. In addition, one of the two field seasons was partly compromised by prolonged absences from the platforms due to obligatory evacuations in response to developing tropical weather systems. Nevertheless, we argue that the heaviest trans-Gulf migration traffic in fall originates from the stretch of the northern Gulf Coast running eastward from Alabama. Although we were constrained from sampling much of this area by the absence of platforms in the eastern Gulf during the study period, our contention is supported by observed longitudinal trends in abundance and age ratios. Southbound "fall" migrants were observed as early as May 20 and as late as January, but the vast majority of the migration occurred from mid-August to early November. There seemed to be several phases in the fall migration. During the early fall, migration by long-distance migrants appeared to be obligate and was not strongly influenced by weather. Later in the fall, major trans-Gulf movements of shorter-distance migrants were generally associated with cold fronts and northerly winds. Direct observations at the eastern-most platform indicated that the direction of flight was most often due south but varied from south-southwest to south-southeast. As with spring, variation in the direction of travel was clearly influenced by wind.

We also detected considerable fall migration over the far western Gulf, where flight direction usually had a westerly component. The western-Gulf route was used by a high proportion of juveniles, and appeared to represent a risk-averse migration strategy favoring a shorter, less risky overwater flight leg at the expense of a more circuitous overall migration route. We suspect that many of the adults traveling over the western Gulf were individuals that reached the northeastern Gulf Coast with inadequate fat stores for a direct trans-Gulf and worked their way westward along the coast, perhaps stopping over along the way.

One of the interesting features of the fall migration offshore was the frequent occurrence of a variety of species that do not typically winter south of the northern Gulf Coast. These species were evidently mostly "overshoots" that inadvertently traveled past their intended destinations and found themselves unexpectedly over water at first light, or else circum-Gulf migrants that inadvertently drifted eastward over the Gulf during nocturnal flight. Accordingly, these species were often observed flying north or west during daylight hours, presumably trying to get back to land.

The year-round observations on one platform indicated that northbound ("spring") trans-Gulf migration spans late January to early June, and southbound ("fall") trans-Gulf migration and overshooting spans early July to early December. Surprisingly, we found that northbound and southbound migrations overlapped temporally at the extremes: The latest southbound migrant recorded during the study (Common Snipe) occurred on 28 January, and the earliest northbound migrant (Purple Martin) occurred the following day. Southbound migration of Purple Martins began in late April and southbound shorebird migration began in late May, well before the latest northbound migrant was recorded on 8 June (Northern Waterthrush). Overwater movements during the brief interim periods between spring and fall migrations (mid-December to mid-January, mid-June to early July) seemed to be dominated by herons traveling along an east-west axis. The nature of these movements is currently unknown.

Death of migrants by starvation was fairly common in the spring. Dead birds in spring lacked any trace of fat and had conspicuously protruding keels, indicating that they had begun to catabolize nonfat dry body components prior to arrival on the platforms. Water consumption by trans-Gulf migrants was very rare, indicating that water is not a limiting factor to trans-Gulf migrants.

Platforms have three primary proximate impacts on migrant birds: 1) they provide habitat for resting and refueling; 2) they induce nocturnal circulations; and 3) they result in some mortality through collisions.

Platforms appeared to be suitable stopover habitats for most species, and most of the migrants that stopped over on platforms probably benefited from their stay, particularly in spring. Many of these migrants were able to feed successfully, and some appeared to achieve rates of mass gain that exceeded what is typical in terrestrial habitats. Even the individuals that do not feed probably benefit physiologically from the availability of the platforms. Migrants may be affected by sources of fatigue other than total depletion of fat stores, such as excessive accumulation of lactic acid, failure of the nerve-muscle junction, or upset of central nervous coordination. These types of fatigue may be eliminated by simple rest. Many of the migrants that rested quietly on the platforms for hours to days were probably recovering from such sources of fatigue.

Migrants used platforms in highly nonrandom ways and selected specific platform microhabitats (i.e., used alternative microhabitats nonrandomly), much in the same way that they select specific habitats during terrestrial stopovers. Preferred platform microhabitats were species-specific and generally consistent between spring and fall.

Platforms may facilitate the evolution of trans-Gulf migration strategies in certain species by providing "steppingstones" that allow incipient migrants to cross the Gulf successfully via a series of shorter flights. Cattle Egrets colonized eastern North America only in the last half-century, but have already become one of the most common species on platforms. White-winged Doves and Eurasian Collared-Doves are rapidly evolving trans-Gulf migration strategies in concert with population explosions and major range expansions into the southeastern United States.

Peregrine Falcons are perhaps the most striking beneficiaries of platforms. This species, which formerly was near extinction, underwent a dramatic population recovery that was temporally coincident with the period of fastest expansion of the platform archipelago in the Gulf. The majority of juveniles in the North American population of this species now uses oil platforms in the northern Gulf during the fall for resting and hunting. Their behavior and the similarity of ecological circumstances to the Mediterranean Sea, where a related species has evolved a strategy of breeding on islands during the fall when abundant trans-Mediterranean migrant landbird prey are available for provisioning young, suggests that Peregrine Falcons might eventually establish a breeding population on the Gulf platform archipelago.

Migrants sometimes arrived at certain platforms shortly after nightfall and proceeded to circle those platforms for variable periods ranging from minutes to hours. These circulations clearly occurred because nocturnal migrants were attracted to platform lights, and tended to occur on overcast nights. It is believed that circulations are maintained when birds get inside the cone of light surrounding the platform and are reluctant to leave, seemingly becoming trapped by the surrounding “wall of darkness” and the loss of visual cues to the horizon. Circulations put birds at risk for collision with the platform or with each other, and result in non-useful expenditure of energy.

Collisions with platforms were most common in fall because most migrants were aloft over the platforms during hours of darkness in that season. Available information suggests that the platform archipelago may cause roughly 200,000 collision deaths per year, which is negligible compared to other anthropogenic sources of mortality. However, several lines of evidence suggest that future development of the eastern Gulf of Mexico may result in a disproportionately large increase in collision mortality in fall trans-Gulf neotropical migrants.

We provide six specific recommendations for the Minerals Management Service and other parties concerned with trans-Gulf migration and the impact of offshore oil and gas activities on birds:

1. Attention should be paid to the possibility of developing and maintaining a network of decommissioned platforms as permanent “observatories” for long-term ecological research. In addition to facilitating the long-term monitoring of migratory bird populations, such observatories would permit studies of seabirds, insects, fishes, meteorology, oceanography, and other subjects. Economic feasibility of such a project would be made possible by cost-sharing among a wide variety of agencies and organizations.
2. We suggest that the Minerals Management Service should consider implementing an ongoing platform monitoring program in the eastern Gulf of Mexico as that area is developed by the petroleum industry. Our findings suggest that the heaviest trans-Gulf migration in fall emanates from the stretch of the northern Gulf Coast running eastward from Alabama, and that neotropical migrants over the eastern Gulf may be particularly vulnerable to collisions with platforms. The observer program operated by the National Marine Fisheries Service to monitor catch and bycatch in commercial fisheries may serve as a useful model for developing an analogous program to monitor mortality (= “bycatch”) on eastern Gulf platforms.
3. The impact of nocturnal circulation events on both spring and fall trans-Gulf migrants remains poorly known, and this phenomenon should be examined in a focused observational study using night-vision optics and thermal imaging equipment. The goals of such a study should be to quantify in greater detail the dimensions of the circulation phenomenon, to try to determine why some platforms often induce circulations and others never do, to assess the rate of turnover during major circulation events, and to model the energetic impacts on migrants.

4. If fall collision mortality in the eastern Gulf proves to be significant or if results from the study of circulations suggest that the adverse impacts of this phenomenon should be addressed, experiments should be undertaken to evaluate the role of different color schemes and lighting regimes in the attraction of migrants to platforms. Simple changes in light signatures have resulted in dramatic reductions in avian attraction and mortality at tall lighted structures on land, and would presumably be equally effective at sea.
5. Production of a colorful informational brochure about trans-Gulf migration for distribution to offshore workers and other people involved in the industry would be a useful way to promote a wider awareness of the ecological importance of the Gulf, and may be an incentive to platform workers to help maintain a safe environment for avian visitors to platforms.
6. Biologists interested in the ecology and conservation of trans-Gulf migrants should initiate outreach efforts to involve international colleagues in the development of a network for information exchange concerning events in all geographic sectors of the Gulf, since trans-Gulf migration occurs over waters subject to hydrocarbon development governed by other nations (Mexico, Cuba).

PART 1

BACKGROUND

Chapter 2

Introduction

Robert W. Russell

2.1 BACKGROUND AND OBJECTIVES

Each spring, vast numbers of landbirds migrate northward across the Gulf of Mexico en route to breeding habitats in the United States and Canada from their wintering quarters in the neotropics. Following a short breeding season in the north, most of these birds return southward across the Gulf, their numbers then augmented by offspring produced over the summer. From the standpoint of sheer numbers, these annual trans-Gulf migrations constitute one of the great wildlife events of the world. Nevertheless, many basic aspects of the migrations have remained poorly known until now; indeed, until the 1950s, the very idea that birds routinely and "intentionally" migrate across the Gulf was treated with skepticism by some respected scientists (e.g., Williams 1945, 1947, 1952).

Scholarly studies of the trans-Gulf flights — based largely on indirect evidence and coastal observations — were initiated in the 1940s by George Lowery (1945, 1946, 1951) at Louisiana State University. Those early studies, together with subsequent work by Lowery's students and colleagues (e.g., Buskirk 1968; Hebrard 1971; Gauthreaux 1971, 1972; Able 1972), have until now remained the basis for our understanding of trans-Gulf migration.

Radar studies have indicated that the flight pathway of the majority of trans-Gulf migrants in spring is directed toward the coasts of Louisiana and Texas (Gauthreaux 1970, 1971, 1992), and thus over Gulf waters in which are located the majority of offshore oil and gas production facilities. Offshore platforms, which house production equipment and living quarters for personnel, have played a central role in the development of oil and gas resources in the Gulf of Mexico. The history of offshore platforms in the Gulf has been short but dynamic. The first offshore platform was installed in the Gulf of Mexico in 1947. The first multi-platform complex was installed in 1960. By 1974, 800 platforms had been installed in the Gulf. As the number of platforms grew, so did the geographic extent of their distribution offshore. Fixed platform installation depth reached 30 m in 1955, 60 m in 1962, and 300 m in 1978. Production began in waters exceeding 600 m in 1984, and in waters exceeding 1500 m in 1997. The thousands of platforms now located on the continental shelf of the northern Gulf of Mexico make up the largest artificial island system in the world.

One of the most important components of birds' migration strategies is their use of local habitats for resting and refueling while en route. In light of the absence of natural islands or other terrestrial habitats during crossings of the Gulf of Mexico, it seems inevitable that the installation of thousands of artificial islands in the northern Gulf must affect migrants in some fashion. However, to date, no systematic studies had examined the influence of Gulf platforms on trans-Gulf migrating birds.

Beginning in spring 1998, interactions between migrating birds and offshore platforms were investigated by personnel at Louisiana State University, initially based at the Museum of Natural Science and later at the School of the Coast and Environment. This study, funded by the Minerals Management Service (MMS) through a cooperative agreement with the LSU Coastal Marine Institute, had the support of several major oil companies (British Petroleum, ChevronTexaco, ConocoPhillips, ExxonMobil, Newfield Exploration, and Shell Offshore).

The MMS is a bureau within the Department of the Interior that supports marine environmental studies as part of its mission to gather technical information for management decisions concerning mineral resources on the continental shelf. The long-term survival of migratory birds is of considerable concern to the Department of the Interior. Long-term monitoring of populations in the eastern United States has suggested that major declines of some forest-dwelling species may be underway (e.g., Robbins et al. 1989; Terborgh 1989; Askins et al. 1990; Hill and Hagan 1991; Peterjohn et al. 1995). Because neotropical migrants comprise a large percentage of these breeding birds, a widespread decline in their numbers could seriously reduce the biodiversity of eastern and central North America. Most neotropical migrants travel across the Gulf of Mexico during the spring and/or fall, so documenting the possible influences of offshore platforms on their migrations is an important prerequisite for the development of long-term conservation strategies (Faaborg 2002).

The objectives of this study were to quantify spring and fall trans-Gulf migrations and to evaluate the influence of offshore platforms on trans-Gulf migrating birds. In particular, this study sought to address the following broad questions:

1. Which species are trans-Gulf migrants?
2. Are there specific migration routes across the Gulf of Mexico?
3. When do migrants use platforms for stopovers, and how does the timing of platform use relate to the seasonal and diel timing of trans-Gulf migration as well as weather?
4. How many individual migrants use platforms for stopovers, and how are the numbers of migrants using platforms related to total trans-Gulf migration traffic aloft?
5. What is the condition of migrating birds that stop on platforms, and what factors determine how long they stay?
6. During stopovers, do migrants use platforms in predictable ways?
7. How many migrants that stop on platforms depart successfully versus die there, and why do some birds die?

2.2 SELECTION OF STUDY PLATFORMS

We sought to select platforms for study that were representative of the population of platforms at large, with respect to both structure and geography.

A production platform consists of two major components: an underwater support structure and an above-water production system. The production system comprises a deck or series of decks accommodating production equipment, control buildings, and living quarters. The most commonly used type of production platform in the northern Gulf of Mexico is the fixed-leg platform, which is supported by a rigid metal jacket that is attached to the sea floor with piles. All platforms used in this study (Table 2.1, Figure 2.1) are fixed-leg platforms except Viosca Knoll 786 ("Petronius"), which is a compliant tower. Compliant towers differ from fixed platforms in that the underwater support structure is not a rigid jacket but rather a narrow, flexible tower that can move horizontally and thereby withstand stronger forces of wind and current that are of greater concern in deep water.

Platforms may be categorized into "major structures" and "minor structures." Major structures include traditional fixed-leg platforms as well as more recent innovations such as compliant towers, tension leg platforms, and spars. Minor structures are defined here to comprise caissons and well protectors. All platforms used in this study were necessarily major structures; we were unable to include minor structures in the study because of the lack of housing facilities and other support on those structures. Opportunistic visits to minor structures suggested that they are also used by migrating birds and that most of the findings reported here are also applicable to minor structures, albeit on a smaller scale.

At the conclusion of this study, there were 3881 production platforms in the U.S. Gulf of Mexico, including 2125 major structures (1762 in the Central Planning Area and 363 in the Western Planning Area) and 1756 minor structures (1591 in the Central Planning Area and 165 in the Western Planning Area). The selection of platforms used in this study covered the entire longitudinal range of the platform archipelago (Figure 2.1).

A number of characteristics of platforms were considered to be potentially important factors influencing their use by migrants, but because of the relatively small number of platforms we were able to sample, it was not possible to incorporate all factors into a rigorously blocked study design. Consequently, it is necessary to consider the possible impact of these factors on a platform-specific basis.

One potentially important factor is the distance of a platform to the nearest shore. We expected that tired spring migrants might be more likely to use the first platforms they encounter during northbound flight across the Gulf, i.e., platforms farthest from the northern Gulf Coast. Similarly, we expected that spring migrants might be less likely to use platforms very close to shore since natural habitats would often be visible to an airborne migrant over such platforms. Our study platforms vary in distance to nearest shore from 8-204 km. Land is visible to the human eye in appropriate atmospheric conditions from only three of our platforms (PL10, MI622, SP89).

Table 2.1.

Platforms used in this study

	Block/Platform		Location	Water Depth	
Host Company	Abbreviation	Name	(lat N, long W)	(feet)	Year Installed
Shell	PN975	North Padre Island 975-A	26°49’58”, 96°56’24”	156	1987
BP Amoco	MI622	Matagorda Island 622-C	28°06’06”, 96°22’52”	83	1983
Newfield	HI561	High Island 561-A	27°58’54”, 94°30’20”	255	1978
Texaco	GB189	Garden Banks 189-A	27°46’43’’, 93°18’34’’	720	1991
Exxon	VR265	Vermilion 265-A	28°30’45”, 92°27’04”	165	1971
Newfield	SM147	South Marsh Island 147-A	28°13’40”, 92°00’60”	235	1990
Phillips	SM66	South Marsh Island 66-C	28°38’48”, 91°56’15”	129	1967
Mobil	GC18	Green Canyon 18-A	27°56’37”, 91°01’45”	750	1986
Mobil	PL10	South Pelto 10-B	28°56’53”, 90°43’25”	35	1979
BP Amoco	EW826	Ewing Bank 826-A	28°09’48”, 90°21’31”	483	1988
Exxon	SP89	South Pass 89-B	28°40’50”, 89°23’15”	400	1982
Texaco	VK786	Viosca Knoll 786 (“Petronius”)	29°13’44”, 87°46’55”	1754	1998

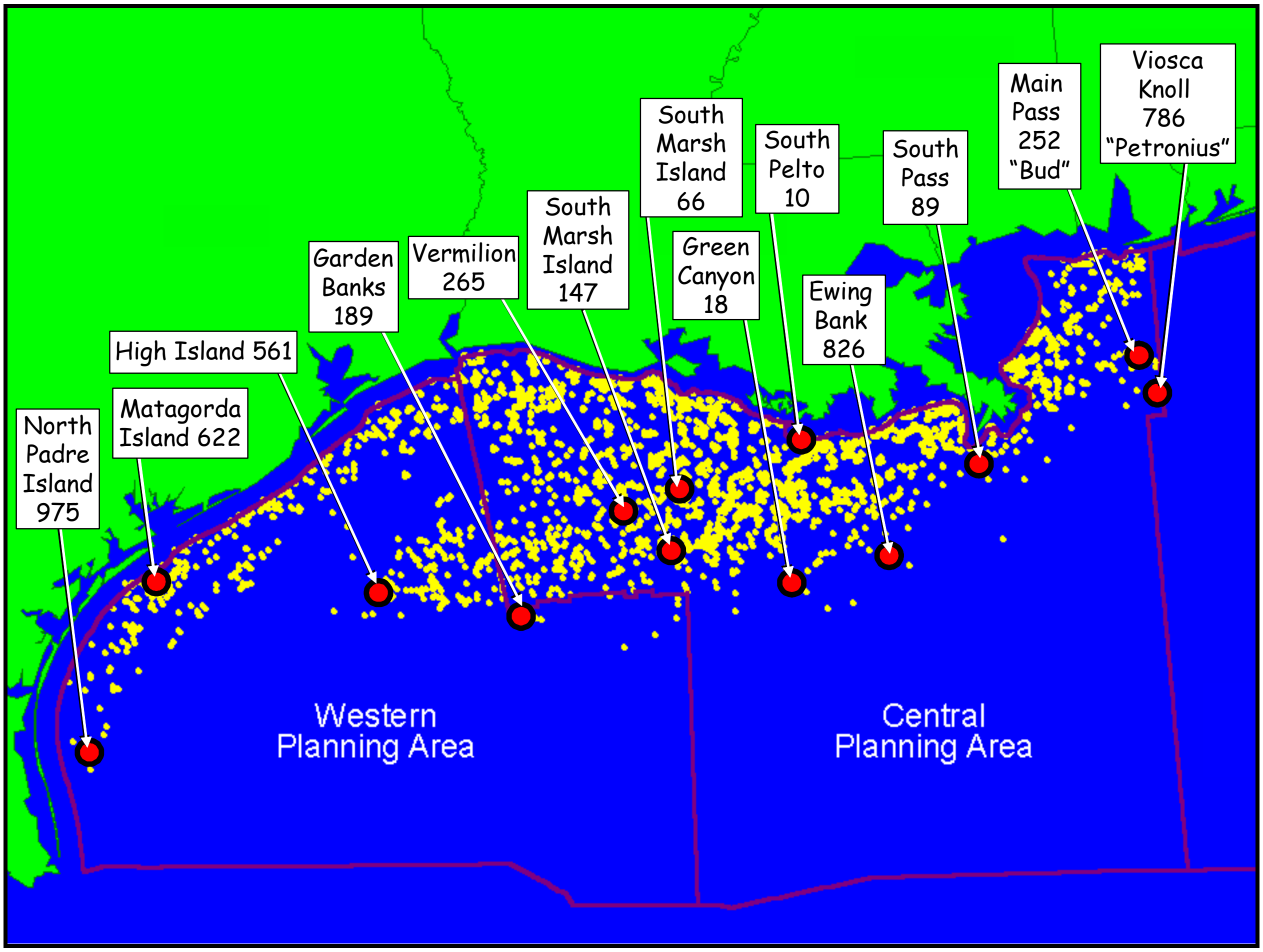


Figure 2.1. Map showing the locations of platforms used in this study (large red circles) relative to the distribution of all platforms in the northern Gulf (small yellow circles).

Another potentially important factor is the density of neighboring platforms in waters surrounding a study platform. The zone of airspace that is closer to a particular platform than to any neighboring platform may be termed the platform's "hinterland" (cf. Cairns 1989). The hinterland is important because it may determine the source population of airborne migrants from which a platform may draw. The extent of the hinterlands of our study platforms varies greatly, with some platforms being extremely isolated and others being embedded within extensive platform "metropolises" (Figure 2.2).

Another potentially important factor is whether a platform is part of a complex. A "platform complex" is defined here as a group of platform structures connected by walkways. Three of our study platforms (PL10, VR265, MI622) are actually multi-platform complexes.

Another potentially important factor is whether a platform flares gas (i.e., has an active flame). Flaring is potentially important because some previous reports have suggested that nocturnal migrants may be attracted to and/or burned in gas flares (e.g., Davies 1940; Sage 1979; Bjorges 1987). Only two of our platforms (SP89, VR265) routinely flared gas during the study.

Distance from shore, extent of isolation, status as a complex, and occurrence of flaring on our study platforms are summarized in Table 2.2.

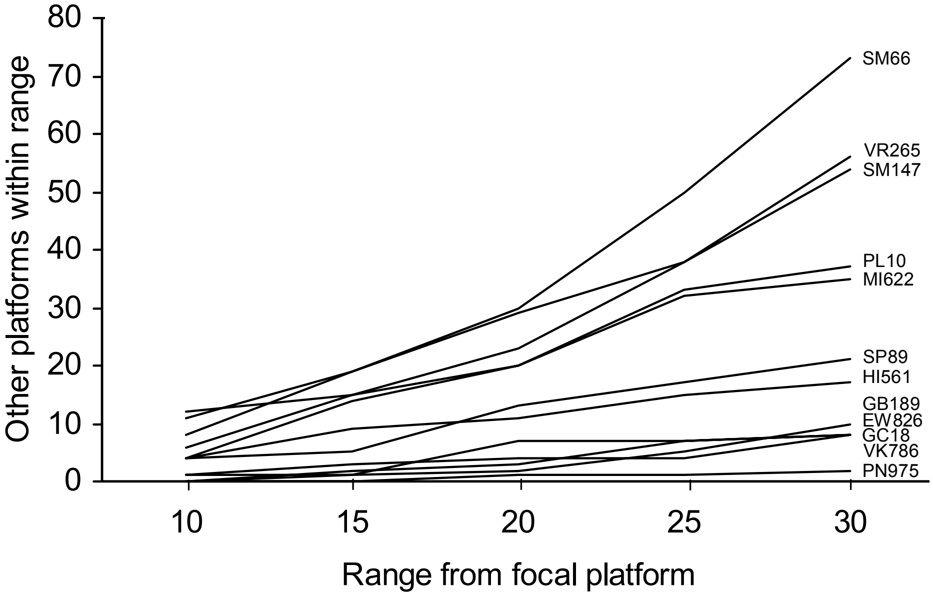


Figure 2.2. Relative isolation of the study platforms. The figure shows the number of platforms located within a given radius of each platform as a function of radius.

Table 2.2.

Selected characteristics of the study platforms

The table shows the distance to the nearest shoreline, degree of isolation of the platform (categorized in three arbitrary levels; see Figure 2.2), whether the platform is actually a complex of platforms, and whether the platform flared gas (i.e., had an active flame) during the study.

Platform	Distance to Nearest Shore (km)	Isolation Category	Platform Complex?	Flaring?
VK786	145	isolated	no	no
SP89	23	moderate	no	yes
EW826	87	isolated	no	no
GC18	154	isolated	no	no
PL10	8	crowded	yes	no
SM66	92	crowded	no	no
SM147	127	crowded[1]	no	no
VR265	116	crowded	yes	yes
GB189	204	isolated	no	no
HI561	134	moderate	no	no
MI622	24	crowded	yes	no
PN975	48	isolated	no	no

[1] However, there are virtually no platforms to the south of SM147.

2.3 SUMMARY OF FIELD OPERATIONS

Standardized field work was conducted during five migration seasons from spring 1998 through spring 2000 (Table 2.3). In spring 1998, five platforms were staffed continuously from mid-March through mid-May with no interruptions. SM147 was substituted for SM66 beginning in fall 1998 due to extensive maintenance activity on SM66. In fall 1998, five platforms were staffed from mid-August through mid-November, but much of September was unfortunately lost to hurricane evacuations. GC18 was substituted for PL10 beginning in spring 1999 due to the sale of the latter by Mobil to Vastar and the unwillingness of Vastar to permit us to continue working on PL10. In spring 1999, five platforms were staffed from late March through early May, with interruption only at GC18 for less than a week due to a contingency on the platform.

The study was expanded considerably in temporal and geographical scope beginning in fall 1999, when ten platforms were staffed from early August through mid-November. A few interruptions of <10 days resulted from hurricane evacuations, availability of personnel, and a family emergency. VK786 was unavailable in spring 2000 due to construction activity, and nine platforms were staffed from early March through late May, with only three interruptions of less than a week caused by illness, a family emergency, and a staffing limitation.

In addition to the standard field program, GC18 was staffed during the winter of 1999-2000 (November 18-December 16, January 6-February 29) and during the summer of 2000 (June 1-August 1). During the fall of 2000, specialized studies of migratory orientation and foraging behavior were conducted on PN975, MI622, and Main Pass 252-A (MP252, also known as “Bud”; 29°21’39”N, 87°53’09”W).

Table 2.3.

Summary of field effort (inclusive dates of field work)

Platforms are listed in order from east to west.

Platform	Spring 1998	Fall 1998	Spring 1999	Fall 1999	Spring 2000
VK786	---	---	---	Aug 11-Oct 14, Oct 16-Nov 16	---
SP89	---	---	---	Aug 4-Oct 20, Oct 27-Nov 17	Mar 7-May 31
EW826	Mar 15-May 14	Aug 13-31, Sept 15-16, Sept 22-25, Oct 1-Nov 9	Mar 18-May 13	Aug 5-Sept 19, Sept 23-Nov 18	Mar 9-May 25
PL10	Mar 16-May 15	Aug 14-31, Sept 7-8, 15-16, Sept 22-24, Oct 2-Nov 1	---	---	---
GC18	---	---	Mar 18-20, Mar 26-May 13	Aug 4-Nov 17	Mar 7-May 31
SM66	Mar 13-May 14	---	---	---	---
SM147	---	Aug 14-31, Sept 5-17, Sept 21-25, Oct 1-Nov 13	Mar 18-May 12	Aug 4-Sept 8, Sept 18-Nov 16	Mar 8-May 10, May 17-31
VR265	Mar 13-May 12	Aug 14-Sep 1, Sept 4-16, Sept 21-26, Oct 1-Nov 17	Mar 18-May 13	Aug 4-Nov 16	Mar 7-May 29
GB189	Mar 13-May 15	Aug 15-31, Sept 3-8,13-16, Sept 21-24, Oct 1-Nov 14	Mar 19-May 12	Aug 4-21, Aug 24-Nov 17	Mar 7-May 27
HI561	---	---	---	Aug 5-Sept 8, Sept 15-Oct 21, Oct 28-Nov 17	Mar 9-May 30
MI622	---	---	---	Aug 4-20, Aug 25-Nov 17	Mar 9-17, Mar 20-May 31
PN975	---	---	---	Aug 6-21, Aug 25-Sept 15, Sept 25-Nov 17	Mar 9-31, Apr 7-May 31
Total platform-days	310	363	277	998	738

Chapter 3

Field Methods

Robert W. Russell

3.1 PLATFORM CENSUSES

The basic field protocol consisted of a standardized, time-designated census conducted by an observer while walking around the platform on a prescribed route. The goal of this "platform census" (PC) was to locate, count, and identify all living birds on the platform at different times during the day. The platform census was repeated identically throughout the day from pre-dawn to post-sunset, allowing us to determine when birds arrived and when they left. When we detected a migrant, we identified it to species and when possible age and sex; we assessed its likely body condition based on factors such as alertness, wariness, vigor, and apparent thermal stress; and we recorded details of its behavior.

This repetitive and highly standardized monitoring scheme permitted us to develop detailed longitudinal case histories for nearly all individuals that undertook extended stopovers on the study platforms. Whenever possible, we attempted to track the stopover of each bird, relying on distinctive plumage characteristics, individual behavioral idiosyncrasies, and sheer hard work when many birds of a given species were present. Nevertheless, it was sometimes impossible to keep track of individual birds when more than two individuals of a given species were present on the platform simultaneously; consequently, our data on stopover durations are slightly biased toward birds that arrived on the platforms during periods of relatively low migration traffic.

3.2 FLIGHT CENSUSES

The platform censuses were intended to provide information on platform use by migrants. Because not all incoming migrants landed on platforms, it was important to obtain independent information on incoming migration traffic. Thus, in addition to the platform censuses, we conducted several time-designated surveys from a fixed point of the airspace over and around the platform. These flight censuses were conducted from a south-facing site during the spring and from a north-facing site during the fall. During flight censuses, observers attempted to locate, count, identify, and follow all visible flying migrants. When we detected a bird in flight, we recorded its flight altitude, ascertained whether or not it approached or attempted to use the platform, and recorded its vanishing bearing (see below for details).

3.3 CENSUS SCHEDULES

In spring, the platform census was repeated identically six times at equally spaced intervals throughout the day from pre-dawn to post-sunset (Table 3.1). The start of PC0 was about nine hours after the expected time of departure of migrants from the Yucatan Peninsula (taken to be the midpoint between the end of evening civil twilight and the end of nautical twilight; Hebrard 1971), and the conclusion of PC5 was about 25 hours after the expected time of departure from the Yucatan. Flight censuses were conducted in late morning and late afternoon to discern between early and late flights; the midday flight census (FCm) was added to the schedule starting in spring 1999. The seawatch census (SEA) was conducted as part of an ancillary study to quantify seabird occurrence in waters surrounding platforms, but data on trans-Gulf migrants were recorded in a fashion identical to the flight censuses. In spring 2000 on GB189 only, we conducted an additional "circulation census" for an hour beginning at the end of evening astronomical twilight to attempt to quantify the nocturnal circulation phenomenon (described in Chapter 16).

Table 3.1.

Schedule of daily field operations in the spring

Census Designation	Time (CST)
Platform census 0 (PC0):	04:00-05:00
Platform census 1(PC1):	07:00-08:00
Seawatch census (SEA):	08:00-08:30
Flight census 1 (FC1):	09:30-10:00
Platform census 2 (PC2):	10:00-11:00
Midday flight census (FCm):	12:30-13:00
Platform census 3 (PC3):	13:00-14:00
Flight census 2 (FC2):	15:30-16:00
Platform census 4 (PC4):	16:00-17:00
Platform census 5 (PC5):	19:00-20:00

The schedule during the fall (Table 3.2) was modified to account for the expectation that most trans-Gulf migrants would be aloft over the platforms at night, and the consequent expectation that rapid changes in ambient light conditions would be important events for migrants. Because of the longer duration of the fall field season and an expectation that transitions in lighting would figure more importantly during the fall, the fall schedule was tied directly to astronomical benchmarks. Thus, the precise clock timing of censuses varied from platform to platform and over the course of the season. The first platform census (PC1) ended at the beginning of morning civil twilight and was intended to quantify the use of platforms at night, since departures were unexpected before morning civil twilight. Subsequent censuses were keyed to sunrise or sunset to facilitate meaningful comparisons among platforms and over the long season. Platform census 4 (PC4) had to be conducted at a fixed time in order to permit observers on all platforms to attend dinner over the entire course of the season. Flight censuses were conducted beginning one hour after sunrise, three hours after sunrise, and five hours after sunrise to attempt to quantify the timing of arrival of diurnal migrants that were expected to depart the northern Gulf Coast at first light. A final flight census was conducted at sunset to attempt to document diurnal migrants that might descend to the platforms at nightfall.

Table 3.2.

Schedule of daily field operations in the fall

BMCT = beginning of morning civil twilight; SR = sunrise; SS=sunset.

Census Designation	Time (CST)
Predawn census (PC1):	BMCT-1 → BMCT
Sunrise census (PC2):	SR → SR+1
Flight census 1 (FC1):	SR+1 → SR+1.5
Seabird census (SEA):	SR+1.5 → SR+2
Platform census 3 (PC3):	SR+2 → SR+3
Flight census 2 (FC2):	SR+3 → SR+3.5
Flight census 3 (FC3):	SR+5 → SR+5.5
Platform census 4 (PC4):	14:00-15:00
Sunset census (PC5):	SS-1 → SS
Flight census 4 (FC4):	SS → SS+0.5
Night census (PC6):	SS+0.5 → SS+1.5

3.4 OPPORTUNISTIC WORK

Flight directional information and general behavioral notes were also recorded opportunistically throughout the day between formal platform censuses.

In addition to censusing live migrants, we salvaged dead birds under a U.S. Fish and Wildlife Service permit to the Louisiana State University Museum of Natural Science. Specimens were frozen on the platforms until transferred ashore for preparation as voucher specimens for the Museum's permanent collections. Tissue samples of selected species were obtained and deposited in the Museum's genetic resources collection, where available to qualified researchers for molecular systematics studies. Additional tissue samples were provided to Mr. Donald Norman for comparative ecotoxicological studies of organochlorine residues in spring versus fall migrants.

3.5 DATA RECORDING

3.5.1 Local Weather

Local ambient weather was characterized at the beginning of each census on each platform using the following schemes.

Overall weather was assigned to one of the following categories:

CP = convective precipitation (e.g., thunderstorms, heavy rain, intermittent heavy rain)
SP = stratiform precipitation (e.g., continuous drizzle with low cloud deck)
F = fog
S = clear (< 25% cloud cover)
PC = partly cloudy (25% ≤ cloud cover < 75%)
O = overcast (≥ 75% cloud cover)

Visibility was estimated on a logarithmic scale:

4 = >10 km
3 = 1-10 km
2 = 100 m - 1 km
1 = 10-100 m
0 = <10 m

When an accurate anemometer was available, precise measurements of wind speed were taken. Otherwise, wind speed was assessed using the Beaufort scale (Table 3.3).

Table 3.3.

Beaufort scale

Beaufort Force	Wind Speed (knots)	Wind Speed km·h-1	Description of Wind	Sea State
0	<1	<1	Calm	Sea like a mirror
1	1-3	1-5	Light air	Ripples only, no foam crests
2	4-6	6-11	Light breeze	Small wavelets (0.2 m); crests do not break, and have a glassy appearance
3	7-10	12-19	Gentle breeze	Large wavelets (0.6 m); crests begin to break, perhaps scattered white horses.
4	11-16	20-29	Moderate breeze	Small waves (1 m), fairly frequent white horses
5	17-21	30-39	Fresh breeze	Moderate waves (1.8 m), many white horses
6	22-27	40-50	Strong breeze	Large waves (3 m), white foam crests; probably some spray
7	28-33	51-61	Near gale	Mounting sea (4 m) with white foam blown in streaks downwind
8	34-40	62-74	Gale	Moderately high waves (5.5 m), crests break into spindrift
9	41-47	76-87	Strong gale	High waves (7 m), dense foam, visibility affected
10	48-55	88-102	Storm	Very high waves (9 m), heavy sea roll, visibility impaired; surface generally white
11	56-63	103-118	Violent storm	Exceptionally high waves (11 m), visibility poor
12	64+	119+	Hurricane	Massive waves (14 m), air filled with foam and spray, visibility bad

3.5.2 Body Condition of Migrants

The apparent physical condition of a migrant during each encounter was assessed using the following scheme:

Migrants were classified as “alive and vigorous” (AV) if they appeared healthy, wary, and vigorous, and exhibited behaviors typical for the species. As a rule of thumb, a bird was assigned to this category if it flushed (flew away) before being approached to within 3 m, or if it spent a good deal of time (>10%) flying around the platform.

Migrants were classified as “alive but tired” (AT) if they were obviously tired. Birds observed sleeping during the day were usually assigned to this category, as were active birds that appeared moderately disheveled from physical exertion. Birds in this category usually flew readily and easily before being approached to within 3 m (if they were awake).

Migrants were classified as “alive but exhausted” (AE) if they exhibited signs of energetic distress, such as lethargy, extreme feather-fluffing, or a noticeably disheveled appearance. As a rule of thumb, a bird was assigned to this category if it could be approached while awake to within 3 m before flying or hopping away.

Migrants were classified as “moribund” (M) if they were alive but could be picked up without resistance, or if they otherwise appeared to be injured or severely emaciated.

3.5.3 Foraging Behavior

Upon each observation, an individual migrant was classified into one of three categories according to foraging behavior:

0 = Did not appear to be looking for food
1 = Appeared to be looking actively for food
2 = Successfully obtained food

If a migrant was ever observed foraging during the course of its stopover, then for the purposes of statistical analysis its foraging status was considered to be positive (i.e., it foraged); if the migrant was never observed foraging, then its foraging status was considered to be negative (i.e., it did not forage). We classified foraging success using similar reasoning. If a migrant was ever observed to obtain food, then it was classified as a successful forager; if it foraged but was never observed to obtain food, then it was classified as an unsuccessful forager.

Drinking behavior was categorized similarly. If a migrant was ever observed drinking during the course of its stopover, then its drinking status was positive; otherwise, its drinking status was negative.

3.5.4 Microhabitat Use

Based on initial observations that migrants appeared to be selecting specific “habitats” on the platforms, we expanded the observational program to include microhabitat use beginning in fall 1999. Microhabitat use was assessed using the following scheme, which incorporates both physical structure and how the birds use the structure:

Exposed Perch (EP): Pipe rails, antennas, communication towers, flare booms, building roofs, helipad edges, cranes, edges or peaks of open equipment such as machinery or tanks. Birds used EP habitats to rest and sleep on and to forage from.

Open Deck (OD): Ordinary steel decks, woods decks, flat building roofs, and helipad decks. Birds used OD habitats to rest, sleep, and forage on. Birds were assigned to this habitat if they were spending most of their time on the deck; for example, a bird that flew down from a railing to grab a moth from the deck would be assigned EP habitat, not OD.

Grating (GG): Open grating composing decks, sections of decks, and stairs, and sometimes functioning as both deck and ceiling. Birds used GG habitats to rest and sleep on and to forage in, under, and over. On parts of the platforms squares of grating are interspersed with squares of open deck. If a bird were just hopping around indiscriminately, it was generally assigned OD habitat; however, if it engaged in probing in and around the grating, then it was assigned GG habitat.

Low Cover (LC): Piles of grating, pipe, or rope; spools of wire, cable, or hose; boxes, machinery, tanks, and piping. Substrates composing LC habitat may extend from the deck up to a substantial height (~5 m), but this habitat specifically excludes the beams and large pipes running underneath but close to other floors or decks (which constitute HC habitat). Birds used LC habitats to rest, sleep, and forage in. Birds often loitered around low cover but hopped out onto the deck as well. If they seemed to be centered in the cover, occasionally venturing out from it, then they were assigned LC habitat; if they were in the cover primarily when disturbed, then they were assigned OD habitat.

High Cover (HC): Beams and pipes running just below overhead decks and ceilings. Birds used HC habitats primarily for resting and sleeping, and sometimes for foraging. Most birds assigned HC habitat were sitting on the lips of high beams.

Trapped (TR): Overhead beams or grating, sheds, warehouses, and breezeways. Birds assigned to TR "habitat" were trapped and unable to escape, at least temporarily; they generally showed distress, trying to escape or resting between efforts to escape. On some platforms, the well bay was especially likely to trap birds during darkness.

We recorded the habitat of an individual migrant when it was first detected on the platform ("initial habitat") and when it was observed for the second time ("second habitat"). In addition, we assigned a "usual habitat" to longer-staying individuals; this was a subjective assessment based on repeated experience with an individual over the course of its stopover.

3.5.5 Cause of Death

When a dead migrant was discovered or a death was observed directly, the cause of death was assigned to one of the following categories:

Starvation: Starvation victims were evident by the protruding keel and vestigial quantities of breast muscle.

Predation: The principal predators of migrants were Peregrine Falcons (*Falco peregrinus*), Merlins (*Falco columbarius*), American Kestrels (*Falco sparverius*), Sharp-shinned Hawks (*Accipiter striatus*), Loggerhead Shrikes (*Lanius ludovicianus*), and Laughing Gulls (*Larus atricilla*).

Collision: Collision victims were typically found below tall structures such as flare booms, communication towers, cranes, drill derricks, tanks, helipads, and platform legs. Indications of trauma were usually evident (external bleeding, blood in mouth, feathers missing, broken neck).

Drowning: Exhausted migrants in flight were sometimes observed splashing in the water and drowning as a result.

Oiling: Birds discovered dead with >10% of plumage fouled by oil were assigned to this category, although the precise cause of death (ingestion, insulation failure, etc.) was usually impossible to determine.

Burning: Birds burned in gas flares had obviously singed plumage.

Air Intake Fans: Birds attempting to pass through compressor fans and generator fans were often decapitated and either became lodged within the fans or else fell directly below the fans.

Entrapment: Birds sometimes got their legs or toes caught in tight spaces between grating squares and subsequently died of exposure or starvation. Birds landing in a strong wind evidently could get blown over and have their head caught in grating slats, and subsequently die from cervical dislocation or exposure.

Poisoning: Birds observed consuming toxic chemicals and later found dead with no other evident cause of death were assumed to have been poisoned.

Workers: Platform workers sometimes inadvertently killed tired or naïve birds by sitting on them, kicking them, or stepping on them.

Unknown: Occasional fat individuals were found dead with no signs of trauma, oiling, or other problems. Some of these individuals probably died from ingestion of toxic materials, but we were unable to assign a cause of death with confidence.

3.5.6 Flight Behavior

General flight behavior of birds passing by the platform without landing ("flybys") was characterized as follows:

F = Flew by without approaching or attempting to land on the platform.
A = Approached the platform by deviating from a straight course, but did not land.
CR = "Cruising". This category was applicable for individuals that never landed but that associated with the platform in a more persistent way than could accommodated under the "Approached" category. CR was generally used only for aerial insectivores (swallows, swifts, nighthawks) and raptors that appeared to be foraging around the platforms.

Flight altitude (above sea level) was estimated using the following scale:

4 = >500 m (difficult to see with binoculars)
3 = >100 m (easily overlooked with naked eye)
2 = 10-100 m
1 = 1-10 m
0 = skimming the sea surface (<1 m)

Vanishing bearings of flybys were recorded on a 16-point scale (N, NNE, NE, ENE, etc.). To minimize parallax error, we followed all flybys for as long as possible with binoculars, and recorded the vanishing bearings when the birds disappeared from view.

In addition to the flybys, we recorded flight directions of all migrants observed arriving on or departing from the platforms. Arrival bearings were recorded only for birds arriving directly from over the water and initially detected far enough out that a bearing could be determined with a reasonable degree of confidence.

Chapter 4

Radar Methods

Robert W. Russell and Sidney A. Gauthreaux, Jr.

4.1 INTRODUCTION

(by Robert W. Russell)

An important adjunct to our field work on the platforms was the remote observation of migration over the Gulf using land-based radars. Radar (RAdio Detection And Ranging) operates by transmitting a radio signal into the atmosphere. If there are objects in the path of the radio beam, the beam is scattered and part of the energy is reflected back to the radar site, where a wide-dish antenna captures the signals and sends them through a receiver for processing. The amount of energy returned to the receiver is partly a function of the targets' size and density. Theoretical and empirical models of radar cross section are available which permit one to estimate the density of migrants based on returned energy (Wilson et al. 1994; Russell and Wilson 1997). Thus, radar can ideally provide both large-scale distributional information as well as quantitative measures of the local abundance of bird and insect migrants. Doppler radars have the additional capability of being able to determine the radial component of the velocity of targets by measuring frequency shifts in the reflected signal caused by the targets' motion.

The National Weather Service operates a national network of modern WSR-88D Doppler weather surveillance radars known as NEXRAD (Next Generation Radar), which operate at a wavelength of 10.5 cm (S-band) with a beamwidth of 0.96° and a peak power output of 750 kW. Currently there are 10 NEXRAD radars in operation at sites around the Gulf Coast, providing a nearly complete observational network stretching from Brownsville, Texas, to Key West, Florida. We opportunistically accessed high-resolution, near-real-time radar imagery via the internet at <http://www.intellicast.com> and at <http://www.weathertap.com>. The near-real-time imagery was used to focus observational effort in the field and to determine large-scale geographic patterns of migration. In addition, the raw data products from two NEXRAD sites were downloaded to optical disk under an MMS subcontract to Dr. Sidney Gauthreaux at Clemson University (see Chapter 4.3). These raw data were used to analyze the timing of migration and to estimate the abundance of migrants involved in the trans-Gulf migrations.

4.2 RADAR THEORY

(by Robert W. Russell)

Radar operates by emitting a beam of radio waves into the atmosphere and measuring the amount of power reflected back to the radar unit by any "targets" in the beam's path. The radar equation expresses average returned power (P_r) as a function of distance to the targets (r) and the total reflectivity of the targets:

$$\overline{P}_r = \frac{C \cdot |K|^2 \cdot Z}{r^2}, \qquad (4.1)$$

where C is a constant that depends on characteristics of the radar unit (wavelength [λ], peak transmitted power, antenna gain, beam width, and pulse length), K is a parameter dependent on the complex index of refraction, and Z is the "reflectivity factor." The value of $|K|^2$ is 0.93 for water. Assuming that the radar targets are spherical particles with diameter D_i such that $D_i/\lambda \lesssim 0.1$ (i.e., under the "Rayleigh approximation"), Z is defined as the summation over a unit volume of the particle diameters raised to the sixth power:

$$Z = \sum_{vol} D_i^6. \tag{4.2}$$

If the particle size distribution is known, then by measuring P_r and r, one can use equations 4.1 and 4.2 to calculate the target density.

When the Rayleigh approximation is not applicable or if it is not known whether it is applicable, Z is written as Z_e (the effective reflectivity factor) and the size of a target must be characterized instead by its radar cross section. Radar cross section is a measure of a target's backscattering efficiency, and therefore describes the size of a target as "seen" by radar. More formally, radar cross section is defined as "the area of a [hypothetical] target that reflects back isotropically and would have caused the same return power as the original [i.e., actual] target" (Levanon 1988). Z_e can be expressed in terms of the volume reflectivity (η):

$$Z_e = \frac{\eta \cdot \lambda^4}{\pi^5 \cdot |K|^2}, \tag{4.3}$$

where η is defined as the summation of the radar cross sections (σ_i) of all the scatterers in a unit volume of space scanned by radar:

$$\eta = \sum_{vol} \sigma_i. \tag{4.4}$$

The reflectivity factor Z_e has units of $mm^6 \cdot m^{-3}$. By convention, reflectivity factors are usually reported in the logarithmic form (dBZ_e), where

$$dBZ_e = 10 \cdot \log_{10} Z_e. \tag{4.5}$$

For the NEXRAD radars used in this study ($\lambda = 10.5$ cm), equation 4.3 can be rewritten as:

$$\eta = 23.4 \cdot Z_e, \tag{4.6}$$

where η has units of $cm^2 \cdot km^{-3}$. The volume density of bird migration can be calculated directly from equation 4.6 if the radar cross section of the bird targets is known, and the flux of migration can then be calculated from the measured air speed (S) of the migrants. Assuming an average cross section of $\sigma_{\bar{x}}$ (units = cm^2), migration flux can be estimated by:

$$\text{flux} = \frac{43.3 \cdot Z_e \cdot S}{\sigma_{\bar{x}}}, \tag{4.7}$$

where S is given in knots (the standard unit reported in NEXRAD data) and flux has units of birds $km^{-2} \cdot h^{-1}$.

Unfortunately, the radar cross section of a real target generally does not coincide with its actual physical area. Cross sections of targets with regular geometric forms can be calculated from theoretical equations (Ruck et al. 1970). In practice, however, cross sections of biological organisms (which have very complex morphologies) must be determined empirically, and relatively few such empirical determinations have been made.

Russell and Wilson (1997) analyzed all available literature data on radar cross sections of arthropods and birds (almost all obtained with X-band radars) and found a biphasic relationship, with species having body length ≤10 mm (microinsects) showing a stronger pattern of mass-dependence of their cross sections than longer species (macroinsects and birds). The best-fitting model relating X-band radar cross section to body length (L, units = mm) and to wet body mass (M, units = g) was:

$$\sigma = e^{10.12} M^{3.12} \qquad (L \leq 10) \qquad (4.8)$$

$$\sigma = e^{0.13} M^{0.40} \qquad (L > 10) \qquad (4.9)$$

To be useful for analysis, the X-band cross sections predicted by this empirical model must be scaled to S-band cross sections as would be observed by NEXRAD radars. Complicating matters, the relationship between radar cross section and actual target size varies with the radar wavelength (λ), with the form of this relationship depending on the ratio of λ to target size. In the Rayleigh scattering region ($L/\lambda \lesssim 0.1$), cross section is inversely proportional to the fourth power of radar wavelength:

$$\sigma \propto \lambda^{-4}. \qquad (4.10)$$

This relationship obtains because targets that are small compared to the radar wavelength scatter energy nearly isotropically. In contrast, larger targets scatter energy in a more directive pattern, often scattering considerably more energy in the forward direction rather than back toward the radar. This is called Mie scattering and results in a complicated radar return that shows large fluctuations and no simple wavelength dependence (Skolnik 1962; Konrad et al. 1968).

In the Rayleigh region, scattering cross section varies approximately with the square of the target's mass. Microinsects approximated this pattern of mass-dependence and can thus be characterized as Rayleigh scatterers. However, longer organisms show a much weaker pattern of mass-dependence and clearly fall into the Mie scattering region, so Rayleigh scaling cannot be applied to birds. Instead, wavelength-dependency of birds' cross sections was estimated to be

$$\sigma \propto \lambda^{1.21} \qquad (4.11)$$

from a model fit to published multiwavelength cross section data on Boat-tailed Grackles (*Quiscalus major*), House Sparrows (*Passer domesticus*), and a Rock Dove (*Columba livia*). Combining equations 4.9 and 4.11 yields the following equation for estimating S-band radar cross sections of birds:

$$\sigma_s = 4.8 \cdot M^{0.40} \qquad (4.12)$$

When information is available on the species composition of a migratory flight, equations 4.7 and 4.12 can be used to estimate migration traffic rates.

4.3 QUANTIFICATION OF NEXRAD IMAGERY

(by Sidney A. Gauthreaux, Jr., and Robert W. Russell)

Intensive collection of weather and radar data for the project began on March 1, 1998. Radar data came from NEXRAD stations at Slidell (LIX) and Lake Charles (LCH), Louisiana (Figure 4.1). Once every hour a base reflectivity product and a base velocity product were downloaded to a computer in the

Clemson University Radar Ornithology Laboratory (CUROL). The base reflectivity product is an image showing the distribution and the reflectivity (measured in dBZ_e) of targets in the atmosphere within 230 km of the radar. The base velocity product is an image showing the radial velocity (the component of a target's velocity traveling along the radar beam and measured in knots) of the same targets. The radar data files were provided by a NEXRAD Information Distribution Service (NIDS). The files were downloaded by modem from Unisys, Inc., during 1998 (from March 1 at 00:00 UTC through May 31 at 23:00 UTC and from August 15 at 00:00 UTC through November 15 at 23:00 UTC) and via satellite from Marta Systems, Inc., in 1999 (March 1 at 00:00 UTC through May 31 at 23:00 UTC and from August 15 at 00:00 through November 15 at 23:00 UTC). All files were archived on CDs and are stored at CUROL.

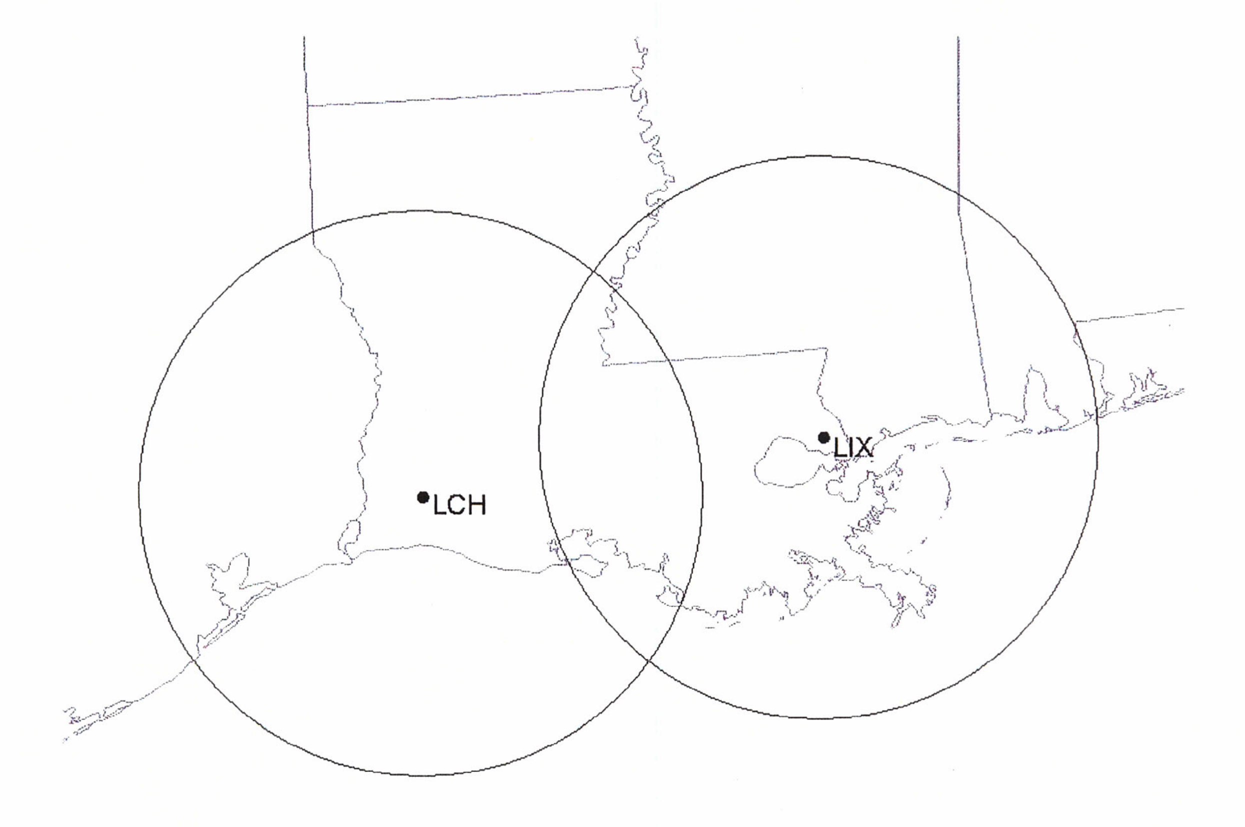


Figure 4.1. Locations of the Lake Charles (LCH) and New Orleans (LIX) NEXRAD sites. The circles delimit the normal surveillance range of 230 km.

Because data on winds aloft are critically important for the discrimination of different types of targets (e.g., insects, dust and smoke, birds), we downloaded skew-t text files for LCH and LIX via the internet twice each day. The data were gathered by radiosondes launched by the National Weather Service at 23:00 and 11:00 UTC, and the data for each height above the station include the barometric pressure, wind direction and speed, temperature, and dew point temperature.

To identify targets most likely to have been migrating birds in base reflectivity images, we used a Netscape plug-in that opens Level III data (NIDS files) and examined the patterns of echoes in the images. Unlike weather echoes, echoes from birds, bats, and insects frequently produce a disk-like or an annular pattern of echoes with the radar site at the center. Although the patterns may be saturated and extend out to a range of 185 km when heavy movements are underway, the patterns are usually stippled, indicating that not all pulse volumes in a radar scan contain targets. To confirm that echoes were from migrating birds, we used the Netscape plug-in to open base velocity files and we filtered out pulse volumes with radial velocities within 15 knots of balloon-measured wind velocity for the same altitudes. Because most insect movements rarely exceed velocities of 15 knots above wind speed, when targets were moving in excess of 15 knots above following winds, or moving against a head wind, we concluded that the targets were likely birds.

Precipitation, beam bending from superrefraction, strobing, and chaff confound the determination of echoes from birds by masking echoes or disrupting the echo pattern (Figure 4.2). Insects and other slow moving aerial biota in the atmosphere also present a serious problem, contributing to pulse volume reflectivity. Slow targets like insects have low base velocities or drift with the wind at or near ambient wind speed (Figure 4.2). In cases when these issues arose, we noted such conditions in the database.

Once we classified an image as depicting birds, we used a pixel counting program (FullPixelSearch) to quantify pixels of different reflectivity (dBZ_e). We first drew a 50-by-50 pixel square over an area of maximum reflectivity within the echo pattern produced by birds and within a range of 55 to 110 km (Figure 4.3). We then counted the number of pixels in each reflectivity category. In cases when weak strobes, scattered precipitation, or insects (or a combination of the three) occurred, we placed the square within an area that maximized the reflectivity from birds and minimized the contamination. We followed a similar procedure for counting pixels in radial velocity images by placing the square in the area of greatest velocity. Because radial velocity measures the component of target speed along a radius from the radar site, the values within the box represents the true ground speed of a field of uniformly moving targets. We recorded in the database the coordinates of the top, left corner of every square because we placed the square in different positions on different reflectivity and velocity images. Because pixel values are provided in dBZ_e ranges rather than as precise values of Z_e, we converted pixel counts into average reflectivity factors using back-transformed range midpoints and the following equations:

Clear-air operating mode:

$$\begin{aligned} Z_e = {} & (1/2{,}500) \cdot \{[4.41 \cdot (\text{4-8 } dBZ_e \text{ count})] + [11.08 \cdot (\text{8-12 } dBZ_e \text{ count})] \\ & + [27.83 \cdot (\text{12-16 } dBZ_e \text{ count})] + [69.91 \cdot (\text{16-20 } dBZ_e \text{ count})] \\ & + [175.59 \cdot (\text{20-24 } dBZ_e \text{ count})] + [441.07 \cdot (\text{24-28 } dBZ_e \text{ count})] \\ & + [1{,}107.93 \cdot (\text{28-32 } dBZ_e \text{ count})]\} \end{aligned}$$

Precipitation operating mode:

$$\begin{aligned} Z_e = {} & (1/2{,}500) \cdot [6.58 \cdot (\text{5-10 } dBZ_e \text{ count})] + [20.81 \cdot (\text{10-15 } dBZ_e \text{ count})] \\ & + [65.81 \cdot (\text{15-20 } dBZ_e \text{ count})] + [208.11 \cdot (\text{20-25 } dBZ_e \text{ count})] \\ & + [658.11 \cdot (\text{25-30 } dBZ_e \text{ count})] + [2{,}081.14 \cdot (\text{30-35 } dBZ_e \text{ count})] \end{aligned}$$

Similarly, we converted pixel counts into average ground speed values using the following equation, arbitrarily selecting a value of 70 knots for the 64+ knot range:

$$\begin{aligned} S = {} & (1 \div \textstyle\sum \text{count}) \cdot \{[15 \cdot (\text{10-20 knot count})] + [23 \cdot (\text{20-26 knot count})] \\ & + [31 \cdot (\text{26-36 knot count})] + [43 \cdot (\text{36-50 knot count})] \\ & + [57 \cdot (\text{50-64 knot count})] + [70 \cdot (\text{64+ knot count})]\} \end{aligned}$$

where $\sum$count represents the total count of pulse volumes (out of 2,500 possible) that were determined to have been dominated by birds (i.e., radial velocities exceeded 15 knots above balloon-measured wind velocity).

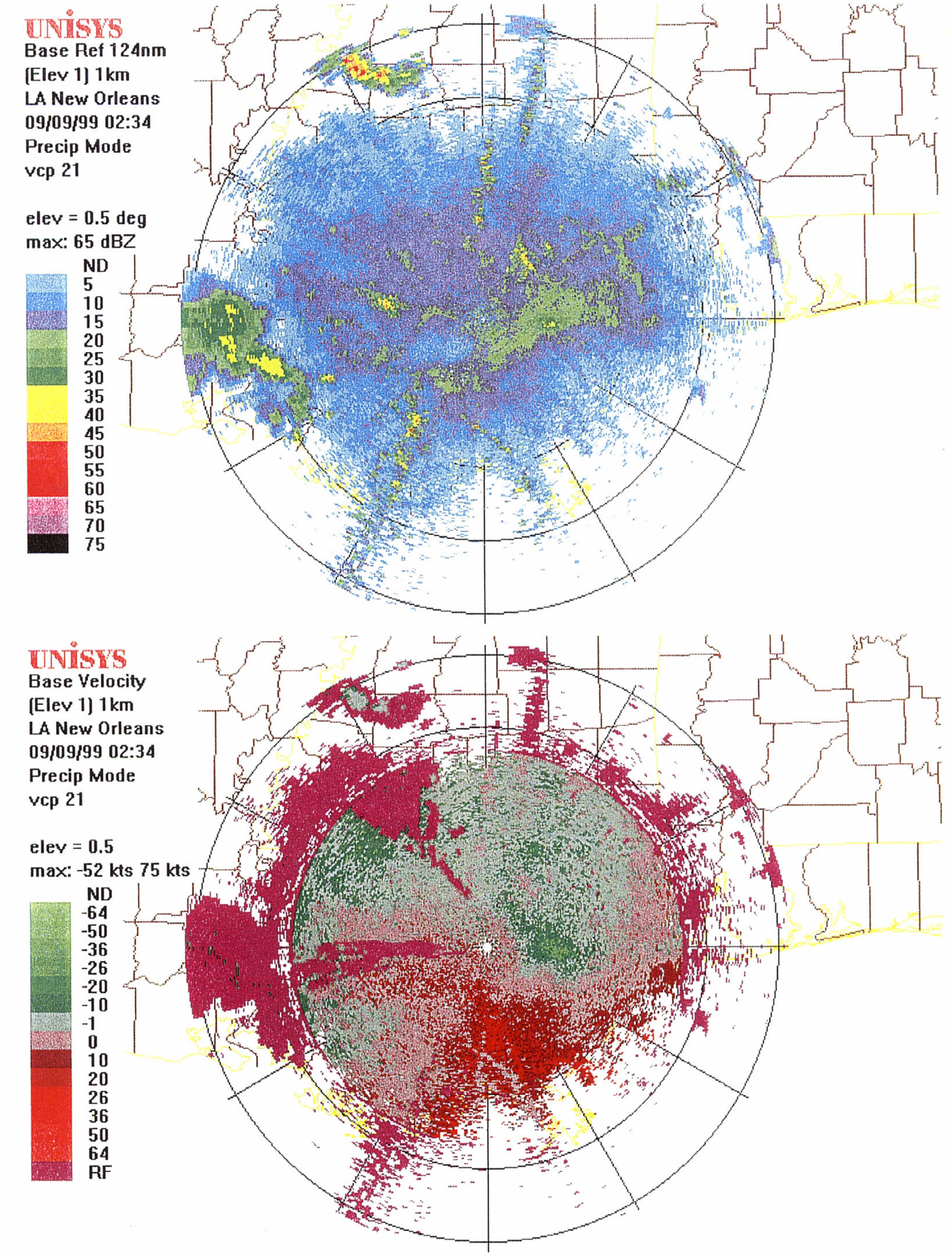
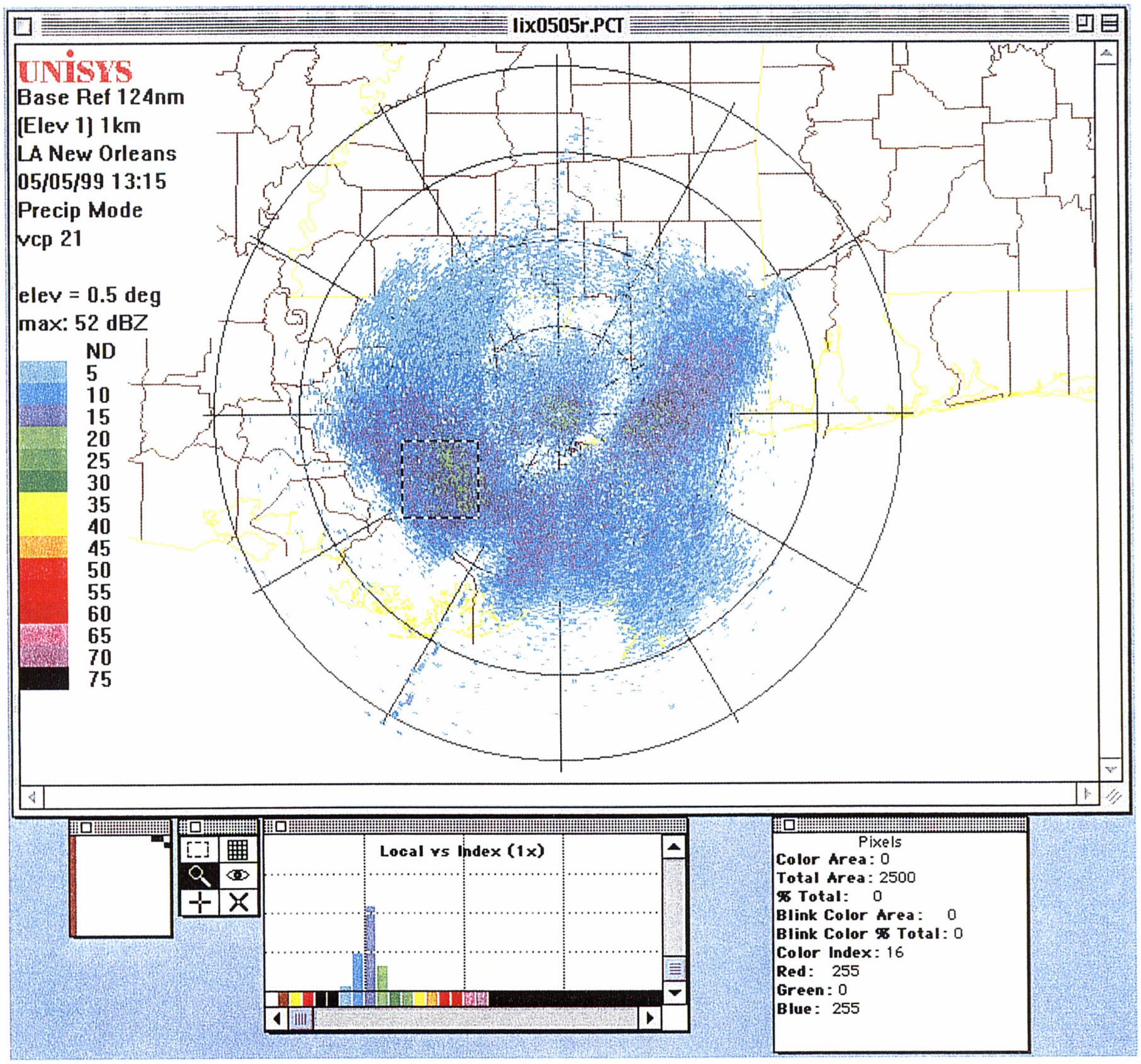


Figure 4.2. Radar images showing precipitation, strobing, and insect contamination. The reflectivity image from LIX on September 9, 1999 at 02:34 UTC (top) is contaminated by strobes (visible around the perimeter as linear spikes) and precipitation (visible most clearly in the far west as blocky green and yellow patterns). The corresponding base velocity image (bottom) suggests return from insects (uniform grayish region representing low velocity). Contamination of these types obscures echoes from birds.



Base Ref 124nm
(Elev 1) 1km
LA New Orleans
05/05/99 13:15
Precip Mode
vcp 21

elev = 0.5 deg
max: 52 dBZ

Pixels
Color Area: 0
Total Area: 2500
% Total: 0
Blink Color Area: 0
Blink Color % Total: 0
Color Index: 16
Red: 255
Green: 0
Blue: 255

Figure 4.3. Pixel counting technique in radar image analysis. When an image contains bird echoes, the number of pixels for each dBZ_e value within a 50-by-50 pixel square (delimited by a black and white line to the SW of the station) is counted using the FullPixelSearch program. The square is always drawn on the image within a 55-110 km range. The program displays the number of pixels when the cursor is placed over one of the bars in the bar graph.

Chapter 5

Synoptic Climatology of the Northern Gulf of Mexico

Robert W. Russell

5.1 INTRODUCTION

To understand the influence of weather on trans-Gulf migration and platform use, we sought to relate day-to-day variability in observed migration to large-scale weather patterns over the Gulf via a synoptic climatology. In synoptic climatological analyses, one attempts to identify a relatively small number of representative weather patterns that are capable of characterizing the observed daily variability in some phenomenon of interest, and then relates these types to variation in some environmental parameter or process of interest (Barry and Perry 1973; Yarnal 1993). Construction of a synoptic climatology of migration involves the categorization of atmospheric circulation types relevant to migrating birds and the determination of the climatological frequency of occurrence of different types of migration events.

The method for classifying daily weather patterns into discrete types may be either manual or automated. In manual weather-typing schemes, the investigator subjectively classifies the continuum of atmospheric circulation patterns into a reduced set of characteristic weather types, usually on the basis of isobaric patterns. Automated procedures usually use clustering algorithms with measured surface variables as input (the "air-mass approach"). Manual typing schemes are necessarily subjective but have the important advantage of being flexible to the needs of a particular investigation. Automated typing schemes have the advantages of being objective and of classifying the weather itself, but are relatively insensitive to atmospheric circulation patterns that may affect processes operating over large scales.

A synoptic climatology for the northern Gulf Coast has previously been developed by Muller (1977; see also Muller and Wax 1977, Muller 1979) and modified by Yocke et al. (2000). We revised these earlier schemes slightly to be relevant to migrating birds.

5.2 METHODS

We recognized the following eight synoptic-scale weather types, which are hereafter indicated by their abbreviations in boldface for easy recognition:

Gulf Front (**GF**) — This type subsumed Yocke et al.'s "Gulf Front or Trough N/S" and "Gulf Front or Trough E/W" types, which correspond respectively to Muller's "Pacific High" and "Frontal Overrunning" types. On days characterized by this type, cyclonic circulation around a deep surface low over the Mississippi Valley brings mild and dry air following the cold front across the northern Gulf. An east-west or northeast-southwest oriented front or trough is located in the northern Gulf region within about 100 km of the coastline. Winds in the northern Gulf are variable, but generally have a northerly component on the northern or western side of the front and a southerly component on the southern or eastern side. Frequently waves develop along the front over the western Gulf, and then sweep northeastward bringing heavy clouds and precipitation to the Gulf Coast. This pattern is often accompanied by other patterns. In this study, if winds on both sides of the front were from the same direction (indicating a weak front) and the wind directions were consistent with the other accompanying synoptic pattern, then the **GF** pattern was ignored and the other accompanying pattern was chosen.

East Coast Low (**ELOW**) — This new type described by Yocke et al. is similar to **GF** except that the low-pressure system has moved east of the Mississippi River and the front has correspondingly swept over the Gulf, through Florida, and into the Atlantic. From the standpoint of our study region in the northern Gulf, prevailing weather is often very similar between **GF** and **ELOW** days. However, on **GF** days, the front has not penetrated to the Yucatan Peninsula and so in spring **GF** is likely to be conducive to the initiation of northward trans-Gulf migration. In contrast, winds over the Yucatan on **ELOW** days will generally be unfavorable for the initiation of spring trans-Gulf migration.

Midwest Continental High (**MCH**) — This type corresponds to Muller's "Continental High" type. On **MCH** days, winds over the northern Gulf are dominated by anticyclonic flow around a high-pressure system centered west of the Mississippi River, over or east of the Rocky Mountains, and north of the Texas/Mexico border. Surface winds are from the northeast, and the region is dominated by fair weather associated with the core of the anticyclone.

Eastern Continental High (**ECH**) — This type devised by Yocke et al. subsumes Muller's "Coastal Return" type as well as some situations that would be classified under Muller's "Continental High" type. On **ECH** days, winds over the northern Gulf are dominated by anticyclonic flow around a high-pressure system located east of the Mississippi River and west of the eastern seaboard, somewhere between the Gulf Coast and southern Canada. Surface winds may be from the east or southeast (eastern areas) or from the south (western areas).

Bermuda High (**BH**) — This type is a subdivision of Muller's "Coastal Return" type (with the remainder of the Coastal Return type falling under **ECH**). It is very similar to the **ECH** type, but the high-pressure system is centered over the Atlantic Ocean. A ridge of tropical air extends westward from the Atlantic over the southeastern states, and surface winds in the northern Gulf may be from the southeast or south.

Gulf High (**GH**) -- This type corresponds to Mueller's type of the same name. On **GH** days. high pressure is centered over the Gulf or over the immediate Gulf Coast and usually associated with a weak pressure gradient and weak or nonexistent winds. We subsumed the Yocke et. al. (2000) "No Gradient" type into the **GH** type.

Tropical Low (**TLOW**) — This type corresponds to Mueller's "Gulf Tropical Disturbances." On **TLOW** days, a hurricane, tropical storm, or tropical depression exists in the Gulf region and dominates its weather. Winds reflect the strong cyclonic flow around the low pressure center and are locally highly variable, depending upon the precise position of the system.

Not Determined (**ND**) — This default type comprised complex weather situations that did not fall clearly into one of the seven other types.

We did not use the "Midwest Low" type recognized by Yocke et al., which corresponds to Muller's "Gulf Return" type. In a Midwest Low scenario, a low-pressure system is located east of the Rockies with a north-south or northeast-southwest oriented front approaching the Gulf. Surface winds are dominated by cyclonic flow around the Low, with a strong return flow of maritime tropical air developing over the northern Gulf in advance of the front. Wind direction is generally from the SW (western Gulf) or S (farther east). We did not formally recognize this type because it was very infrequent during this study, and easily subsumed into the **ECH** or **BH** types.

On **GF** days during the fall, we also assigned a weather type behind the frontal boundary (i.e., as if the front were absent). The reason for this was that migrating birds departing the northern Gulf Coast on **GF** days generally travel in the same direction as the frontal boundary (which is not the case during the spring), and primarily experience post-frontal conditions on **GF** days. This secondary type (usually **MCH** or **ELOW**) was used in all analyses of fall migration, unless otherwise noted.

Each day during "spring" (March-May) and "fall" (August-November) in 1998, 1999, and 2000 was manually classified into one of the eight synoptic weather types based on surface pressure contours and wind flow patterns at 12:00 UTC (06:00 CST). Sources of information used to assign daily weather types included: 1) daily synoptic maps archived by Unisys at <http://weather.unisys.com/archive/sfc_map/>; 2) daily surface synoptic charts published by NOAA (Daily Weather Maps: Weekly Series); and when the previous two data sources were unavailable, inconsistent, or inconclusive, 3) local weather data recorded on the platforms. Pressure patterns and the configuration of major high- and low-pressure systems were used as the principal decision criteria. In cases where more than one pattern was present, we chose the feature with the greater influence on winds in the northern Gulf. If it was difficult to determine which feature had a greater influence on winds in the northern Gulf, we favored the upstream feature (generally the feature to the west) rather than the downstream feature (generally to the east). All classifications were made without reference to any bird migration data.

5.3 RESULTS

The weather types assigned to each day during each migration season throughout the study are presented in Table 5.1 ("spring": March-May) and Table 5.2 ("fall": August-November).

Inspection of Tables 5.1 and 5.2 reveals that weather over the Gulf usually follows a predictable cycle (Figure 5.1). As the center of an anticyclone drifts eastward across the continent and out over the Atlantic Ocean, winds over the northern Gulf veer from NE (**MCH**) to E (**ECH**) and eventually to SE (**BH**). Eventually a cyclone moves eastward and a front passes over the Gulf (**GF**) bringing winds from the NW. Following frontal passage, winds over the Gulf are dominated by the departing cyclone (**ELOW**) until a new anticyclone approaches and the cycle repeats. Occasionally the cycle is interrupted when the anticyclone drifts out over the Gulf (**GH**), usually resulting in light winds over the northern Gulf. During the summer and fall, tropical weather systems may develop in the Gulf or enter the Gulf from the east (**TLOW**), usually bringing strong winds and foul weather.

The relative frequencies of the different weather types in each spring are depicted in Figure 5.2. Conditions were rarely unfavorable for northward trans-Gulf departures in May. However, favorability of departure conditions earlier in the spring varied dramatically from year to year, with unfavorable conditions (**ELOW** and **MCH**) more than twice as frequent in 1998 than in 1999 and 2000. Conditions conducive to departure but likely to induce fallouts in the northern Gulf of Mexico (**GF**) were common in March in 1999 and 2000; were common in April in 1998 and 2000; and were rare in May in all years. May tended to be dominated by a single weather pattern, which was different in each of the three years: **GH** in 1998, **ECH** in 1999, and **BH** in 2000.

The relative frequencies of the different weather types in each fall are depicted in Figure 5.3. The most striking features in fall were the strong predominance of the **GH** type in August and the tremendous variation in frequency of **TLOW** from year to year. **TLOW** was the most common weather pattern during the first half of the fall migration season in 1998, but was uncommon in 1999 and was rare in 2000. **ECH** was the most common weather type during October and, in two years of three, in September. November was characterized by a more even distribution of weather types, with no pattern persisting across years.

Synoptic weather conditions are compared between spring and fall in Figure 5.4. Overall, spring was characterized by a greater predominance of weather types most favorable for trans-Gulf flight in the seasonally appropriate direction (**BH**, **ECH**) than was fall (**MCH**, **ELOW**).

Table 5.1.

Synoptic weather types during spring migration, 1998-2000

	Synoptic Type		
Date	1998	1999	2000
1-Mar	ELOW	GH	BH
2-Mar	ELOW	GH	GF
3-Mar	MCH	GF	GH
4-Mar	ECH	ECH	GF
5-Mar	BH	ECH	GF
6-Mar	ECH	BH	ECH
7-Mar	BH	GF	ECH
8-Mar	GF	ECH	ECH
9-Mar	ELOW	GF	BH
10-Mar	MCH	GF	BH
11-Mar	MCH	GF	GF
12-Mar	MCH	GF	GF
13-Mar	ECH	GF	ECH
14-Mar	ECH	ELOW	ECH
15-Mar	ECH	ELOW	ECH
16-Mar	ECH	ECH	BH
17-Mar	ECH	BH	GF
18-Mar	ECH	BH	GF
19-Mar	GF	GH	GF
20-Mar	ELOW	GF	GF
21-Mar	ELOW	GF	ECH
22-Mar	MCH	MCH	ECH
23-Mar	GH	GH	ECH
24-Mar	GH	BH	ECH
25-Mar	ECH	GF	ECH
26-Mar	BH	GF	GH
27-Mar	BH	ECH	GF
28-Mar	BH	ECH	GF
29-Mar	BH	ECH	BH
30-Mar	BH	GF	GF
31-Mar	GF	ND	GF
1-Apr	GF	BH	ECH
2-Apr	BH	BH	BH
3-Apr	GF	BH	GF
4-Apr	GF	ECH	GF
5-Apr	MCH	BH	MCH
6-Apr	ECH	GH	BH
7-Apr	BH	ECH	BH
8-Apr	BH	BH	GF
9-Apr	GF	BH	MCH
10-Apr	ELOW	BH	GH
11-Apr	MCH	GH	BH
12-Apr	ECH	GH	GF

Table 5.1.

Synoptic weather types during spring migration,
1998-2000

	Synoptic Type		
Date	1998	1999	2000
13-Apr	BH	ECH	GF
14-Apr	BH	ECH	GF
15-Apr	BH	GF	GH
16-Apr	BH	ELOW	ECH
17-Apr	GF	ELOW	GH
18-Apr	GF	MCH	GH
19-Apr	GF	GH	ECH
20-Apr	MCH	GH	BH
21-Apr	MCH	GH	GF
22-Apr	ELOW	BH	GF
23-Apr	ELOW	BH	ECH
24-Apr	GH	GH	GF
25-Apr	BH	GH	GF
26-Apr	BH	BH	MCH
27-Apr	BH	BH	GH
28-Apr	GF	GF	GH
29-Apr	GF	ECH	GF
30-Apr	GF	MCH	ECH
1-May	GH	MCH	ECH
2-May	GH	ECH	BH
3-May	BH	ECH	ND
4-May	GF	ECH	ECH
5-May	ECH	BH	ECH
6-May	BH	GF	BH
7-May	BH	GF	BH
8-May	BH	GF	BH
9-May	BH	ECH	BH
10-May	GF	ECH	BH
11-May	GF	ECH	BH
12-May	ECH	ECH	BH
13-May	ECH	GF	GF
14-May	ECH	BH	MCH
15-May	GH	BH	MCH
16-May	GH	ECH	GH
17-May	GH	ECH	BH
18-May	GH	ECH	BH
19-May	GH	MCH	BH
20-May	GH	ECH	BH
21-May	GH	ECH	BH
22-May	GH	ECH	GH
23-May	GH	GH	GH
24-May	GH	GH	BH
25-May	ECH	GH	BH

Table 5.1.

Synoptic weather types during spring migration, 1998-2000

	Synoptic Type		
Date	1998	1999	2000
26-May	ECH	GH	BH
27-May	ND	GH	BH
28-May	GH	GH	GH
29-May	GH	ECH	GH
30-May	GH	ECH	GH
31-May	GH	ECH	ECH

Table 5.2.

Synoptic weather types during fall migration, 1998-2000

	Synoptic Type		
Date	1998	1999	2000
1-Aug	GH	GH	GH
2-Aug	GH	GH	GH
3-Aug	ND	GH	GH
4-Aug	ND	TLOW	GH
5-Aug	ND	TLOW	GH
6-Aug	GH	TLOW	GH
7-Aug	TLOW	ND	GH
8-Aug	TLOW	GH	GH
9-Aug	GH	GH	GH
10-Aug	GH	GH	GH
11-Aug	GH	GH	GH
12-Aug	GH	GH	GH
13-Aug	GH	GH	GF/MCH
14-Aug	GH	GH	TLOW
15-Aug	GH	TLOW	GH
16-Aug	GH	TLOW	GH
17-Aug	GH	GH	GH
18-Aug	GH	GH	GH
19-Aug	ECH	GH	GH
20-Aug	TLOW	GH	GH
21-Aug	TLOW	GH	GH
22-Aug	TLOW	TLOW	ECH
23-Aug	ECH	TLOW	ECH
24-Aug	ECH	GH	ECH
25-Aug	ECH	GH	GH
26-Aug	GH	GH	GH
27-Aug	GH	GH	GH
28-Aug	GH	GH	GH
29-Aug	TLOW	GH	GH
30-Aug	TLOW	GH	GH

Table 5.2.

Synoptic weather types during fall migration, 1998-2000

	Synoptic Type		
Date	1998	1999	2000
31-Aug	TLOW	ECH	GH
1-Sep	TLOW	ECH	GH
2-Sep	TLOW	ECH	ND
3-Sep	TLOW	GH	ND
4-Sep	GH	GH	GH
5-Sep	ECH	GH	ND
6-Sep	ECH	GH	GF/ECH
7-Sep	ECH	GH	GF/ECH
8-Sep	TLOW	GH	ECH
9-Sep	TLOW	GF/ELOW	ECH
10-Sep	TLOW	GF/MCH	ECH
11-Sep	TLOW	ECH	ECH
12-Sep	TLOW	ECH	ECH
13-Sep	TLOW	ECH	ECH
14-Sep	ECH	MCH	ECH
15-Sep	ECH	MCH	ND
16-Sep	ECH	MCH	MCH
17-Sep	TLOW	MCH	TLOW
18-Sep	TLOW	ECH	TLOW
19-Sep	TLOW	TLOW	ECH
20-Sep	TLOW	TLOW	BH
21-Sep	ND	TLOW	TLOW
22-Sep	GH	MCH	TLOW
23-Sep	MCH	MCH	BH
24-Sep	ECH	GH	GH
25-Sep	TLOW	ECH	GF/ELOW
26-Sep	TLOW	ECH	GF/ELOW
27-Sep	TLOW	ECH	MCH
28-Sep	TLOW	ECH	MCH
29-Sep	TLOW	ECH	ECH
30-Sep	ELOW	MCH	ECH
1-Oct	GH	MCH	ECH
2-Oct	GH	ECH	ECH
3-Oct	ECH	ECH	ECH
4-Oct	BH	ECH	ECH
5-Oct	BH	MCH	ND
6-Oct	ECH	TLOW	GH
7-Oct	GF/ELOW	TLOW	GF/MCH
8-Oct	GF/MCH	ECH	MCH
9-Oct	MCH	BH	MCH
10-Oct	MCH	ELOW	MCH
11-Oct	ECH	MCH	MCH
12-Oct	ECH	ECH	ECH
13-Oct	MCH	ECH	ECH

Table 5.2.

Synoptic weather types during fall migration, 1998-2000

Date	Synoptic Type 1998	1999	2000
14-Oct	MCH	TLOW	ECH
15-Oct	ECH	TLOW	ECH
16-Oct	ECH	TLOW	ECH
17-Oct	ECH	GH	GH
18-Oct	BH	MCH	GF/MCH
19-Oct	GF/MCH	MCH	MCH
20-Oct	MCH	MCH	ECH
21-Oct	MCH	MCH	ECH
22-Oct	MCH	MCH	ECH
23-Oct	MCH	ELOW	ECH
24-Oct	ECH	MCH	ECH
25-Oct	ECH	ECH	ECH
26-Oct	ECH	ECH	ECH
27-Oct	ECH	GH	ECH
28-Oct	ECH	ECH	GH
29-Oct	ECH	ECH	GH
30-Oct	GH	ECH	GH
31-Oct	GH	GF/ELOW	GH
1-Nov	GH	GF/ELOW	GH
2-Nov	GF/ELOW	ELOW	ECH
3-Nov	GF/ELOW	ELOW	ECH
4-Nov	MCH	ECH	GH
5-Nov	MCH	ECH	GH
6-Nov	MCH	ECH	ND
7-Nov	ECH	MCH	GF/MCH
8-Nov	ECH	MCH	GF/ELOW
9-Nov	BH	ECH	GF/ELOW
10-Nov	BH	ECH	ELOW
11-Nov	GF/MCH	ND	MCH
12-Nov	ECH	MCH	GH
13-Nov	ECH	ECH	GF/ELOW
14-Nov	ND	GH	GF/ELOW
15-Nov	GF/ELOW	ELOW	MCH
16-Nov	ELOW	ELOW	ECH
17-Nov	ELOW	MCH	GF/MCH
18-Nov	ECH	ECH	GF/MCH
19-Nov	ECH	ECH	TLOW
20-Nov	ECH	ND	GF/ELOW
21-Nov	GF/MCH	ND	MCH
22-Nov	ECH	ECH	GH
23-Nov	BH	ECH	ECH
24-Nov	ND	GF/MCH	GF/ELOW
25-Nov	GH	GF/MCH	GF/ELOW
26-Nov	GH	ELOW	GH

Table 5.2.

Synoptic weather types during fall migration, 1998-2000

Date	Synoptic Type 1998	 1999	 2000
27-Nov	GH	GH	GH
28-Nov	ECH	GH	GH
29-Nov	ECH	MCH	GH
30-Nov	BH	MCH	MCH

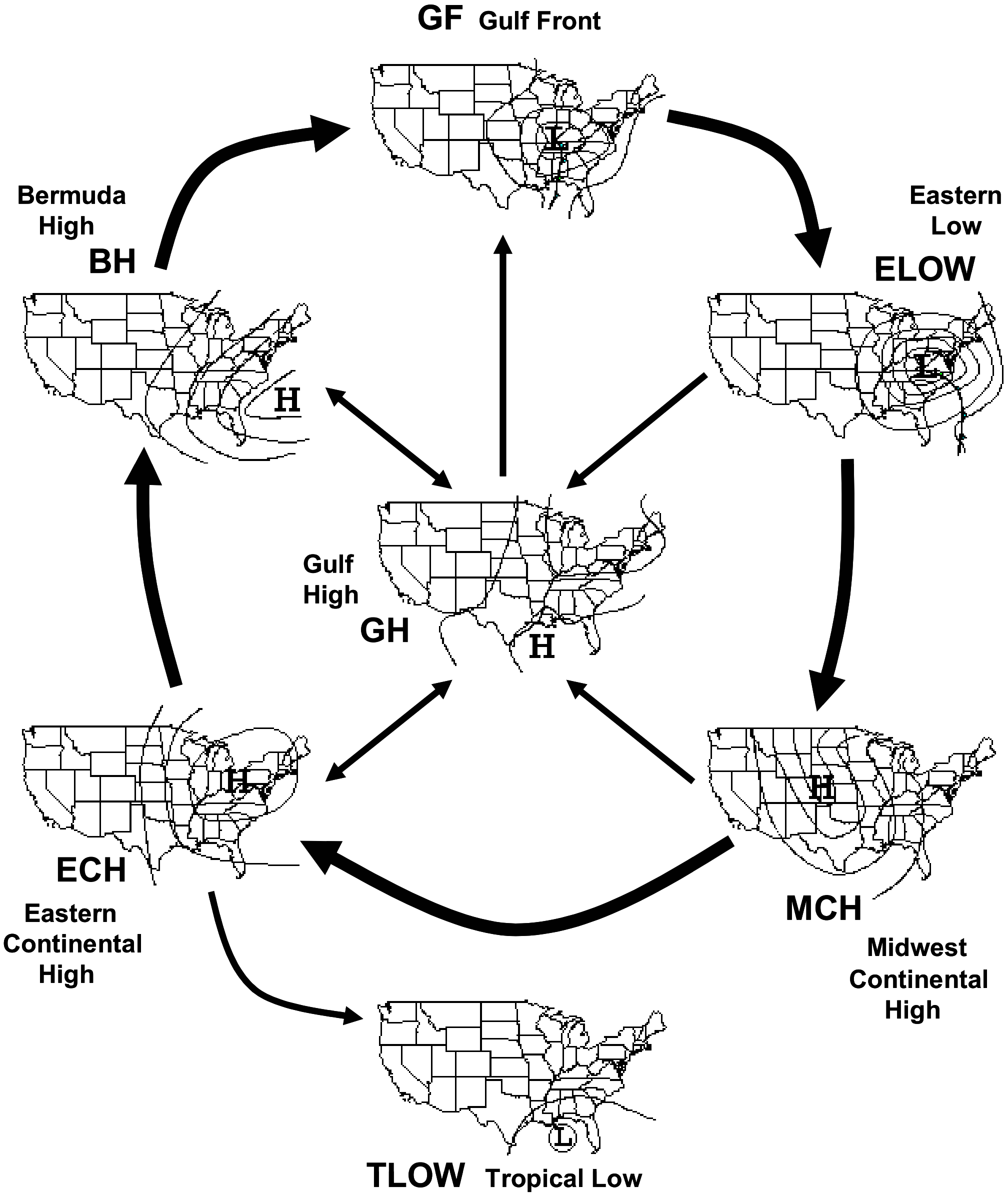


Figure 5.1. Seven synoptic types used for classifying large-scale weather patterns in this study. The arrows indicate typical synoptic weather transitions in the study area. The diagrammatic weather maps are modified from Yocke et al. (2000) with permission.

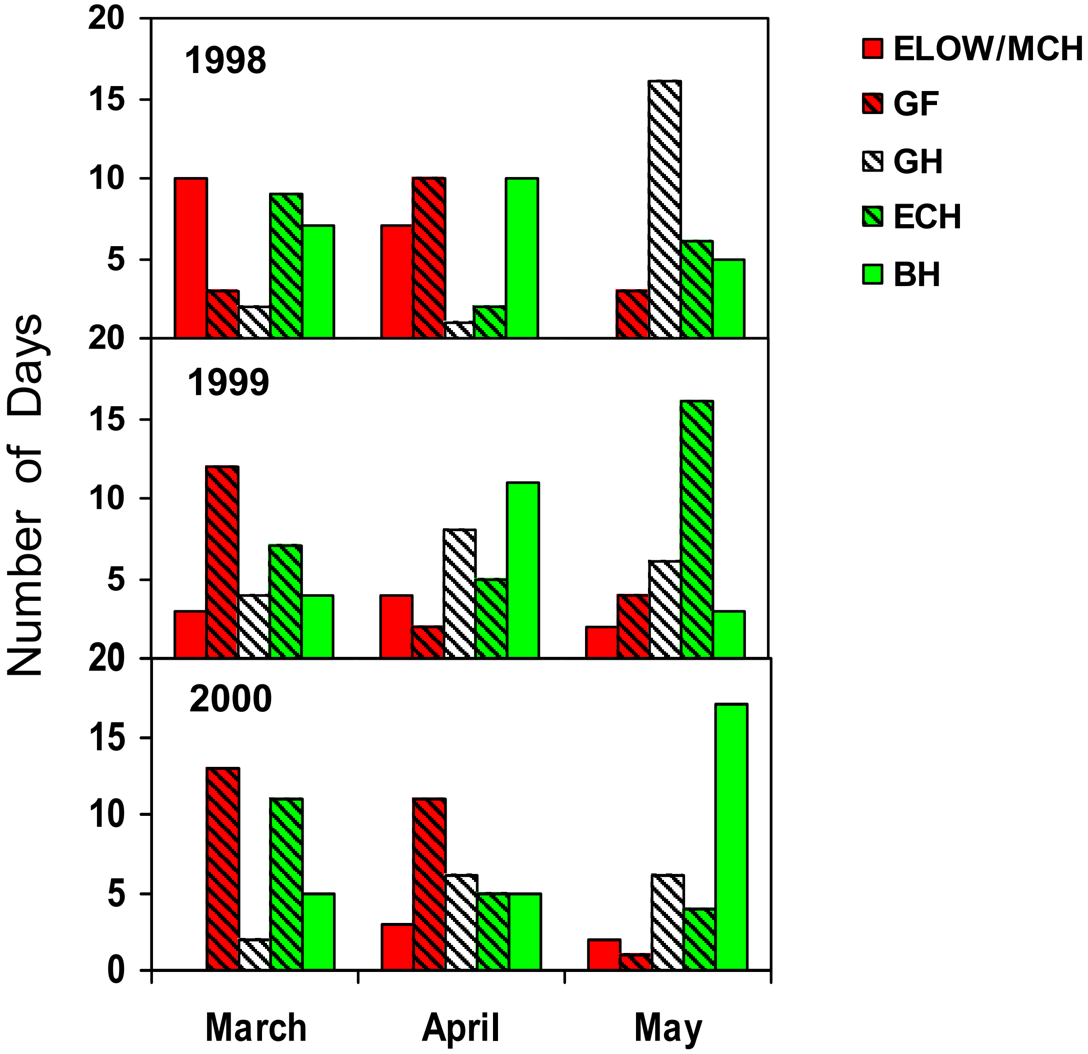


Figure 5.2. Relative frequencies of the different weather types in spring 1998-2000. Weather types that are consistently favorable for northbound migrants are colored green, and those that are consistently unfavorable are red.

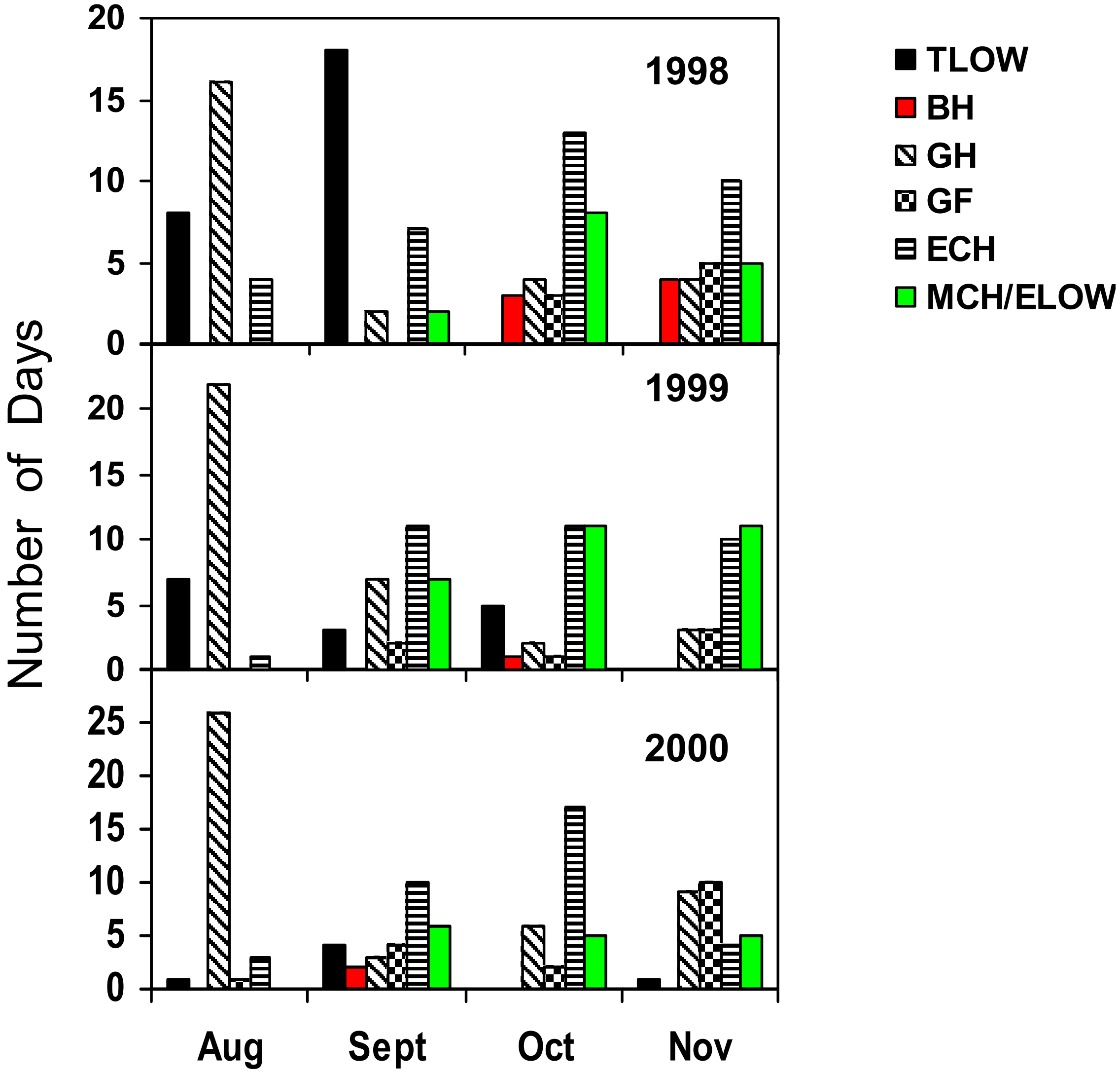


Figure 5.3. Relative frequencies of the different weather types in fall 1998-2000. Weather types that are consistently favorable for southbound migrants are colored green, and those that are consistently unfavorable are red.

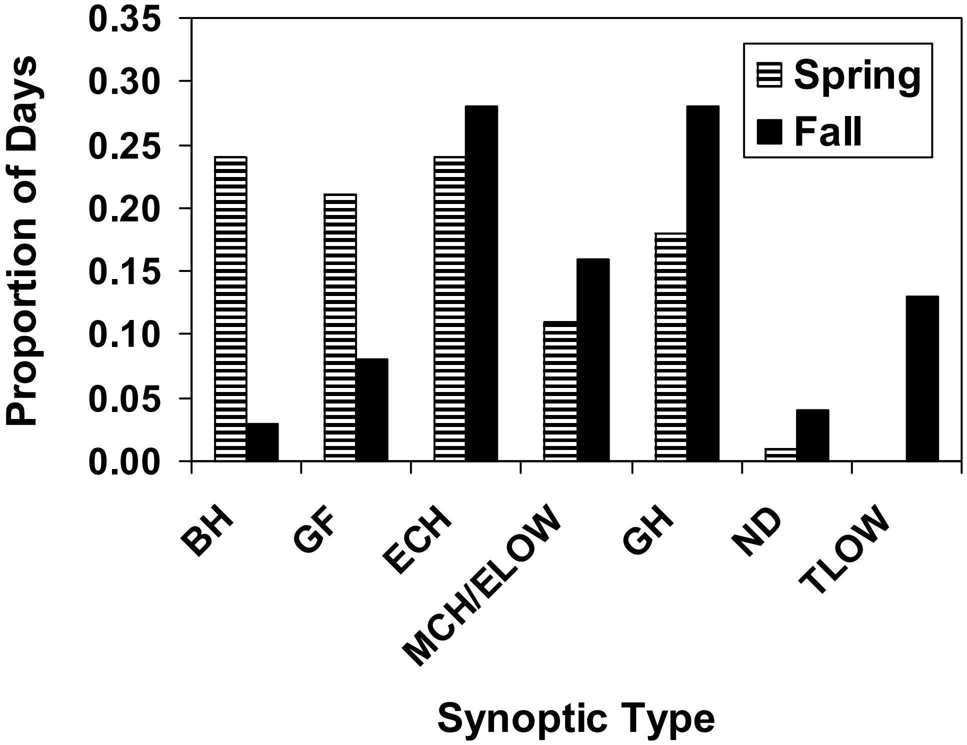


Figure 5.4. Relative frequency of the different weather types in spring versus fall. Days from all years (1998-2000) are combined for each season.

PART 2

ECOLOGY OF TRANS-GULF BIRD MIGRATION

Chapter 6

Species Composition of Offshore Migrants

Robert W. Russell

6.1 ECOLOGICAL CATEGORIZATION OF SPECIES RECORDED FROM PLATFORMS

Many unexpected species were recorded during the study, and it was clear that multiple factors were responsible for the presence of different species on Gulf platforms. In order to attempt to isolate the factors responsible for their presence, all species recorded during the study were first classified into groups based on biogeography, migratory behavior, and other ecological characteristics.

All ducks and geese (family Anatidae) were included together in one group hereafter referred to as "waterfowl" (Table 6.1). Most waterfowl species are nocturnal migrants that travel in flocks, and most were not expected to be trans-Gulf migrants on the basis of their known winter distributions. Gregarious wading birds including herons, egrets, ibises, and spoonbills (families Ardeidae, Threskiornithidae) were considered together in one group hereafter referred to as "herons" (Table 6.2). Most heron species are nocturnal migrants that travel in flocks, and most were expected to be trans-Gulf migrants on the basis of their known winter distributions. Bitterns were excluded from the "herons" group because of their solitary behavior. Falconiform raptors (families Accipitridae, Falconidae) are all diurnal migrants, but different species exhibit widely varying water-crossing behaviors. Diurnal raptors are generally treated here on a species-specific basis (Table 6.3). Shorebirds (families Charadriidae, Recurvirostridae, Scolopacidae) migrate by both day and night, generally traveling in flocks, and all species were included together in one group (Table 6.4).

Neotropical migrant "landbird" species with wintering ranges extending routinely into Central America beyond the Isthmus of Tehuantepec were considered to be potential trans-Gulf migrants on the basis of distribution, and were included together in one group hereafter referred to as "neotropical migrant landbirds" (Table 6.5). This group included landbirds as well as solitary marsh birds (Pied-billed Grebe, bitterns, gallinules, rails); members of this group are nocturnal migrants that travel alone. For some analyses, this group was further subdivided into small neotropical migrant landbirds (body mass <21 g) and large neotropical migrant landbirds (body mass >21 g), in part to accommodate the fact that flight speed increases with body mass (Pennycuick 1989).

The group referred to as "medium-distance migrants" included species that routinely winter along the northern Gulf Coast and at least as far south as southern Tamaulipas, but not beyond southern Veracruz, and not on the Yucatan Peninsula, except as a vagrant (Table 6.6). Medium-distance migrant species were so identified because their winter distributions suggest that some portion of the population might travel over the Gulf, but only over the western Gulf. The group referred to as "short-distance migrants" included species that have no known regular wintering populations south of northern Tamaulipas and are unrecorded elsewhere from Atlantic Slope of Mexico (Table 6.7). Short-distance migrants were expected (a priori) <u>not</u> to be "intentional" trans-Gulf migrants.

Table 6.1.

Waterfowl recorded from the study platforms

Species are listed in taxonomic order according to AOU (1998). Body mass data are from Sibley (2000).

Species	Body Mass (g)
Fulvous Whistling-Duck (*Dendrocygna bicolor*)	670
Black-bellied Whistling-Duck (*Dendrocygna autumnalis*)	830
Greater White-fronted Goose (*Anser albifrons*)	2,200
Snow Goose (*Chen caerulescens*)	2,420
Ross's Goose (*Chen rossii*)	1,250
Gadwall (*Anas strepera*)	910
American Wigeon (*Anas americana*)	720
Mallard (*Anas platyrhynchos*)	1,100
Blue-winged Teal (*Anas discors*)	380
Cinnamon Teal (*Anas cyanoptera*)	400
Northern Shoveler (*Anas clypeata*)	610
Northern Pintail (*Anas acuta*)	800
Green-winged Teal (*Anas crecca*)	350
Redhead (*Aythya americana*)	1,050
Ring-necked Duck (*Aythya collaris*)	700
Greater Scaup (*Aythya marila*)	1,050
Lesser Scaup (*Aythya affinis*)	830
Surf Scoter (*Melanitta perspicillata*)	950
White-winged Scoter (*Melanitta fusca*)	1,670
Hooded Merganser (*Lophodytes cucullatus*)	620
Red-breasted Merganser (*Mergus serrator*)	1,060

Table 6.2.

Herons recorded from the study platforms

Listing order and source of body mass data as in Table 6.1.

Species	Body Mass (g)
American Bittern (*Botaurus lentiginosus*)	700
Great Blue Heron (*Ardea herodias*)	2,400
Great Egret (*Ardea alba*)	870
Snowy Egret (*Egretta thula*)	360
Little Blue Heron (*Egretta caerulea*)	340
Tricolored Heron (*Egretta tricolor*)	380
Reddish Egret (*Egretta rufescens*)	450
Cattle Egret (*Bubulcus ibis*)	340
Green Heron (*Butorides virescens*)	210
Black-crowned Night-Heron (*Nycticorax nycticorax*)	870
Yellow-crowned Night-Heron (*Nyctanassa violacea*)	690
White Ibis (*Eudocimus albus*)	900
White-faced Ibis (*Plegadis chihi*)	610
Roseate Spoonbill (*Ajaia ajaja*)	1,500

Table 6.3.

Diurnal raptors recorded from the study platforms

Listing order and source of body mass data as in Table 6.1.

Species	Body Mass (g)
Osprey (*Pandion haliaetus*)	1,600
Swallow-tailed Kite (*Elanoides forficatus*)	420
Mississippi Kite (*Ictinia mississippiensis*)	280
Northern Harrier (*Circus cyaneus*)	420
Sharp-shinned Hawk (*Accipiter striatus*)	140
Cooper's Hawk (*Accipiter cooperii*)	450
Broad-winged Hawk (*Buteo platypterus*)	390
American Kestrel (*Falco sparverius*)	117
Merlin (*Falco columbarius*)	190
Aplomado Falcon (*Falco femoralis*)	335
Peregrine Falcon (*Falco peregrinus*)	720

Table 6.4.

Shorebirds recorded from the study platforms

Listing order and source of body mass data as in Table 6.1.

Species	Body Mass (g)
Black-bellied Plover (*Pluvialis squatarola*)	240
American Golden-Plover (*Pluvialis dominica*)	145
Wilson's Plover (*Charadrius wilsonia*)	60
Semipalmated Plover (*Charadrius semipalmatus*)	45
Killdeer (*Charadrius vociferus*)	95
Black-necked Stilt (*Himantopus mexicanus*)	160
American Avocet (*Recurvirostra americana*)	315
Greater Yellowlegs (*Tringa melanoleuca*)	160
Lesser Yellowlegs (*Tringa flavipes*)	80
Solitary Sandpiper (*Tringa solitaria*)	50
Willet (*Catoptrophorus semipalmatus*)	215
Spotted Sandpiper (*Actitis macularia*)	40
Upland Sandpiper (*Bartramia longicauda*)	170
Whimbrel (*Numenius phaeopus*)	390
Long-billed Curlew (*Numenius americanus*)	590
Hudsonian Godwit (*Limosa haemastica*)	300
Marbled Godwit (*Limosa fedoa*)	370
Ruddy Turnstone (*Arenaria interpres*)	110
Red Knot (*Calidris canutus*)	135
Sanderling (*Calidris alba*)	60
Semipalmated Sandpiper (*Calidris pusilla*)	25
Western Sandpiper (*Calidris mauri*)	26
Least Sandpiper (*Calidris minutilla*)	20
White-rumped Sandpiper (*Calidris fuscicollis*)	42

Table 6.4.

Shorebirds recorded from the study platforms

Listing order and source of body mass data as in Table 6.1.

Species	Body Mass (g)
Baird's Sandpiper (*Calidris bairdii*)	38
Pectoral Sandpiper (*Calidris melanotos*)	73
Dunlin (*Calidris alpine*)	60
Stilt Sandpiper (*Calidris himantopus*)	58
Buff-breasted Sandpiper (*Tryngites subruficollis*)	63
Long-billed Dowitcher (*Limnodromus scolopaceus*)	115
Common Snipe (*Gallinago gallinago*)	105
Wilson's Phalarope (*Phalaropus tricolor*)	60
Red-necked Phalarope (*Phalaropus lobatus*)	35

Table 6.5.

Neotropical migrant landbirds recorded from the study platforms

This group includes those species and recognizable subspecies of landbirds and marsh birds that have wintering ranges routinely extending into Central America (beyond the Isthmus of Tehuantepec). "Range" provides relevant details on each species' known winter distribution (**Win**), summer breeding distribution (**Sum**), and/or migration route (**Mig**). Except where otherwise noted, all species are considered to be widespread during migration along the Atlantic Slope from Tamaulipas to n. Honduras. Listing order and source of body mass data as in Table 6.1. Range data are from Howell and Webb (1995), Rising (1996), Dunn and Garrett (1997), and Sibley (2000).

Species	Body Mass (g)	Range
Pied-billed Grebe (*Podilymbus podiceps*)	450	**Win:** s. USA-?
Least Bittern (*Ixobrychus exilis*)	80	**Win:** s. Texas-Columbia; also s. Florida.
Black Rail (*Laterallus jamaicensis*)	30	**Win:** unclear due to extremely secretive behavior and existence of several disjunct populations; probably s. USA, w. West Indies, and possibly e. Mexico and n. Central America.
Sora (*Porzana carolina*)	75	**Win:** s. USA-n. South America.
Purple Gallinule (*Porphyrula martinica*)	235	**Win:** Veracruz-South America.
Common Moorhen (*Gallinula chloropus*)	315	**Win:** s. USA-?
American Coot (*Fulica americana*)	650	**Win:** s. USA-n. Columbia.
Mourning Dove (*Zenaida macroura*)	120	**Win:** n. USA-s. Central America.
Black-billed Cuckoo (*Coccyzus erythropthalmus*)	52	**Win:** South America.
Yellow-billed Cuckoo (*C. americanus*)	65	**Win:** South America.
Common Nighthawk (*Chordeiles minor*)	62	**Win:** South America.
Chuck-will's-widow (*Caprimulgus carolinensis*)	120	**Win:** n. Veracruz-n. Central America, except not on Yucatan Peninsula
Whip-poor-will (*C. vociferus*)	54	**Win:** s. USA-w. Panama, except not on Yucatan Peninsula. **Mig:** widespread, except unrecorded on Yucatan Peninsula
Belted Kingfisher (*Ceryle alcyon*)	150	**Win:** n. USA-n. South America.
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	50	**Win:** s. USA-Panama.
Eastern Wood-Pewee (*Contopus virens*)	14	**Win:** South America.
Yellow-bellied Flycatcher (*Empidonax flaviventris*)	11.5	**Win:** Veracruz-Panama.
Acadian Flycatcher (*E. virescens*)	13	**Win:** e. Nicaragua-Ecuador. **Fall Mig:** from Yucatan Peninsula eastward.
Alder Flycatcher (*E. alnorum*)	13.5	**Win:** South America. **Mig:** widespread, except unrecorded on Yucatan Peninsula
Willow Flycatcher (*E. traillii*)	13.5	**Win:** Honduras-Panama. **Mig:** widespread, except unrecorded on Yucatan Peninsula
Least Flycatcher (*E. minimus*)	10.3	**Win:** s. Tamaulipas-Costa Rica.
Great Crested Flycatcher (*Myiarchus crinitus*)	34	**Win:** s. Veracruz-n. South America.
Eastern Kingbird (*Tyrannus tyrannus*)	40	**Win:** South America.

Table 6.5.

Neotropical migrant landbirds recorded from the study platforms

This group includes those species and recognizable subspecies of landbirds and marsh birds that have wintering ranges routinely extending into Central America (beyond the Isthmus of Tehuantepec). "Range" provides relevant details on each species' known winter distribution (**Win**), summer breeding distribution (**Sum**), and/or migration route (**Mig**). Except where otherwise noted, all species are considered to be widespread during migration along the Atlantic Slope from Tamaulipas to n. Honduras. Listing order and source of body mass data as in Table 6.1. Range data are from Howell and Webb (1995), Rising (1996), Dunn and Garrett (1997), and Sibley (2000).

Species	Body Mass (g)	Range
Scissor-tailed Flycatcher (*T. forficatus*)	43	Sum: east to sw. Missouri, w. Arkansas, w. Louisiana, coastal Texas, n. Tamaulipas. **Win:** s. Veracruz-w. Campeche; a few in s. Florida; vagrant on Yucatan Peninsula and in Belize.
White-eyed Vireo (*Vireo griseus*)	11.5	**Win:** se. USA-n. Nicaragua.
Yellow-throated Vireo (*V. flavifrons*)	18	**Win:** s. Veracruz-n. South America.
Warbling Vireo (*V. gilvus*)	12	**Win:** w. Mexico-s. Honduras; absent from Yucatan Peninsula. **Mig:** Tamaulipas-s. Veracruz; unrecorded on Yucatan Peninsula
Philadelphia Vireo (*V. philadelphicus*)	12	**Win:** s. Veracruz-n. Columbia.
Red-eyed Vireo (*V. olivaceus*)	17	**Win:** South America.
Blue-gray Gnatcatcher (*Polioptila caerulea*)	6	**Win:** s. USA-Honduras.
Veery (*Catharus fuscescens*)	31	**Win:** Columbia-Brazil. **Mig:** from s. Veracruz eastward.
Gray-cheeked Thrush (*C. minimus*)	32	**Win:** Columbia-Brazil. **Mig:** from s. Veracruz eastward.
Swainson's Thrush (*C. ustulatus*)	31	**Win:** s. Veracruz-n. Argentina, except not on Yucatan Peninsula **Mig:** widespread, but less common on Yucatan Peninsula
Wood Thrush (*Hylocichla mustelina*)	47	**Win:** s. Veracruz-n. Columbia.
Gray Catbird (*Dumetella carolinensis*)	37	**Win:** se. USA-Panama.
Blue-winged Warbler (*Vermivora pinus*)	8.5	**Win:** S Veracruz-Costa Rica.
Golden-winged Warbler (*V. chrysoptera*)	8.8	**Win:** s. Mexico (Chiapas)-n. South America; absent from Yucatan Peninsula
Tennessee Warbler (*V. peregrina*)	10	**Win:** s. Veracruz-n. South America, except not on Yucatan Peninsula; most abundant Costa Rica-nw. Columbia.
Nashville Warbler (*V. ruficapilla*)	8.7	**Win:** s. Texas-Guatemala; absent from Yucatan Peninsula. **Mig:** Tamaulipas-s. Veracruz; vagrant on Yucatan Peninsula; rare in se. USA.
Northern Parula (*Parula americana*)	8.6	**Win:** primarily West Indies, where common; also fairly common s. Veracruz-n. Honduras.

Table 6.5.

Neotropical migrant landbirds recorded from the study platforms

This group includes those species and recognizable subspecies of landbirds and marsh birds that have wintering ranges routinely extending into Central America (beyond the Isthmus of Tehuantepec). "Range" provides relevant details on each species' known winter distribution (**Win**), summer breeding distribution (**Sum**), and/or migration route (**Mig**). Except where otherwise noted, all species are considered to be widespread during migration along the Atlantic Slope from Tamaulipas to n. Honduras. Listing order and source of body mass data as in Table 6.1. Range data are from Howell and Webb (1995), Rising (1996), Dunn and Garrett (1997), and Sibley (2000).

Species	Body Mass (g)	Range
Yellow Warbler (*Dendroica petechia*)	9.5	**Win:** n. Veracruz-n. South America.
Chestnut-sided Warbler (*D. pensylvanica*)	9.6	**Win:** s. Veracruz-e. Panama, primarily from Honduras eastward; absent from Yucatan Peninsula.
Magnolia Warbler (*D. magnolia*)	8.7	**Win:** n. Veracruz-w. Panama.
"Myrtle" Warbler (*D. coronata coronata*)	12.3	**Win:** s. USA-Honduras; Greater Antilles.
Black-throated Green Warbler (*D. virens*)	8.8	**Win:** s. Tamaulipas-cen. Panama.
Blackburnian Warbler (*D. fusca*)	9.8	**Win:** n. South America. **Mig:** widespread, except uncommon on Yucatan Peninsula.
Yellow-throated Warbler (*D. dominica albilora*)	9.4	**Win:** s. Texas-Nicaragua.
Bay-breasted Warbler (*D. castanea*)	12.5	**Win:** Panama-nw. South America. Fall **Mig:** mainly from Yucatan Peninsula eastward.
Cerulean Warbler (*D. cerulea*)	9.3	**Win:** n. South America. **Mig:** widespread from Veracruz southward.
Black-and-white Warbler (*Mniotilta varia*)	10.7	**Win:** s. Texas-nw. South America; s. Florida; West Indies.
American Redstart (*Setophaga ruticilla*)	8.3	**Win:** n. Veracruz-n. South America; West Indies.
Prothonotary Warbler (*Protonotaria citrea*)	16	**Win:** Yucatan Peninsula (rare) and n. Honduras (scarce) to nw. South America. **Mig:** mainly from Yucatan Peninsula eastward.
Worm-eating Warbler (*Helmitheros vermivora*)	13	**Win:** s. Veracruz-central Panama; West Indies.
Swainson's Warbler (*Limnothlypis swainsonii*)	19	**Win:** primarily in West Indies, especially Greater Antilles; also Yucatan Peninsula, Belize.
Ovenbird (*Seiurus aurocapillus*)	19.5	**Win:** s. Tamaulipas-cen. Panama; s. Florida; West Indies.
Northern Waterthrush (*S. noveboracensis*)	18	**Win:** s. Tamaulipas-n. South America; West Indies.
Louisiana Waterthrush (*S. motacilla*)	20.5	**Win:** s. Tamaulipas-Panama, except not on Yucatan Peninsula; West Indies.
Kentucky Warbler (*Oporornis formosus*)	14	**Win:** s. Veracruz to w. Panama.

Table 6.5.

Neotropical migrant landbirds recorded from the study platforms

This group includes those species and recognizable subspecies of landbirds and marsh birds that have wintering ranges routinely extending into Central America (beyond the Isthmus of Tehuantepec). "Range" provides relevant details on each species' known winter distribution (**Win**), summer breeding distribution (**Sum**), and/or migration route (**Mig**). Except where otherwise noted, all species are considered to be widespread during migration along the Atlantic Slope from Tamaulipas to n. Honduras. Listing order and source of body mass data as in Table 6.1. Range data are from Howell and Webb (1995), Rising (1996), Dunn and Garrett (1997), and Sibley (2000).

Species	Body Mass (g)	Range
Mourning Warbler (*O. philadelphia*)	12.5	**Win:** s. Nicaragua-nw. South America. **Mig:** widespread, except rare on Yucatan Peninsula; rare in se. USA.
Common Yellowthroat (*Geothlypis trichas*)	10	**Win:** s. USA-cen. Panama; West Indies.
Hooded Warbler (*Wilsonia citrina*)	10.5	**Win:** s. Veracruz-Nicaragua.
Wilson's Warbler (*W. pusilla*)	7.7	**Win:** mainly n. Tamaulipas-Costa Rica; also regular but uncommon se. Louisiana-s. Texas. **Mig:** widespread, except rare to uncommon on Yucatan Peninsula; rare in se. USA.
Canada Warbler (*W. canadensis*)	10.3	**Win:** n. South America. **Mig:** widespread, except rare on Yucatan Peninsula; scarce in se. USA.
Yellow-breasted Chat (*Icteria virens*)	25	**Win:** s. Tamaulipas-w. Panama.
Summer Tanager (*Piranga rubra*)	29	**Win:** n. Veracruz-n. South America.
Scarlet Tanager (*P. olivacea*)	28	**Win:** Columbia-Bolivia. **Mig:** mainly from Yucatan Peninsula eastward.
Savannah Sparrow (*Passerculus sandwichensis*)	20	**Win:** s. USA-Belize; w. West Indies (Bahamas, Cuba, Isle of Pines, Cayman Is., Swan Is.)
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	45	**Win:** s. Veracruz-Peru.
Blue Grosbeak (*Guiraca caerulea*)	28	**Win:** s. Tamaulipas-Costa Rica.
Indigo Bunting (*Passerina cyanea*)	14.5	**Win:** n. Veracruz-Panama.
Painted Bunting (*P. ciris*)	15.5	**Win:** s. Tamaulipas-cen. Panama.
Dickcissel (*Spiza americana*)	27	**Win:** s. Veracruz-n. South America, except not on Yucatan Peninsula. **Mig:** widespread, but uncommon on Yucatan Peninsula.
Orchard Oriole (*Icterus spurius*)	19	**Win:** s. Veracruz-n. South America.
Baltimore Oriole (*I. galbula*)	33	**Win:** s. Tamaulipas-n. South America. **Mig:** widespread, but uncommon on Yucatan Peninsula.

Table 6.6.

Medium-distance migrants recorded from the study platforms

This group includes those species and recognizable subspecies of landbirds and marsh birds that routinely winter along the northern Gulf Coast and at least as far south as s. Tamaulipas, but not beyond s. Veracruz (and not on the Yucatan Peninsula, except as a vagrant). "Winter range" provides relevant details on each species' known winter distribution along the Gulf Coast. Listing order and data sources as in Tables 6.1 and 6.5.

Species	Body Mass (g)	Winter Range
Virginia Rail (*Rallus limicola*)	85	s. Florida-n. Veracruz; unrecorded on Yucatan Peninsula.
"Yellow-shafted" Flicker (*Colaptes auratus auratus*)	130	s. Florida-s. Tamaulipas; unrecorded on Yucatan Peninsula.
Eastern Phoebe (*Sayornis phoebe*)	20	s. Florida-s. Veracruz; vagrant to Yucatan Peninsula.
Loggerhead Shrike (*Lanius ludovicianus*)	48	s. Florida-s. Veracruz; unrecorded on Yucatan Peninsula.
Blue-headed Vireo (*Vireo solitarius*)	16	s. Florida-s. Veracruz; vagrant on Yucatan Peninsula.
House Wren (*Troglodytes aedon*)	11	s. Florida-s. Veracruz; unrecorded on Yucatan Peninsula.
Sedge Wren (*Cistothorus platensis*)	9	s. Florida-n. Veracruz; unrecorded on Yucatan Peninsula.
Marsh Wren (*C. palustris*)	11	s. Florida-n. Veracruz; unrecorded on Yucatan Peninsula.
Hermit Thrush (*Catharus guttatus*)	31	cen. Florida-s. Tamaulipas; rare in s. Florida; vagrant to s. Veracruz; unrecorded on Yucatan Peninsula.
American Robin (*Turdus migratorius*)	77	s. Florida-n. Veracruz; vagrant to s. Veracruz, Yucatan Peninsula, Belize.
Northern Mockingbird (*Mimus polyglottos*)	49	s. Florida-s. Veracruz; unrecorded on Yucatan Peninsula.
American Pipit (*Anthus rubescens*)	21	s. Florida-s. Veracruz; vagrant to Tabasco, Yucatan Peninsula.
Orange-crowned Warbler (*Vermivora celata*)	9	s. Florida-s. Veracruz; vagrant on n. Yucatan Peninsula.
Chipping Sparrow (*Spizella passerina*)	12	cen. Florida-s. Tamaulipas; rare in s. Florida; unrecorded on Yucatan Peninsula.
Clay-colored Sparrow (*S. pallida*)	12	cen. Texas-s. Tamaulipas; vagrant farther east along n. Gulf Coast; rare in Veracruz; vagrant on n. Yucatan Peninsula.
Vesper Sparrow (*Pooecetes gramineus*)	26	cen. Florida-s. Tamaulipas; rare in s. Florida; vagrant on n. Yucatan Peninsula.

Table 6.6.

Medium-distance migrants recorded from the study platforms

This group includes those species and recognizable subspecies of landbirds and marsh birds that routinely winter along the northern Gulf Coast and at least as far south as s. Tamaulipas, but not beyond s. Veracruz (and not on the Yucatan Peninsula, except as a vagrant). "Winter range" provides relevant details on each species' known winter distribution along the Gulf Coast. Listing order and data sources as in Tables 6.1 and 6.5.

Species	Body Mass (g)	Winter Range
Lark Sparrow (*Chondestes grammacus*)	29	e. Texas-n. Veracruz; rare farther east along n. Gulf Coast; vagrant on n. Yucatan Peninsula.
Grasshopper Sparrow (*Ammodramus savannarum*)	17	s. Florida-Veracruz; rare to uncommon on Yucatan Peninsula; also locally in w. West Indies (Bahamas, Cuba, Isle of Pines, Cayman Is., Swan Is.).
Lincoln's Sparrow (*Melospiza lincolnii*)	17	s. Florida-s. Veracruz; vagrant on Yucatan Peninsula, in Belize, and in West Indies.
Swamp Sparrow (*M. georgiana*)	17	s. Florida-n. Veracruz; irregular and less common from Texas south; unrecorded on Yucatan Peninsula.
White-crowned Sparrow (*Zonotrichia leucophrys*)	29	nw. Florida-s. Tamaulipas; rare on Florida Peninsula; vagrant on n.Yucatan Peninsula, in Belize, and in West Indies.
Western Meadowlark (*Sturnella neglecta*)	97	e. Louisiana-n. Veracruz; unrecorded on Yucatan Peninsula.
Brewer's Blackbird (*Euphagus cyanocephalus*)	63	Alabama-n. Veracruz; unrecorded on Yucatan Peninsula.
Brown-headed Cowbird (*Molothrus ater*)	44	s. Florida-s. Veracruz; unrecorded on Yucatan Peninsula.
Pine Siskin (*Carduelis pinus*)	15	cen. Florida-s. Tamaulipas; unrecorded on Yucatan Peninsula.
American Goldfinch (*C. tristis*)	13	s. Florida-n. Veracruz; unrecorded on Yucatan Peninsula.

Table 6.7.

Short-distance migrants recorded from the study platforms

This group includes those species and recognizable subspecies of landbirds and marsh birds with no known regular wintering populations south of n. Tamaulipas. All are unrecorded from Atlantic Slope of Mexico (including the Yucatan Peninsula) unless otherwise indicated. "Winter range" provides relevant details on each species' known winter distribution along the Gulf Coast. Listing order and data sources as in Tables 6.1 and 6.5.

Species	Body Mass (g)	Winter Range
Yellow Rail (*Coturnicops noveboracensis*)	50	cen. Florida-cen. Texas.
Clapper Rail (*Rallus longirostris*)	290	s. Florida-n. Tamaulipas (disjunct population in coastal Yucatan Peninsula thought to be resident).
King Rail (*Rallus elegans*)	360	s. Florida-s. Texas; disjunct resident population in coastal Veracruz, but migrants from USA populations unrecorded in Mexico.
Long-eared Owl (*Asio otus*)	260	Virginia-Kentucky-Arkansas-cen. Texas; irregular and rare vagrant south to Gulf Coast from s. Florida-s. Texas.
Short-eared Owl (*A. flammeus*)	350	South Carolina-Tennessee-Arkansas-cen. Texas; a few regularly winter south to Gulf Coast from s. Florida-cen. Texas; irregular and rare south to n. Veracruz.
Red-headed Woodpecker (*Melanerpes erythrocephalus*)	72	cen. Florida-cen. Texas; rare in s. Florida, s. Texas.
Downy Woodpecker (*Picoides pubescens*)	27	s. Florida-cen. Texas.
Red-breasted Nuthatch (*Sitta canadensis*)	10	n. Florida-e. Texas; irregular in s. Florida, s. Texas; vagrant to Nuevo Leon.
White-breasted Nuthatch (*S. carolinensis*)	21	s. Georgia —ne. Texas.
Carolina Wren (*Thryothorus ludovicianus*)	21	usually considered to be nonmigratory; resident to s. Tamaulipas; unrecorded on Yucatan Peninsula.
Winter Wren (*Troglodytes troglodytes*)	9	nw. Florida-cen. Texas; vagrant to Tamaulipas.
Golden-crowned Kinglet (*Regulus satrapa*)	6	n. Florida-s. Texas; irregularly rare to uncommon in s. Florida, n. Tamaulipas.
Ruby-crowned Kinglet (*R. calendula*)	6.5	s. Florida-n. Tamaulipas; vagrant to s. Veracruz, Yucatan Peninsula.
Brown Thrasher (*Toxostoma rufum*)	69	s. Florida-cen. Texas; vagrant to Tamaulipas.
European Starling (*Sturnus vulgaris*)	82	s. Florida-n. Tamaulipas; vagrant to s. Veracruz, n. Yucatan Peninsula.
Pine Warbler (*Dendroica pinus*)	12	cen. Florida-cen. Texas; vagrant to n. Tamaulipas.
"Yellow" Palm Warbler (*D. palmarum hypochrysea*)	10.3	n. Florida-se. Louisiana; one record in Quintana Roo.

Table 6.7.

Short-distance migrants recorded from the study platforms

This group includes those species and recognizable subspecies of landbirds and marsh birds with no known regular wintering populations south of n. Tamaulipas. All are unrecorded from Atlantic Slope of Mexico (including the Yucatan Peninsula) unless otherwise indicated. "Winter range" provides relevant details on each species' known winter distribution along the Gulf Coast. Listing order and data sources as in Tables 6.1 and 6.5.

Species	Body Mass (g)	Winter Range
Eastern Towhee (*Pipilo erythrophthalmus*)	40	s. Florida to s. Texas.
American Tree Sparrow (*Spizella arborea*)	20	Virginia-Tennessee-nw. Arkansas-n. Texas.
Field Sparrow (*Spizella pusilla*)	12.5	s. Florida-n. Tamaulipas.
Henslow's Sparrow (*Ammodramus henslowii*)	13	n. Florida-cen. Texas.
LeConte's Sparrow (*A. leconteii*)	13	n. Florida-s. Texas.
Nelson's Sharp-tailed Sparrow (*A. nelsoni*)	17	cen. Florida-s. Texas; vagrant to n. Tamaulipas.
Song Sparrow (*Melospiza melodia*)	20	n. Florida-cen. Texas; rare in s. Florida; uncommon in s. Texas; rare to uncommon in n. Nuevo Leon, but otherwise unrecorded on Atlantic Slope of Mexico.
White-throated Sparrow (*Zonotrichia albicollis*)	26	cen. Florida to n. Tamaulipas; uncommon in s. Florida.
"Slate-colored" Junco (*Junco hyemalis hyemalis*)	19	n. Florida to cen. Texas; rare in s. Florida; irregularly rare to uncommon to s. Tamaulipas; vagrant to s. Veracruz.
Common Grackle (*Quiscalus quiscula*)	115	s. Florida-cen. Texas.
Boat-tailed Grackle (*Q. major*)	168	s. Florida-cen. Texas.

The group referred to as "Caribbean vagrants" included those species that normally breed, winter, or migrate in the Caribbean area and were unexpected (a priori) to occur in the study area except as rare vagrants (Table 6.8). The group referred to as "western vagrants" comprised species that normally breed and winter no farther east than central coastal Texas and were unexpected (a priori) to occur in the study area except as rare vagrants (Table 6.9).

Swifts and swallows are obligate aerial insectivores and all are diurnal migrants; this group is referred to as "aerial insectivores" (Table 6.10).

Ruby-throated Hummingbirds (*Archilochus colubris*; body mass = 3.2 g) are diurnal migrants with a variety of unique ecological and physiological characteristics, and are treated separately here.

Finally, species whose expected trans-Gulf status was unclear because of unknown migratory status, the existence of widespread resident populations, or other factors are listed in Table 6.11.

Table 6.8.

Caribbean vagrants recorded from the study platforms

This group includes those species and recognizable subspecies that normally breed, winter, or migrate in the Caribbean area and were unexpected a priori to occur in the study area except as rare vagrants. "Range" provides relevant details on each species' known winter distribution (**Win**), summer breeding distribution (**Sum**), and/or migration route (**Mig**). Listing order and data sources as in Tables 6.1 and 6.5.

Species	Body Mass (g)	Range
Black Swift (*Cypseloides niger*)	45	Caribbean population considered to be resident.
Cuban Pewee	?	Unrecorded in Mexico.
Gray Kingbird (*Tyrannus dominicensis*)	44	**Win**: Caribbean to n. South America. **Mig**: rare on e. coast of Yucatan Peninsula.
Loggerhead Kingbird (*T. caudifasciatus*)	?	Unrecorded in Mexico.
Black-whiskered Vireo (*Vireo altiloquus*)	18	**Sum**: resident along peninsular Florida coast. **Win**: South America. **Mig**: vagrant in Quintana Roo, Belize.
"Caribbean" Cave Swallow (*Petrochelidon fulva citata*)	15	**Win**: Breeding population on n. Yucatan Peninsula thought to be nomadic in winter. **Mig**: unknown.
Cape May Warbler (*Dendroica tigrina*)	11	**Win**: primarily West Indies; uncommon along Caribbean coast (mainly offshore islands) from Quintana Roo to n. Honduras. **Mig**: from e. coast of Yucatan Peninsula eastward, primarily via Florida.
Black-throated Blue Warbler (*D. caerulescens*)	10.2	**Win**: primarily West Indies; rare-uncommon along Caribbean coast (mainly offshore islands) from Quintana Roo to nw. South America. **Mig**: from e. coast of Yucatan Peninsula eastward, primarily via Florida.
Prairie Warbler (*D. discolor*)	7.7	**Win**: mainly West Indies; rare-uncommon along Caribbean coast (mainly offshore islands) from Quintana Roo to n. Honduras; also s. Florida. **Mig**: from e. coast of Yucatan Peninsula eastward, primarily via Florida.
"Western" Palm Warbler (*D. palmarum palmarum*)	10.3	**Win**: se. USA (west to Louisiana), West Indies, and along Caribbean coast from n. Yucatan Peninsula to Costa Rica. **Mig**: from n. Yucatan Peninsula east.

Table 6.8.

Caribbean vagrants recorded from the study platforms

This group includes those species and recognizable subspecies that normally breed, winter, or migrate in the Caribbean area and were unexpected a priori to occur in the study area except as rare vagrants. “Range” provides relevant details on each species’ known winter distribution (**Win**), summer breeding distribution (**Sum**), and/or migration route (**Mig**). Listing order and data sources as in Tables 6.1 and 6.5.

Species	Body Mass (g)	Range
Blackpoll Warbler (*D. striata*)	13	**Win**: South America. **Spring mig**: probably mainly over w. Caribbean toward Florida, overflying the islands; rare in ne. Yucatan Peninsula. **Fall mig**: probably entirely overwater from Atlantic Coast to n. South America; rare in ne. Yucatan Peninsula.
Connecticut Warbler (*Oporornis agilis*)	15	**Win**: South America. **Spring mig**: probably across Caribbean to Florida; one record in Belize. **Fall mig**: probably across Atlantic Ocean from e. USA to n. South America.
Bobolink (*Dolichonyx oryzivorus*)	43	**Win**: s. South America. **Mig**: mainly across Caribbean; irregularly uncommon-fairly common in spring and rare-uncommon in fall from ne. Yucatan Peninsula to Honduras Bay Islands.

Table 6.9.

Western vagrants recorded from the study platforms

This group includes those species and recognizable subspecies that normally breed and winter no farther east than central coastal Texas and were unexpected a priori to occur in the study area except as rare vagrants. All are unrecorded from the Yucatan Peninsula unless otherwise indicated. "Range" provides relevant details on each species' known winter distribution (**Win**), summer breeding distribution (**Sum**), and/or migration route (**Mig**). Listing order and data sources as in Tables 6.1 and 6.5.

Species	Body Mass(g)	Range
Band-tailed Pigeon (*Columba fasciata*)	360	**Sum**: east to cen. Colorado, w. Texas, and throughout interior Central America. **Win**: mostly resident within summer range, but populations in sw. USA move elsewhere in winter.
Groove-billed Ani (*Crotophaga sulcirostris*)	85	**Sum**: s. Texas-South America. **Win**: mostly resident within summer range; a few east to Upper Texas Coast.
Flammulated Owl (*Otus flammeolus*)	60	**Sum**: east to cen. Colorado, se. New Mexico, w. Texas, cen. Mexico. **Win**: highlands of cen. Mexico-Guatemala; unrecorded on Atlantic slope of Mexico.
Burrowing Owl (*Athene cunicularia*)	155	**Sum**: east to e. North Dakota, cen. Kansas, cen. Texas, cen. Mexico; also a disjunct resident population in Florida. **Win**: cen. Texas-s. Veracruz, and on Pacific Slope into Honduras; vagrant on Yucatan Peninsula.
Lesser Nighthawk (*Chordeiles acutipennis*)	50	**Sum**: east to se. New Mexico, cen. Texas coast, Tamaulipas; a disjunct population on n. Yucatan Peninsula. **Win**: north to n. Veracruz, including Yucatan Peninsula.
Black-chinned Hummingbird (*Archilochus alexandri*)	3.3	**Sum**: east to w. Montana, w. Colorado, se. New Mexico, cen. Texas, n. Nuevo Leon. **Win**: primarily on Pacific Slope of Mexico.
Rufous Hummingbird (*Selasphorus rufus*)	3.4	**Sum**: east to sw. Alberta, w. Montana, e. Idaho. **Win**: primarily on Pacific Slope of Mexico; in recent years, range has expanded dramatically into se. USA due to artificial selection by hummingbird feeding enthusiasts.
Ringed Kingfisher (*Ceryle torquata*)	315	**Sum**: s. Texas-South America, but not on n. Yucatan Peninsula. **Win**: mainly in summer range.

Table 6.9.

Western vagrants recorded from the study platforms

This group includes those species and recognizable subspecies that normally breed and winter no farther east than central coastal Texas and were unexpected a priori to occur in the study area except as rare vagrants. All are unrecorded from the Yucatan Peninsula unless otherwise indicated. “Range” provides relevant details on each species’ known winter distribution (**Win**), summer breeding distribution (**Sum**), and/or migration route (**Mig**). Listing order and data sources as in Tables 6.1 and 6.5.

Species	Body Mass(g)	Range
Western Wood-Pewee (*Contopus sordidulus*)	13	**Sum**: east to sw. Manitoba, w. North Dakota, w. Nebraska, e. New Mexico, w. Texas, Coahuila, and through interior to Honduras. **Win**: South America.
Say’s Phoebe (*Sayornis saya*)	21	**Sum**: east to s. Saskatchewan, w. South Dakota, w. Kansas, e. New Mexico, w. Texas, Coahuila, cen. Mexico. **Win**: east to cen. Texas coast, Tamaulipas, and in interior to Oaxaca.
Vermilion Flycatcher (*Pyrocephalus rubinus*)	14.5	**Sum**: east to e. New Mexico, cen. Texas, Nuevo Leon, s. Veracruz, and disjunctly to Nicaragua (including on Yucatan Peninsula). **Win**: in s. portion of breeding range and eastward to cen. Texas coast, Tamaulipas, n. Veracruz.
Ash-throated Flycatcher (*Myiarchus cinerascens*)	27	**Sum**: east to sw. Wyoming, se. Colorado, w. Oklahoma, cen. Texas, w. Nuevo Leon, and in interior to cen. Mexico. **Win**: mostly on Pacific Slope south to Nicaragua; on Atlantic Slope in Tamaulipas and Veracruz.
Brown-crested Flycatcher (*Myiarchus tyrannulus)*	44	**Sum**: s. Texas-South America, including on Yucatan Peninsula. **Win**: north to Veracruz, including on Yucatan Peninsula.
Tropical Kingbird (*Tyrannus melancholicus*)	40	**Sum**: s. Texas-South America, including on Yucatan Peninsula. **Win**: generally considered to be resident through most of summer range.
Couch’s Kingbird (*Tyrannus couchii*)	43	**Sum**: cen. Texas coast-Belize, including Yucatan Peninsula. **Win**: s. Texas-Belize, including Yucatan Peninsula.
Western Kingbird (*Tyrannus verticalis*)	40	**Sum**: east to w. Wisconsin, w. Iowa, e. Kansas, cen. Oklahoma, cen. Texas. **Win**: mostly on Pacific Slope and in interior from cen. Mexico to Costa Rica; a few in s. Florida.

Table 6.9.

Western vagrants recorded from the study platforms

This group includes those species and recognizable subspecies that normally breed and winter no farther east than central coastal Texas and were unexpected a priori to occur in the study area except as rare vagrants. All are unrecorded from the Yucatan Peninsula unless otherwise indicated. "Range" provides relevant details on each species' known winter distribution (**Win**), summer breeding distribution (**Sum**), and/or migration route (**Mig**). Listing order and data sources as in Tables 6.1 and 6.5.

Species	Body Mass(g)	Range
Bell's Vireo (*Vireo bellii*)	8.5	**Sum**: east to Illinois, Missouri, e. Texas, and in interior to cen. Mexico. **Win**: mainly on Pacific Slope of Mexico to El Salvador.
Violet-green Swallow (*Tachycineta thalassina*)	14	**Sum**: east to e. Montana, cen. Colorado, w. Texas, and in interior to cen. Mexico. **Win**: Pacific Slope and interior of Mexico to El Salvador.
"Mexican" Cave Swallow (*Petrochelidon fulva fulva*?)	15	**Sum**: east to cen. Texas, w. Tamaulipas, with disjunct populations along the fringe of an expanding population to e. Texas. **Win**: poorly known; probably mainly in s. portion of summer range.
Sage Thrasher (*Oreoscoptes montanus*)	43	**Sum**: east to se. Montana, cen. Colorado, nw. New Mexico. **Win**: east to cen. Texas, n. Tamaulipas.
Long-billed Thrasher (*Toxostoma longirostre*)	70	**Sum**: s. Texas-n. Veracruz. **Win**: usually considered permanent resident within summer range.
Sprague's Pipit (*Anthus spragueii*)	25	**Sum**: east to s. Manitoba, e. North Dakota. **Win**: east to w. Louisiana, coastal Texas, Tamaulipas, n. Veracruz.
"Audubon's" Warbler (*Dendroica coronata auduboni*)	12.3	**Sum**: east to w. South Dakota, cen. Colorado, extreme w. Texas. **Win**: east to w. Texas, s. Tamaulipas, and through interior highlands to w. Honduras; vagrant in s. Veracruz; unrecorded on Yucatan Peninsula.
Black-throated Gray Warbler (*Dendroica nigrescens*)	8.4	**Sum**: east to nw. Wyoming, se. Colorado, se. New Mexico. **Win**: mainly on Pacific Slope and in interior, east to San Luis Potosí and Oaxaca; rarely to lower Rio Grande Valley in s. Texas; vagrant in s. Veracruz; unrecorded on Yucatan Peninsula.
Townsend's Warbler (*Dendroica townsendi*)	8.8	**Sum**: east to sw. Alberta, w. Montana, cen. Idaho. **Win**: interior highlands from s. Nuevo Leon to w. Nicaragua; vagrant in s. Veracruz; unrecorded on Yucatan Peninsula.

Table 6.9.

Western vagrants recorded from the study platforms

This group includes those species and recognizable subspecies that normally breed and winter no farther east than central coastal Texas and were unexpected a priori to occur in the study area except as rare vagrants. All are unrecorded from the Yucatan Peninsula unless otherwise indicated. "Range" provides relevant details on each species' known winter distribution (**Win**), summer breeding distribution (**Sum**), and/or migration route (**Mig**). Listing order and data sources as in Tables 6.1 and 6.5.

Species	Body Mass(g)	Range
Hermit Warbler (*Dendroica occidentalis*)	9.2	**Sum**: east to Cascades and Sierra Nevada from cen. Washington to cen. California. **Win**: interior highlands from s. Nuevo Leon to w. Nicaragua; vagrant in s. Veracruz; unrecorded on Yucatan Peninsula.
MacGillivray's Warbler (*Oporornis tolmiei*)	10.5	**Sum**: east to sw. Alberta, w. Montana, w. South Dakota (Black Hills), cen. Colorado, cen. New Mexico, s. Nuevo Leon. **Win**: mainly in highlands from s. Nuevo Leon to w. Panama; vagrant in s. Veracruz; unrecorded on Yucatan Peninsula.
Western Tanager (*Piranga ludoviciana*)	28	**Sum**: east to w. Saskatchewan, e. Wyoming, cen. New Mexico, w. Texas. **Win**: mainly on Pacific Slope and in interior from s. Mexico-w. Panama; less common on Atlantic Slope from s. Tamaulipas to Guatemala; vagrant on Yucatan Peninsula.
Green-tailed Towhee (*Pipilo chlorurus*)	29	**Sum**: east to cen. Wyoming, cen. Colorado, nw. New Mexico. **Win**: east to cen. coastal Texas, n. Tamaulipas.
Spotted Towhee (*Pipilo maculatus*)	40	**Sum**: east to cen. North Dakota, cen. Nebraska, cen. Colorado, New Mexico, and in highlands of w. Texas and Mexico south to Oaxaca. **Win**: east to e. Kansas, e. Oklahoma, cen. Coastal Texas, n. Tamaulipas.
Cassin's Sparrow (*Aimophila cassinii*)	19	**Sum**: east to cen. Kansas, cen. Oklahoma, cen. coastal Texas (Corpus Christi area), s. Tamaulipas. **Win**: primarily within summer range, north to s. Texas; unrecorded on Atlantic Slope south of Tamaulipas.
"Gray-headed" Junco (*Junco hyemalis caniceps*)	?	**Sum**: east to cen. Colorado, cen. New Mexico, extreme w. Texas. **Win**: primarily at lower elevations within breeding range; also southeast to Chihuahua, n. Durango; unrecorded on Atlantic slope of Mexico.

Table 6.9.

Western vagrants recorded from the study platforms

This group includes those species and recognizable subspecies that normally breed and winter no farther east than central coastal Texas and were unexpected a priori to occur in the study area except as rare vagrants. All are unrecorded from the Yucatan Peninsula unless otherwise indicated. "Range" provides relevant details on each species' known winter distribution (**Win**), summer breeding distribution (**Sum**), and/or migration route (**Mig**). Listing order and data sources as in Tables 6.1 and 6.5.

Species	Body Mass(g)	Range
"Pink-sided" Junco (*Junco hyemalis mearnsi*)	?	**Sum**: east to cen. Montana, nw. Wyoming. **Win**: east to e.. Colorado, e. New Mexico, sw. Texas, cen. Chihuahua
Chestnut-collared Longspur (*Calcarius ornatus*)	19	**Sum**: east to e. North Dakota, e. South Dakota, se. Colorado. **Win**: east to cen. Oklahoma, cen. Texas, w. Coahuila, and on Mexican Plateau to Zacatecas.
Pyrrhuloxia (*Cardinalis sinuatus*)	36	**Sum**: east to cen. interior Texas, s. coastal Texas, s. Tamaulipas. **Win**: usually resident within summer range.
Lazuli Bunting (*Passerina amoena*)	15.5	**Sum**: east to cen. North Dakota, cen. Nebraska, cen. Oklahoma. **Win**: Pacific Slope of Mexico and interior to Oaxaca.
Varied Bunting (*P. versicolor*)	12	**Sum**: east to w. Texas, extreme s. Texas, s. Tamaulipas. **Win**: n. Tamaulipas-s. Veracruz.
Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*)	65	**Sum**: east to Wisconsin, n. Illinois, n. Nebraska, n. New Mexico. **Win**: east to w. Texas, Tamaulipas, n. Veracruz; vagrant to Yucatan Peninsula.
Bronzed Cowbird (*Molothrus aeneus*)	62	**Sum**: cen. coastal Texas-cen. Panama. **Win**: north to n. Tamaulipas.
Bullock's Oriole (*Icterus bullockii*)	36	**Sum**: east to w. South Dakota, w. Nebraska, w. Texas, and in highlands to cen. Mexico. **Win**: s. Tamaulipas-s. Veracruz, and in interior to Guatemala.
Lesser Goldfinch (*Carduelis psaltria*)	9.5	**Sum**: east to se. Colorado, e. New Mexico, s. Texas, Nuevo Leon, and in interior to Oaxaca; also a disjunct year-round resident population on n. Yucatan Peninsula. **Win**: east to cen. Texas coast, Tamaulipas, n. Veracruz.

Table 6.10.

Aerial insectivores recorded from the study platforms

"Winter range" provides relevant details on each species' known winter distribution. Listing order and data sources as in Tables 6.1 and 6.5.

Species	Body Mass (g)	Winter Range
Chimney Swift (*Chaetura pelagica*)	23	South America.
Purple Martin (*Progne subis*)	56	South America.
Tree Swallow (*Tachycineta bicolor*)	20	s. USA-n. Honduras.
Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)	16	s. Texas-Panama; also s. Florida.
Bank Swallow (*Riparia riparia*)	13.5	South America.
Cliff Swallow (*Petrochelidon pyrrhonota*)	21	South America.
Barn Swallow (*Hirundo rustica*)	19	s. Veracruz-s. South America, but not on Yucatan Peninsula.

Table 6.11.

Species whose expected trans-Gulf status was unclear because of unknown migratory status, the existence of widespread resident populations, or other factors

Listing order and data sources as in Tables 6.1 and 6.5.

Species	Body Mass (g)	Range
Rock Dove (*Columba livia*)	270	All individuals recorded offshore appeared to be racing pigeons.
Eurasian Collared-Dove (*Streptopelia decaocto*)	200	Species is currently colonizing se. USA; migratory status unknown.
White-winged Dove (*Zenaida asiatica*)	150	Status complex; year-round resident from e. Texas-n. Veracruz and on Yucatan Peninsula; additional wintering populations along Gulf Coast from w. Florida-Louisiana and cen. Veracruz-Tabasco; also a permanent resident population in s. Florida thought to be derived from introduced stock. This species is undergoing a dramatic population increase and range expansion with increasingly frequent extralimital breeding and migration records, but details of the expansion remain unclear.
Inca dove (*Columbina inca*)	47	Considered to be a permanent resident from sw. Louisiana-cen. Tabasco, but species has undergone a range expansion with population in Louisiana established recently.

Table 6.11.

Species whose expected trans-Gulf status was unclear because of unknown migratory status, the existence of widespread resident populations, or other factors

Listing order and data sources as in Tables 6.1 and 6.5.

Species	Body Mass (g)	Range
Common Ground-Dove (*C. passerina*)	30	Considered to be a permanent resident along Gulf coast from s. Florida-s, Veracruz; disjunct resident population on Yucatan Peninsula.
Barn Owl (*Tyto alba*)	460	Resident throughout much of USA and Central America; northern part of population known to migrate long distances, but winter range of migratory individuals unclear due to widespread presence of year-round residents.
Cedar Waxwing (*Bombycilla cedrorum*)	32	Winters throughout s. USA; irregularly rare-uncommon in winter on Yucatan Peninsula and along entire Atlantic coast of Mexico, but presumed not to be a trans-Gulf migrant because of its status as a strictly diurnal migrant.
Red-winged Blackbird (*Agelaius phoeniceus*)	52	Resident throughout USA and along entire Atlantic coast of Mexico to nw. Honduras; northern part of population known to be migratory, but winter range of migratory individuals unclear due to widespread presence of year-round residents.
Eastern Meadowlark (*Sturnella magna*)	90	Resident throughout much of USA and along Atlantic coast of Mexico to Honduras; northern part of population known to be migratory, but winter range of migratory individuals unclear due to widespread presence of year-round residents.
Great-tailed Grackle (*Quiscalus mexicanus*)	148	Year-round resident from cen. Louisiana through most of Mexico; population has recently been expanding northward and eastward; northern part of population known to be migratory, but winter range of migratory individuals unclear due to widespread presence of year-round residents.

6.2 SUMMARY OF COUNT DATA

A complete enumeration of all migrant birds recorded on or observed from the study platforms is presented in Table 6.12, with data grouped by season, year, and ecological group.

Altogether, 119,810 individuals of 279 species were recorded offshore during the study. During the spring, 82,281 individuals were recorded, 14% as stopovers and the balance as flybys. During the fall, 37,529 individuals were recorded, 30% as stopovers and the balance as flybys. The significantly larger proportion of fall migrants recorded as stopovers ($G = 3,850$, $P << 0.0001$) was due to the fact that fall migration over the northern Gulf proceeded mostly at night, when the detectability of migrants was relatively low, whereas the opposite was the case during the spring. Table 6.13 shows the number of species and recognizable forms recorded in each season in relation to status (stopover versus flyby) and ecological category.

Table 6.12.

Summary of platform count data grouped by season, year, and ecological group

Species are listed in descending order of abundance within each ecological group.

		SPRING						FALL				
		1998		1999		2000		1998		1999		
Species	Group	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	TOTAL
Blue-winged Teal	waterfowl	0	334	0	728	0	4,305	2	28	6	1,309	6,712
unidentified duck	waterfowl	0	179	0	97	0	619	0	112	0	715	1,722
Lesser Scaup	waterfowl	0	0	0	16	0	242	0	0	0	707	965
Greater White-fronted Goose	waterfowl	0	0	0	0	0	15	0	0	0	274	289
unidentified scoter	waterfowl	0	185	0	0	0	0	0	0	0	0	185
Snow Goose	waterfowl	0	0	0	0	0	0	0	1	0	163	164
Northern Pintail	waterfowl	0	40	0	0	0	18	0	0	0	90	148
Northern Shoveler	waterfowl	0	0	0	0	0	90	0	0	0	30	120
Green-winged Teal	waterfowl	0	0	0	25	0	7	0	1	1	83	117
American Wigeon	waterfowl	0	0	0	0	0	21	0	8	0	39	68
Fulvous Whistling-Duck	waterfowl	0	0	0	0	0	64	0	3	0	0	67
unidentified goose	waterfowl	0	0	0	0	0	0	0	0	0	52	52
Black-bellied Whistling-Duck	waterfowl	0	0	0	0	0	0	0	0	0	26	26
Cinnamon Teal	waterfowl	0	22	0	0	0	1	0	0	0	0	23
Gadwall	waterfowl	0	0	0	0	0	0	0	0	0	17	17
Greater Scaup	waterfowl	0	0	0	16	0	0	0	0	0	0	16
Redhead	waterfowl	0	0	0	0	0	1	0	0	0	15	16
Red-breasted Merganser	waterfowl	0	0	0	0	0	0	0	8	0	1	9
White-winged Scoter	waterfowl	0	9	0	0	0	0	0	0	0	0	9
Ring-necked Duck	waterfowl	0	0	0	0	0	5	0	0	0	3	8
Hooded Merganser	waterfowl	0	0	0	0	0	0	0	0	0	2	2

Table 6.12.

Summary of platform count data grouped by season, year, and ecological group

Species are listed in descending order of abundance within each ecological group.

		SPRING						FALL				
		1998		1999		2000		1998		1999		
Species	Group	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	TOTAL
Mallard	waterfowl	0	0	0	0	0	0	0	0	0	2	2
Ross's Goose	waterfowl	0	0	0	0	0	0	0	0	0	2	2
Surf Scoter	waterfowl	0	0	0	0	0	0	0	0	0	2	2
Cattle Egret	heron	234	823	337	1,470	601	5,056	81	358	200	3,714	12,874
unidentified small white egret	heron	0	85	0	567	1	3,618	0	682	1	1,899	6,850
Little Blue Heron	heron	5	171	1	559	11	1,855	1	67	20	205	2,895
unidentified heron	heron	0	79	0	497	1	1,168	0	192	0	605	2,545
Great Egret	heron	1	71	8	284	21	1,288	3	299	1	306	2,282
Great Blue Heron	heron	3	88	1	197	19	644	3	834	14	436	2,239
Green Heron	heron	71	206	114	76	204	1,062	25	12	50	100	1,920
Snowy Egret	heron	6	95	4	264	17	361	0	76	1	275	1,099
Yellow-crowned Night-Heron	heron	7	32	12	55	14	422	0	13	4	102	661
White Ibis	heron	0	3	2	90	4	12	3	96	1	238	449
Tricolored Heron	heron	1	31	2	56	3	214	0	15	0	17	339
unidentified *Plegadis* ibis	heron	0	0	0	0	0	0	0	1	0	179	180
Black-crowned Night-Heron	heron	1	2	0	11	0	35	0	0	0	34	83
Roseate Spoonbill	heron	0	0	0	0	0	0	0	27	0	0	27
White-faced Ibis	heron	0	0	0	0	0	27	0	0	0	0	27
Reddish Egret	heron	2	10	1	2	0	6	0	0	0	1	22
American Bittern	heron	2	0	0	4	2	1	0	0	2	2	13
Peregrine Falcon	diurnal raptor	31	19	50	33	63	50	96	61	280	101	784

Table 6.12.

Summary of platform count data grouped by season, year, and ecological group

Species are listed in descending order of abundance within each ecological group.

		SPRING						FALL				
		1998		1999		2000		1998		1999		
Species	Group	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	TOTAL
American Kestrel	diurnal raptor	5	5	0	1	12	6	21	2	61	18	131
Osprey	diurnal raptor	6	23	3	16	4	31	3	16	8	20	130
Merlin	diurnal raptor	5	18	6	3	5	14	2	6	21	36	116
unidentified small falcon	diurnal raptor	0	0	0	4	0	2	0	4	1	11	22
Sharp-shinned Hawk	diurnal raptor	0	0	3	1	1	1	3	3	0	1	13
Mississippi Kite	diurnal raptor	0	12	0	0	0	0	0	0	0	0	12
Swallow-tailed Kite	diurnal raptor	0	1	0	5	0	5	0	0	0	0	11
Northern Harrier	diurnal raptor	0	0	0	0	0	0	0	0	0	7	7
Cooper’s Hawk	diurnal raptor	0	0	0	0	0	0	0	1	0	1	2
Aplomado Falcon	diurnal raptor	0	0	0	0	1	0	0	0	0	0	1
Broad-winged Hawk	diurnal raptor	0	0	0	0	0	0	0	0	1	0	1
unidentified shorebird	shorebird	2	227	0	294	1	1,093	0	187	11	97	1,912
Upland Sandpiper	shorebird	0	18	0	17	0	113	0	5	3	263	419
American Golden-Plover	shorebird	0	57	0	232	5	76	0	0	0	1	371
unidentified “peep”	shorebird	0	12	0	19	0	262	0	0	0	32	325
Pectoral Sandpiper	shorebird	0	17	0	33	0	233	0	0	0	3	286
Lesser Yellowlegs	shorebird	0	1	0	0	1	242	0	5	0	4	253
Greater Yellowlegs	shorebird	0	2	0	1	0	123	0	1	0	6	133
Black-necked Stilt	shorebird	0	0	0	0	0	117	0	0	0	4	121
Whimbrel	shorebird	0	1	0	39	0	66	0	0	0	0	106
White-rumped Sandpiper	shorebird	0	0	0	15	0	79	0	0	0	0	94

Table 6.12.

Summary of platform count data grouped by season, year, and ecological group

Species are listed in descending order of abundance within each ecological group.

		SPRING						FALL				
		1998		1999		2000		1998		1999		
Species	Group	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	TOTAL
Least Sandpiper	shorebird	2	17	0	0	5	38	0	5	1	17	85
unidentified dowitcher	shorebird	0	7	0	0	0	39	0	0	0	38	84
Hudsonian Godwit	shorebird	0	50	0	0	0	1	0	0	0	0	51
Killdeer	shorebird	0	0	0	0	0	31	0	1	0	14	46
Willet	shorebird	1	8	1	4	0	23	0	1	0	7	45
Buff-breasted Sandpiper	shorebird	0	4	0	6	0	27	0	1	0	0	38
Solitary Sandpiper	shorebird	0	0	0	0	0	11	0	4	1	22	38
Spotted Sandpiper	shorebird	4	2	4	1	6	2	0	0	2	7	28
Sanderling	shorebird	2	1	1	0	1	4	0	1	2	9	21
Black-bellied Plover	shorebird	0	0	0	0	0	20	0	0	0	0	20
Long-billed Curlew	shorebird	0	20	0	0	0	0	0	0	0	0	20
Common Snipe	shorebird	0	0	0	0	1	1	0	0	2	13	17
Marbled Godwit	shorebird	0	10	0	0	0	7	0	0	0	0	17
Ruddy Turnstone	shorebird	0	0	0	0	1	2	0	5	0	9	17
Baird’s Sandpiper	shorebird	1	0	0	0	0	10	1	0	0	4	16
Dunlin	shorebird	0	15	0	0	0	0	0	0	0	0	15
Semipalmated Plover	shorebird	0	0	0	1	0	0	0	0	1	12	14
Stilt Sandpiper	shorebird	0	0	0	0	0	8	0	3	0	0	11
Red-necked Phalarope	shorebird	0	6	0	0	0	0	0	0	1	0	7
Semipalmated Sandpiper	shorebird	1	4	2	0	0	0	0	0	0	0	7
Western Sandpiper	shorebird	0	3	1	0	1	0	0	0	1	0	6

Table 6.12.

Summary of platform count data grouped by season, year, and ecological group

Species are listed in descending order of abundance within each ecological group.

		SPRING						FALL				
		1998		1999		2000		1998		1999		
Species	Group	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	TOTAL
Long-billed Dowitcher	shorebird	0	0	0	0	0	0	0	0	0	5	5
American Avocet	shorebird	0	0	0	0	0	0	0	0	0	3	3
Wilson's Phalarope	shorebird	0	1	0	0	0	1	0	0	0	0	2
Red Knot	shorebird	0	0	0	0	0	0	0	1	0	0	1
Wilson's Plover	shorebird	0	0	0	0	1	0	0	0	0	0	1
unidentified warbler	neotropical migrant (sm)	24	310	14	88	49	1,906	99	253	106	1,094	3,943
Magnolia Warbler	neotropical migrant (sm)	79	18	82	9	325	1,309	79	5	581	131	2,618
Common Yellowthroat	neotropical migrant (sm)	129	4	78	9	402	112	124	5	458	51	1,372
Mourning Dove	neotropical migrant (lg)	35	17	3	2	72	45	85	14	701	266	1,240
Eastern Kingbird	neotropical migrant (lg)	16	23	5	202	7	783	10	7	32	122	1,207
Bay-breasted Warbler	neotropical migrant (sm)	784	57	7	4	151	130	0	0	60	7	1,200
unidentified Catharus thrush	neotropical migrant (lg)	2	10	1	2	6	572	1	11	3	489	1,097
Gray Catbird	neotropical migrant (lg)	236	21	43	11	248	306	34	2	64	51	1,016
Indigo Bunting	neotropical migrant (sm)	68	13	12	5	90	359	8	17	322	80	974
Common Nighthawk	neotropical migrant (lg)	5	30	0	85	4	627	1	56	4	22	834
Prothonotary Warbler	neotropical migrant (sm)	24	5	34	9	14	19	215	27	196	280	823
American Redstart	neotropical migrant (sm)	45	2	26	5	89	31	81	6	404	60	749
Ovenbird	neotropical migrant (sm)	272	13	18	4	93	54	66	8	185	35	748
Yellow Warbler	neotropical migrant (sm)	41	2	4	0	40	23	144	15	222	248	739
Hooded Warbler	neotropical migrant (sm)	41	6	41	16	156	36	67	3	121	210	697
Black-throated Green Warbler	neotropical migrant (sm)	24	0	5	1	48	15	21	1	371	77	563

Table 6.12.

Summary of platform count data grouped by season, year, and ecological group

Species are listed in descending order of abundance within each ecological group.

		SPRING						FALL				
		1998		1999		2000		1998		1999		
Species	Group	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	TOTAL
Black-and-white Warbler	neotropical migrant (sm)	84	5	16	5	161	95	39	6	112	10	533
Northern Parula	neotropical migrant (sm)	41	3	39	5	63	13	60	0	199	81	504
Tennessee Warbler	neotropical migrant (sm)	137	4	16	1	107	21	18	3	148	16	471
Dickcissel	neotropical migrant (lg)	5	1	0	22	14	98	6	11	73	107	337
"Myrtle" Warbler	neotropical migrant (sm)	24	1	31	7	24	8	38	6	145	23	307
Orchard Oriole	neotropical migrant (lg)	41	3	32	10	99	63	2	0	37	10	297
Sora	neotropical migrant (lg)	35	9	11	1	41	16	0	10	38	115	276
Yellow-billed Cuckoo	neotropical migrant (lg)	70	35	20	11	53	38	5	2	16	18	268
Red-eyed Vireo	neotropical migrant (sm)	99	3	13	0	35	39	16	8	37	12	262
Baltimore Oriole	neotropical migrant (lg)	6	6	3	0	43	165	3	1	31	3	261
Yellow-breasted Chat	neotropical migrant (lg)	2	1	2	0	14	5	17	0	172	29	242
Northern Waterthrush	neotropical migrant (sm)	54	12	13	0	27	2	35	6	50	4	203
Savannah Sparrow	neotropical migrant (sm)	9	0	0	1	59	6	7	0	101	10	193
Chestnut-sided Warbler	neotropical migrant (sm)	50	2	9	1	33	20	9	0	61	1	186
Kentucky Warbler	neotropical migrant (sm)	23	5	13	1	51	16	26	4	31	9	179
Blackburnian Warbler	neotropical migrant (sm)	8	1	3	2	49	37	14	2	51	2	169
Scissor-tailed Flycatcher	neotropical migrant (lg)	5	3	0	1	13	27	1	1	43	62	156
Rose-breasted Grosbeak	neotropical migrant (lg)	44	4	2	0	6	41	0	1	14	36	148
Scarlet Tanager	neotropical migrant (lg)	55	18	9	0	14	28	2	0	18	3	147
unidentified cuckoo	neotropical migrant (lg)	0	0	0	22	0	108	0	0	0	3	133
Chuck-will's-widow	neotropical migrant (lg)	8	1	14	1	20	3	12	2	57	11	129

Table 6.12.

Summary of platform count data grouped by season, year, and ecological group

Species are listed in descending order of abundance within each ecological group.

		SPRING						FALL				
		1998		1999		2000		1998		1999		
Species	Group	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	TOTAL
Belted Kingfisher	neotropical migrant (lg)	9	1	16	0	46	12	13	1	22	8	128
Eastern Wood-Pewee	neotropical migrant (sm)	11	2	3	0	31	18	16	4	40	3	128
Purple Gallinule	neotropical migrant (lg)	19	5	12	2	19	8	0	10	7	26	108
White-eyed Vireo	neotropical migrant (sm)	10	0	6	0	20	2	5	5	42	17	107
Swainson’s Thrush	neotropical migrant (lg)	23	5	1	1	3	12	3	3	26	27	104
Worm-eating Warbler	neotropical migrant (sm)	9	1	9	3	17	1	10	3	25	22	100
Summer Tanager	neotropical migrant (lg)	18	3	5	3	12	21	6	3	18	3	92
Least Flycatcher	neotropical migrant (sm)	6	0	0	0	5	0	5	0	65	1	82
unidentified Empidonax flycatcher	neotropical migrant (sm)	6	0	0	0	2	6	19	1	28	17	79
Yellow-throated Warbler	neotropical migrant (sm)	2	1	8	0	22	2	9	1	27	0	72
Nashville Warbler	neotropical migrant (sm)	6	0	1	0	12	0	2	0	48	2	71
Great Crested Flycatcher	neotropical migrant (lg)	1	0	0	0	4	2	5	0	44	13	69
Least Bittern	neotropical migrant (lg)	7	0	6	0	9	2	3	13	4	22	66
Cerulean Warbler	neotropical migrant (sm)	3	0	1	0	8	3	7	0	16	28	66
Acadian Flycatcher	neotropical migrant (sm)	5	2	2	0	11	0	11	2	23	1	57
Wood Thrush	neotropical migrant (lg)	11	6	9	6	8	6	0	0	0	10	56
Louisiana Waterthrush	neotropical migrant (sm)	6	0	5	0	33	5	2	0	5	0	56
Blue Grosbeak	neotropical migrant (lg)	7	0	2	0	6	6	6	0	19	6	52
Wilson’s Warbler	neotropical migrant (sm)	0	0	0	0	0	1	12	0	36	2	51
unidentified flycatcher	neotropical migrant (sm)	0	0	0	0	1	34	0	1	3	7	46

Table 6.12.

Summary of platform count data grouped by season, year, and ecological group

Species are listed in descending order of abundance within each ecological group.

		SPRING						FALL				
		1998		1999		2000		1998		1999		
Species	Group	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	TOTAL
Pied-billed Grebe	neotropical migrant (lg)	0	0	0	0	0	6	0	1	9	27	43
“Traill’s” Flycatcher	neotropical migrant (sm)	0	0	0	0	3	0	4	0	31	0	38
Blue-winged Warbler	neotropical migrant (sm)	3	0	1	0	18	5	1	0	8	0	36
American Coot	neotropical migrant (lg)	2	1	2	0	1	15	0	0	3	10	34
Mourning Warbler	neotropical migrant (sm)	0	0	0	0	1	0	5	0	25	1	32
Yellow-throated Vireo	neotropical migrant (sm)	1	2	1	0	15	2	1	1	7	2	32
Painted Bunting	neotropical migrant (sm)	4	0	4	2	8	6	3	0	4	0	31
Gray-cheeked Thrush	neotropical migrant (lg)	16	6	2	0	0	0	0	0	3	0	27
Swainson’s Warbler	neotropical migrant (sm)	0	0	7	0	5	1	3	1	8	1	26
Blue-gray Gnatcatcher	neotropical migrant (sm)	1	0	0	0	3	3	1	1	14	1	24
Canada Warbler	neotropical migrant (sm)	0	0	0	0	2	0	4	0	18	0	24
Veery	neotropical migrant (lg)	7	3	0	0	2	3	2	1	3	2	23
Black-billed Cuckoo	neotropical migrant (lg)	2	2	0	1	3	5	0	0	2	3	18
Common Moorhen	neotropical migrant (lg)	4	1	0	0	5	3	1	0	1	2	17
Yellow-bellied Sapsucker	neotropical migrant (lg)	1	1	2	2	6	0	1	1	2	0	16
unidentified tanager	neotropical migrant (lg)	0	0	0	0	1	10	0	0	0	4	15
Philadelphia Vireo	neotropical migrant (sm)	0	0	0	0	5	3	3	0	2	1	14
Golden-winged Warbler	neotropical migrant (sm)	0	0	0	0	7	3	1	1	1	0	13
Warbling Vireo	neotropical migrant (sm)	0	0	0	0	4	0	0	0	6	0	10
Whip-Poor-Will	neotropical migrant (lg)	3	0	0	0	0	0	2	0	3	1	9
unidentified oriole	neotropical migrant (lg)	0	0	0	0	0	4	0	0	0	3	7

Table 6.12.

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Species are listed in descending order of abundance within each ecological group.

		SPRING						FALL				
		1998		1999		2000		1998		1999		
Species	Group	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	TOTAL
Yellow-bellied Flycatcher	neotropical migrant (sm)	0	0	0	0	0	0	0	0	7	0	7
hybrid warbler	neotropical migrant (sm)	0	0	0	0	1	0	0	0	1	0	2
Black Rail	neotropical migrant (lg)	0	0	0	0	0	1	0	0	0	0	1
Alder Flycatcher	neotropical migrant (sm)	0	0	0	0	1	0	0	0	0	0	1
Willow Flycatcher	neotropical migrant (sm)	0	0	0	0	0	0	0	0	0	1	1
Brown-headed Cowbird	medium-distance migrant	61	116	8	0	101	54	1	0	24	9	374
Lincoln’s Sparrow	medium-distance migrant	2	0	0	0	86	5	7	0	210	29	339
House Wren	medium-distance migrant	0	0	0	0	2	0	33	1	204	29	269
Marsh Wren	medium-distance migrant	0	0	0	0	1	0	50	4	157	11	223
Grasshopper Sparrow	medium-distance migrant	3	1	0	1	52	3	3	0	80	11	154
Clay-colored Sparrow	medium-distance migrant	1	0	0	0	33	0	3	0	51	1	89
Orange-crowned Warbler	medium-distance migrant	2	0	0	0	1	0	4	0	60	1	68
Northern Mockingbird	medium-distance migrant	7	0	4	0	11	1	7	0	34	3	67
Chipping Sparrow	medium-distance migrant	0	0	0	0	20	1	4	0	39	0	64
Swamp Sparrow	medium-distance migrant	0	0	0	0	0	0	8	0	41	1	50
Eastern Phoebe	medium-distance migrant	0	0	0	0	1	0	1	1	40	3	46
Western Meadowlark	medium-distance migrant	0	0	0	0	2	0	2	0	36	2	42
Lark Sparrow	medium-distance migrant	3	0	0	0	16	0	1	0	18	3	41
unidentified wren	medium-distance migrant	0	0	0	0	1	0	0	0	3	34	38
Vesper Sparrow	medium-distance migrant	3	1	0	0	5	4	1	0	9	3	26
Sedge Wren	medium-distance migrant	0	0	0	0	0	0	4	0	17	0	21

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Species are listed in descending order of abundance within each ecological group.

		SPRING						FALL				
		1998		1999		2000		1998		1999		
Species	Group	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	TOTAL
American Robin	medium-distance migrant	0	0	0	0	1	3	2	0	6	1	13
White-crowned Sparrow	medium-distance migrant	0	0	0	0	0	0	1	0	10	1	12
“Yellow-shafted” Flicker	medium-distance migrant	0	0	0	0	0	0	2	1	5	4	12
American Pipit	medium-distance migrant	1	0	0	0	0	2	0	0	4	4	11
Blue-headed Vireo	medium-distance migrant	0	0	0	0	4	0	1	0	5	0	10
Virginia Rail	medium-distance migrant	0	0	0	0	1	0	0	0	8	0	9
Hermit Thrush	medium-distance migrant	0	0	0	0	0	0	1	0	4	3	8
Loggerhead Shrike	medium-distance migrant	0	0	0	0	0	1	0	0	7	0	8
Brewer’s Blackbird	medium-distance migrant	1	0	0	0	0	1	0	0	3	1	6
Pine Siskin	medium-distance migrant	0	0	0	0	0	0	1	0	0	1	2
American Goldfinch	medium-distance migrant	0	0	0	0	0	0	0	0	0	1	1
Ruby-crowned Kinglet	short-distance migrant	0	0	0	0	2	0	38	1	115	23	179
Brown Thrasher	short-distance migrant	1	0	0	0	4	0	15	1	50	1	72
White-throated Sparrow	short-distance migrant	1	0	0	0	1	0	2	0	25	3	32
Song Sparrow	short-distance migrant	0	0	0	0	1	0	1	0	25	0	27
Golden-crowned Kinglet	short-distance migrant	0	0	0	0	0	0	7	2	8	0	17
Winter Wren	short-distance migrant	0	0	0	0	0	0	4	0	10	1	15
Pine Warbler	short-distance migrant	0	0	0	0	0	0	0	0	13	0	13
Field Sparrow	short-distance migrant	0	0	0	0	0	0	0	0	8	0	8
Clapper Rail	short-distance migrant	0	0	0	0	0	1	0	0	6	0	7
“Slate-colored” Junco	short-distance migrant	0	0	0	0	1	0	0	0	4	0	5

Table 6.12.

Summary of platform count data grouped by season, year, and ecological group

Species are listed in descending order of abundance within each ecological group.

		SPRING						FALL				
		1998		1999		2000		1998		1999		
Species	Group	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	TOTAL
Common Grackle	short-distance migrant	0	0	0	0	0	1	0	0	3	1	5
Leconte’s Sparrow	short-distance migrant	0	0	0	0	0	0	0	0	2	2	4
Long-eared Owl	short-distance migrant	0	0	0	0	0	0	0	0	4	0	4
Red-headed Woodpecker	short-distance migrant	0	0	0	0	0	0	0	0	2	2	4
Eastern Towhee	short-distance migrant	0	0	0	0	0	1	0	0	1	1	3
Short-eared Owl	short-distance migrant	0	0	0	0	1	1	0	0	0	1	3
Downy Woodpecker	short-distance migrant	0	0	0	0	0	0	0	0	2	0	2
King Rail	short-distance migrant	0	0	0	0	0	0	0	0	2	0	2
Red-breasted Nuthatch	short-distance migrant	0	0	0	0	0	0	0	0	2	0	2
Short-eared/Long-eared Owl	short-distance migrant	0	0	0	0	0	0	0	0	0	2	2
“Yellow” Palm Warbler	short-distance migrant	0	0	0	1	0	0	1	0	0	0	2
Carolina Wren	short-distance migrant	0	0	0	0	1	0	0	0	0	0	1
American Tree Sparrow	short-distance migrant	1	0	0	0	0	0	0	0	0	0	1
Boat-tailed Grackle	short-distance migrant	0	0	0	0	0	0	0	0	1	0	1
Eurasian Starling	short-distance migrant	0	0	0	0	1	0	0	0	0	0	1
Henslow’s Sparrow	short-distance migrant	0	0	0	0	0	0	0	0	1	0	1
White-breasted Nuthatch	short-distance migrant	0	0	0	0	0	0	0	0	1	0	1
Yellow Rail	short-distance migrant	0	0	0	0	0	0	0	0	1	0	1
Blackpoll Warbler	Caribbean vagrant	47	4	38	8	47	11	0	0	4	0	159
“Western” Palm Warbler	Caribbean vagrant	13	0	8	0	9	0	41	1	67	2	141
Bobolink	Caribbean vagrant	11	0	11	9	9	29	2	0	5	1	77

Table 6.12.

Summary of platform count data grouped by season, year, and ecological group

Species are listed in descending order of abundance within each ecological group.

		SPRING						FALL				
		1998		1999		2000		1998		1999		
Species	Group	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	TOTAL
Prairie Warbler	Caribbean vagrant	6	0	2	0	4	1	12	2	25	3	55
Black-throated Blue Warbler	Caribbean vagrant	2	0	1	1	2	0	7	2	19	3	37
Cape May Warbler	Caribbean vagrant	3	1	1	0	3	2	1	0	5	0	16
Gray Kingbird	Caribbean vagrant	1	0	1	0	1	0	2	1	0	0	6
Black Swift	Caribbean vagrant	0	0	0	0	0	0	0	0	0	2	2
Black-whiskered Vireo	Caribbean vagrant	1	0	0	0	1	0	0	0	0	0	2
“Caribbean” Cave Swallow	Caribbean vagrant	0	0	1	0	0	0	0	0	0	0	1
Connecticut Warbler	Caribbean vagrant	1	0	0	0	0	0	0	0	0	0	1
Cuban Pewee	Caribbean vagrant	0	0	0	0	0	0	0	0	1	0	1
Loggerhead Kingbird	Caribbean vagrant	0	0	0	0	0	0	0	0	1	0	1
Lesser Nighthawk	western vagrant	1	4	2	0	10	28	1	1	1	5	53
Western Kingbird	western vagrant	7	1	1	1	1	2	1	0	1	1	16
Yellow-headed Blackbird	western vagrant	4	0	1	0	4	0	1	0	6	0	16
Pyrrhuloxia	western vagrant	0	0	0	0	0	0	0	0	6	4	10
Burrowing Owl	western vagrant	0	0	0	0	2	0	0	0	6	0	8
“Mexican” Cave Swallow	western vagrant	0	0	0	0	0	0	1	0	0	5	6
Ash-throated Flycatcher	western vagrant	2	0	0	0	2	0	0	0	1	0	5
“Audubon’s” Warbler	western vagrant	0	0	0	0	2	0	0	0	3	0	5
Cassin’s Sparrow	western vagrant	0	0	0	0	2	0	0	0	3	0	5
Tropical/Couch’s Kingbird	western vagrant	0	1	1	0	0	0	0	0	2	0	4
Brown-crested Flycatcher	western vagrant	2	0	0	0	1	0	0	0	0	0	3

Table 6.12.

Summary of platform count data grouped by season, year, and ecological group

Species are listed in descending order of abundance within each ecological group.

		SPRING						FALL				
		1998		1999		2000		1998		1999		
Species	Group	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	TOTAL
Bronzed Cowbird	western vagrant	0	1	0	0	0	0	0	0	2	0	3
Couch’s Kingbird	western vagrant	1	0	0	0	1	0	0	0	1	0	3
Groove-billed Ani	western vagrant	0	0	0	0	0	0	0	0	3	0	3
Green-tailed Towhee	western vagrant	0	0	0	0	0	0	0	0	3	0	3
Long-billed Thrasher	western vagrant	0	0	0	0	0	0	0	0	3	0	3
MacGillivray’s Warbler	western vagrant	0	0	0	0	0	0	0	0	3	0	3
Western Tanager	western vagrant	2	0	0	0	0	0	0	1	0	0	3
Bell’s Vireo	western vagrant	0	0	0	0	0	0	0	0	2	0	2
Bullock’s Oriole	western vagrant	0	0	0	0	0	0	0	0	2	0	2
Flammulated Owl	western vagrant	0	0	0	0	0	0	0	0	2	0	2
“Gray-headed” Junco	western vagrant	0	0	0	0	0	0	0	0	2	0	2
Townsend’s Warbler	western vagrant	1	0	0	0	0	0	0	0	1	0	2
Tropical Kingbird	western vagrant	1	0	1	0	0	0	0	0	0	0	2
Vermilion Flycatcher	western vagrant	0	0	0	0	0	0	0	0	2	0	2
Western Wood-Pewee	western vagrant	0	0	0	0	0	0	0	0	2	0	2
Band-tailed Pigeon	western vagrant	0	0	0	0	1	0	0	0	0	0	1
Black-chinned Hummingbird	western vagrant	0	0	0	0	0	0	0	0	1	0	1
Black-throated Gray Warbler	western vagrant	0	0	1	0	0	0	0	0	0	0	1
Chestnut-collared Longspur	western vagrant	0	0	0	0	0	0	0	0	1	0	1
Hermit Warbler	western vagrant	0	0	1	0	0	0	0	0	0	0	1
Lazuli Bunting	western vagrant	0	0	0	0	1	0	0	0	0	0	1

Table 6.12.

Summary of platform count data grouped by season, year, and ecological group

Species are listed in descending order of abundance within each ecological group.

		SPRING						FALL				
		1998		1999		2000		1998		1999		
Species	Group	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	TOTAL
Lesser Goldfinch	western vagrant	0	0	0	0	0	0	0	0	1	0	1
“Pink-sided” Junco	western vagrant	0	0	0	0	0	0	0	0	1	0	1
Ringed Kingfisher	western vagrant	0	0	0	0	0	0	0	0	1	0	1
Rufous Hummingbird	western vagrant	0	0	0	0	0	0	0	0	1	0	1
Say’s Phoebe	western vagrant	0	0	0	0	0	0	0	0	1	0	1
Sage Thrasher	western vagrant	0	0	0	0	0	0	0	0	1	0	1
Sprague’s Pipit	western vagrant	0	0	0	0	0	0	0	0	1	0	1
Spotted Towhee	western vagrant	0	0	0	0	0	0	0	0	1	0	1
Varied Bunting	western vagrant	0	0	0	0	0	1	0	0	0	0	1
Violet-green Swallow	western vagrant	0	0	0	0	0	1	0	0	0	0	1
Barn Swallow	aerial insectivore	540	313	308	211	265	759	63	301	141	701	3,602
Purple Martin	aerial insectivore	138	72	12	110	277	152	12	59	25	87	944
Tree Swallow	aerial insectivore	37	38	19	47	95	622	0	6	1	18	883
unidentified swallow	aerial insectivore	1	21	3	121	5	99	0	32	4	352	638
Bank Swallow	aerial insectivore	32	37	19	11	12	189	5	1	21	139	466
Chimney Swift	aerial insectivore	20	95	1	67	11	160	0	11	1	26	392
Cliff Swallow	aerial insectivore	31	16	6	14	19	54	1	9	46	78	274
Northern Rough-winged Swallow	aerial insectivore	4	3	8	16	13	7	3	5	5	9	73
Ruby-throated Hummingbird		80	14	53	15	57	61	24	11	93	160	568
White-winged Dove	miscellaneous	65	22	30	1	106	20	52	2	222	40	560
Common Ground-Dove	miscellaneous	0	0	0	0	0	0	0	0	27	3	30

Table 6.12.

Summary of platform count data grouped by season, year, and ecological group

Species are listed in descending order of abundance within each ecological group.

		SPRING						FALL				
		1998		1999		2000		1998		1999		
Species	Group	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	TOTAL
Eastern Meadowlark	miscellaneous	1	0	0	0	3	2	1	0	22	0	29
Red-winged Blackbird	miscellaneous	2	0	0	0	1	0	0	0	6	2	11
Eurasian Collared-Dove	miscellaneous	0	0	0	0	0	0	0	0	8	0	8
Rock Dove	miscellaneous	2	1	1	0	1	0	0	0	1	0	6
Barn Owl	miscellaneous	0	0	0	0	0	0	0	0	5	0	5
Inca Dove	miscellaneous	0	0	0	0	0	1	0	0	2	1	4
Cedar Waxwing	miscellaneous	0	0	0	0	0	0	1	0	0	0	1
Great-tailed Grackle	miscellaneous	0	0	0	0	0	0	0	0	1	0	1
unidentified passerine	unidentified	71	1,304	37	5,589	70	17,358	21	337	137	2,879	27,803
unidentified bird	unidentified	0	8	5	579	1	597	0	72	10	431	1703
unidentified sparrow	unidentified	0	0	0	0	7	57	2	1	16	61	144
unidentified meadowlark	unidentified	0	0	0	0	4	2	1	1	60	34	102
unidentified dove	unidentified	0	0	0	5	1	13	0	0	3	4	26
unidentified nighthawk	unidentified	0	0	0	0	0	5	0	1	0	3	9
unidentified hummingbird	unidentified	0	0	0	0	0	0	0	3	0	0	3
Great-tailed/Boat-tailed Grackle	unidentified	0	0	0	0	0	0	0	0	1	0	1

Table 6.13.

Number of species and recognizable forms recorded in each season in relation to status (stopover versus flyby) and ecological group

	SPRING						FALL				
	1998		1999		2000		1998		1999		
Group	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	Stop	Fly	TOTAL
Waterfowl	0	4	0	4	0	11	1	6	2	17	21
Herons	11	11	10	12	10	13	6	11	9	13	15
Diurnal Raptors	4	6	4	6	6	6	5	6	5	7	11
Shorebirds	6	20	5	10	9	24	1	12	9	18	33
Neotropical Migrants	62	48	52	35	67	63	61	44	71	62	74
Medium-distance Migrants	10	3	2	1	16	10	21	4	24	21	26
Short-distance Migrants	3	0	0	1	8	4	7	3	22	9	27
Caribbean Vagrants	9	2	8	3	8	4	6	4	8	5	13
Western Vagrants	9	4	6	1	11	4	4	2	31	4	41
Aerial Insectivores	7	7	7	7	7	7	5	7	7	7	7
Ruby-throated Hummingbird	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	4	2	2	1	4	3	3	1	9	4	10
Unidentified	0	0	0	0	0	0	0	1	0	0	0
TOTAL	126	108	97	82	147	150	121	102	198	168	279

Chapter 7

Spring Migration Routes Across the Gulf of Mexico

Robert W. Russell

7.1 INTRODUCTION

Little progress has been made in quantifying the geography of spring trans-Gulf migration since Cooke (1905) first postulated a spring trans-Gulf route from Mexico to northeastern Texas.

We used five methods to deduce spring migration routes across the Gulf of Mexico. First, we inspected daily time series of radar images from the ten NEXRAD sites around the northern Gulf. Visual inspection of base reflectivity images permitted us to determine directly where landfall occurred (i.e., where the trans-Gulf route terminated), and inspection of radial velocity images permitted us to determine the direction from which the migrants were arriving.

Second, we examined the relationship between synoptic weather patterns and the location of radar-observed landfall along the northern Gulf Coast. Because migrating birds select favorable winds for departing on long-distance flights, the form of the weather-landfall relationship could potentially provide information on the departure points of migrants as well as their destinations.

Third, we analyzed the orientation of migrants observed in direct flight over the Gulf. These observations permitted us to determine migratory flight directions outside of the range of the land-based radars.

Fourth, we looked for east-west gradients in the abundance of migrants stopping over on platforms. Our expectation was that, all else being equal, there should be a positive correlation between the abundance of migrants in the source population aloft and the numbers of migrants dropping out to use platforms below and, therefore, that relative abundance on platforms should delineate migratory corridors (Ralph 1981).

Fifth, we looked for species-specific patterns of abundance across the Gulf, and attempted to determine whether these patterns were invariant with respect to synoptic weather.

At the conclusion of the chapter, we document extraordinarily male-biased sex ratios in a variety of trans-Gulf migrants and examine the possibility of sexual differences in overwater migration routes.

7.2 RADAR OBSERVATIONS OF LANDFALL ON THE NORTHERN GULF COAST

Visual inspection of spring radar images suggested a number of robust patterns, which are described below with graphical examples and quantified more rigorously in subsequent sections.

The first trans-Gulf migrants in the study area were usually detected off Brownsville around 10:00-12:00 Z (e.g., Figure 7.1), with large volumes of offshore migration traffic subsequently occurring between southern Texas and southwest Louisiana, and peak instantaneous densities of migrants usually occurring in the airspace off southern and/or central Texas (e.g., Figure 7.2). The typical pattern over the course of the day was for peak instantaneous densities to diminish while shifting eastward toward southwest Louisiana. Figure 7.3 shows an example from April 15, 2000. By 15:00 Z, dense migration traffic (12-20 dBZ_e) was aloft over waters offshore from central and southern Texas, but migrants were just beginning to enter the airspace off the Upper Texas Coast and were entirely absent off Louisiana. Four hours later, migration traffic was still heaviest off central Texas, where it was nonetheless reduced considerably in magnitude (to ~4-8 dBZ_e, implying roughly an order of magnitude decline), but migration traffic off the Upper Texas Coast had increased to ~0-4 dBZ_e. Another four hours later, migration traffic off central Texas had further diminished to ~0-4 dBZ_e, traffic was heaviest off the Upper Texas Coast where it had increased to ~4-8 dBZ_e, and light migration traffic (~0-4 dBZe) was evident off southwest Louisiana.

Base velocity images generally indicated that the direction of travel was due north off southern and central Texas, and to the northeast off the Upper Texas Coast (e.g., Figures 7.4, 7.5). These NEXRAD velocity data, together with the pattern of progressively later arrival clockwise around the northern Gulf Coast (e.g., Figure 7.3), suggest that the migration pathway of many trans-Gulf migrants is curvilinear, veering eastward as the northern Gulf Coast is approached. The discrepancy between peak instantaneous densities of migrants off the southern and central Texas coast (higher) versus off the Upper Texas Coast and southwest Louisiana (lower) suggests that there is a divergence of flight directions within the main migration stream as the northern Gulf Coast is approached. In other words, some proportion of the migrants begins heading inland along the central Texas coast (typically in Calhoun County, where the orientation of the Texas coastline changes from N-S to SW-NE). This scenario would result in a pattern of declining densities of migrants clockwise around the northern Gulf Coast, which is consistent with observations.

The departure points of trans-Gulf migrants can be estimated using time series of radar reflectivity and velocity images. For example, the base velocity images for April 15 corresponding to Figure 7.2 indicated that the migrants were traveling at ground speeds of 15-25 $m \cdot s^{-1}$. Nocturnal migrants generally initiate migratory flight around a half hour after sunset, which was at about 19:00 CDT along the southern Gulf coast on April 14. Thus, the fastest migrants (~25 $m \cdot s^{-1}$) departing at 19:30 CDT on April 14 had been flying for about 11 hours when they arrived off Brownsville on April 15 (Figure 7.1), and had thus covered about 1000 km. These calculations suggest that the migrants could have departed from the southern Gulf coast between the Isthmus of Tehuantepec and the northern Yucatan Peninsula. Analogous calculations on other days yielded similar conclusions.

Large radar-observed migration events were progressively less common to the east of southwest Louisiana, and were rare as far east as the Florida Panhandle. Significant events along the northeastern Gulf Coast were confined to **BH** days when winds had a westerly component over the northern Gulf (e.g., Figure 7.6) and to **GF** days when trans-Gulf migrants were displaced eastward by an advancing cold front (e.g., Figure 7.7).

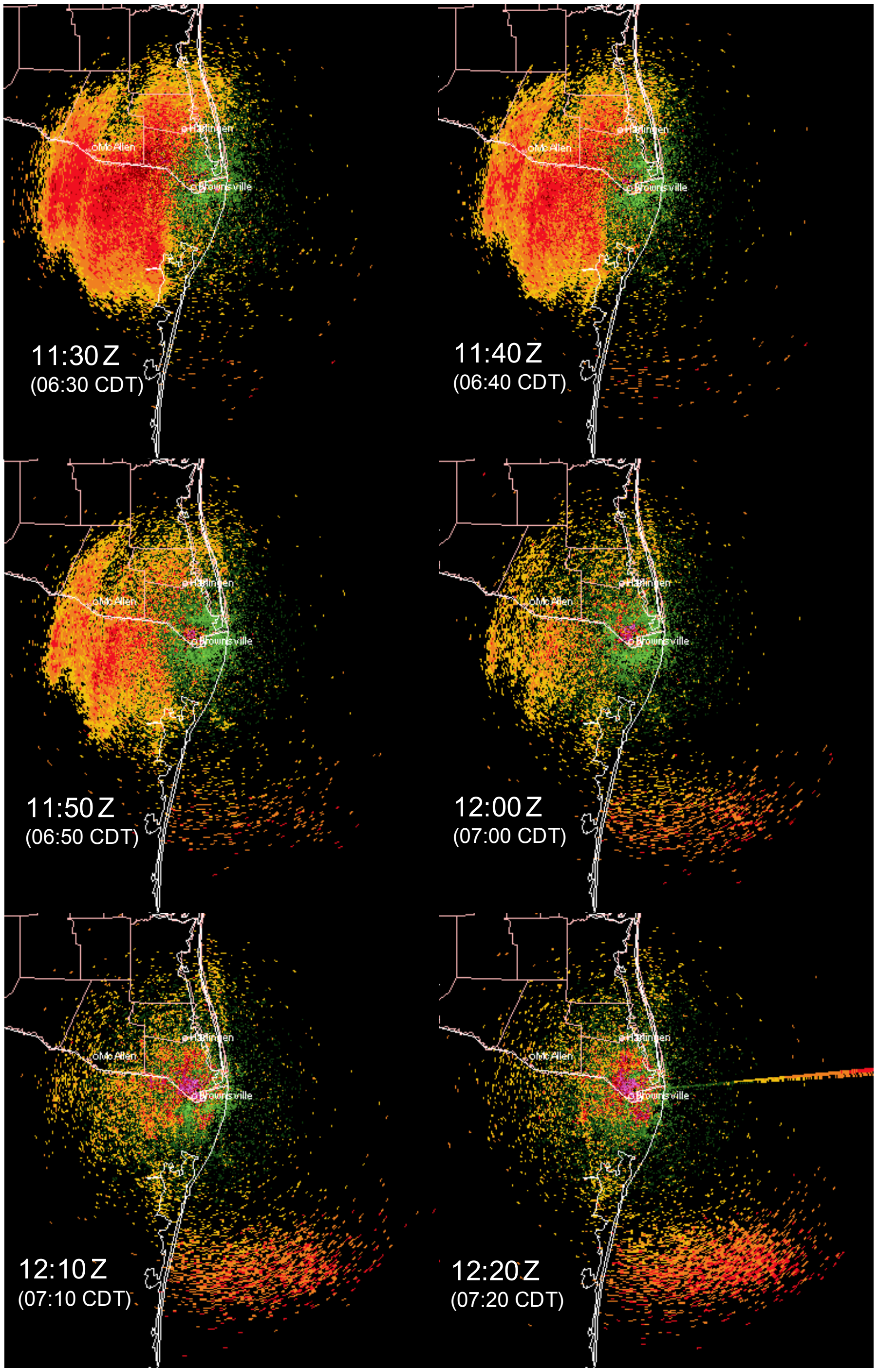

Figure 7.1. Time series of NEXRAD base reflectivity images showing first arrival of trans-Gulf migrants off Brownsville on April 10, 2000. Synoptic weather for this flight was classified as **GH**. All radar scans were obtained in clear-air mode at an elevation of 0.5°. Images are courtesy of TAP Publishing Company.

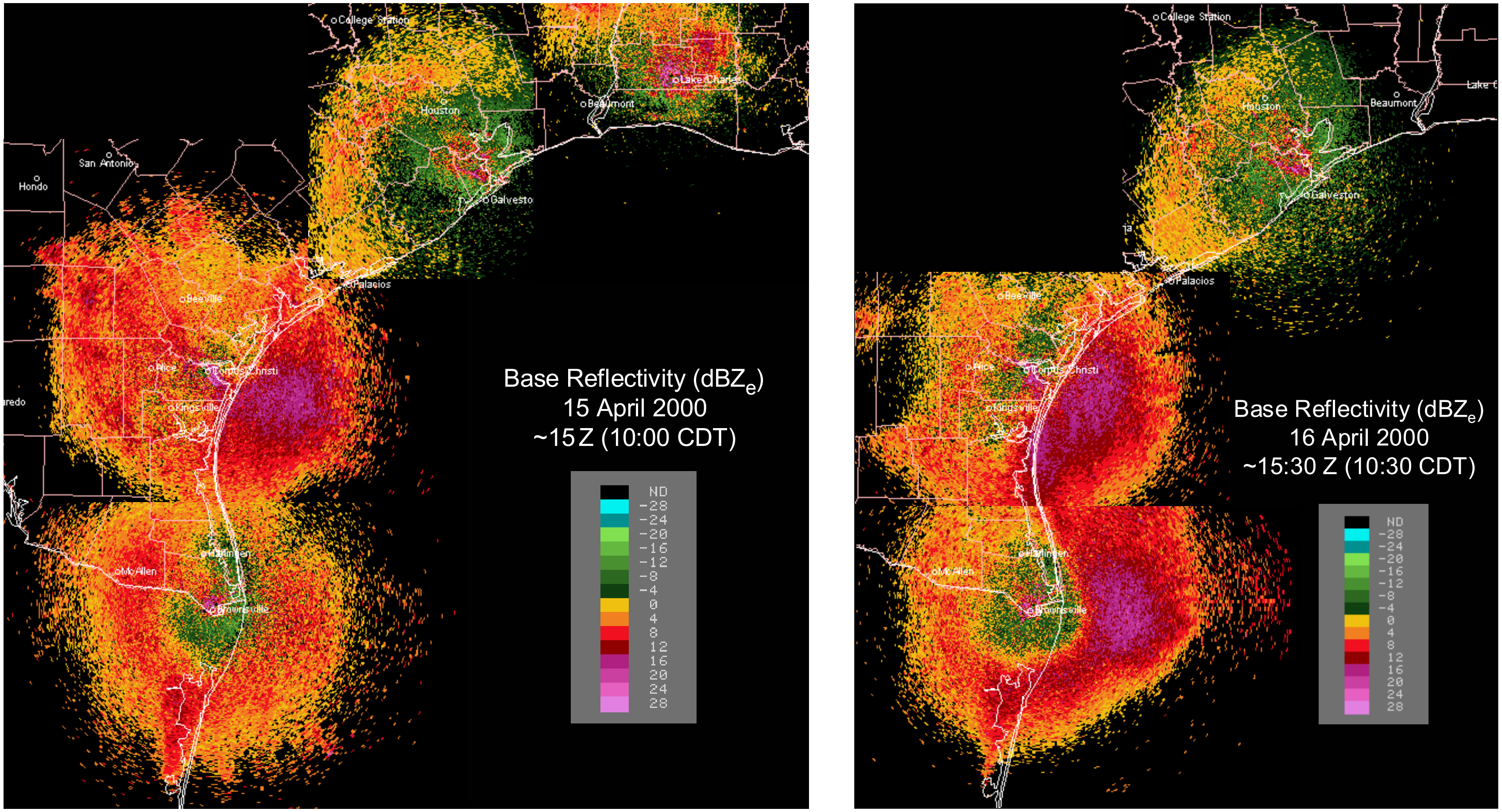

Figure 7.2. Composite NEXRAD images showing base reflectivity along the Gulf Coast on the mornings of April 15 and 16, 2000. Synoptic weather was classified as **GH** for April 15 and as **ECH** for April 16. All radar scans were obtained in clear-air mode at an elevation of 0.5°. Images are courtesy of TAP Publishing Company.

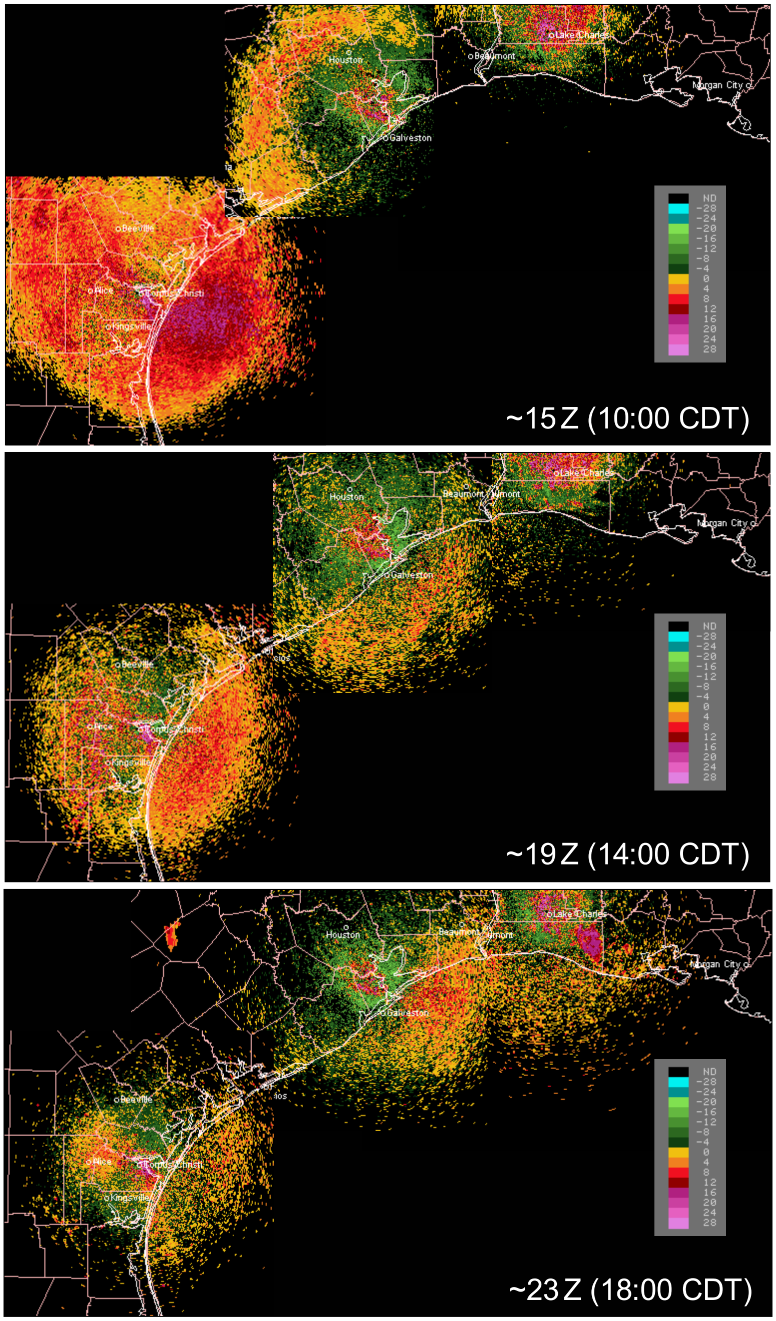

Figure 7.3. Time series of NEXRAD base reflectivity composites on April 15, 2000. All radar scans were obtained in clear-air mode at an elevation of 0.5°. Images are courtesy of TAP Publishing Company.

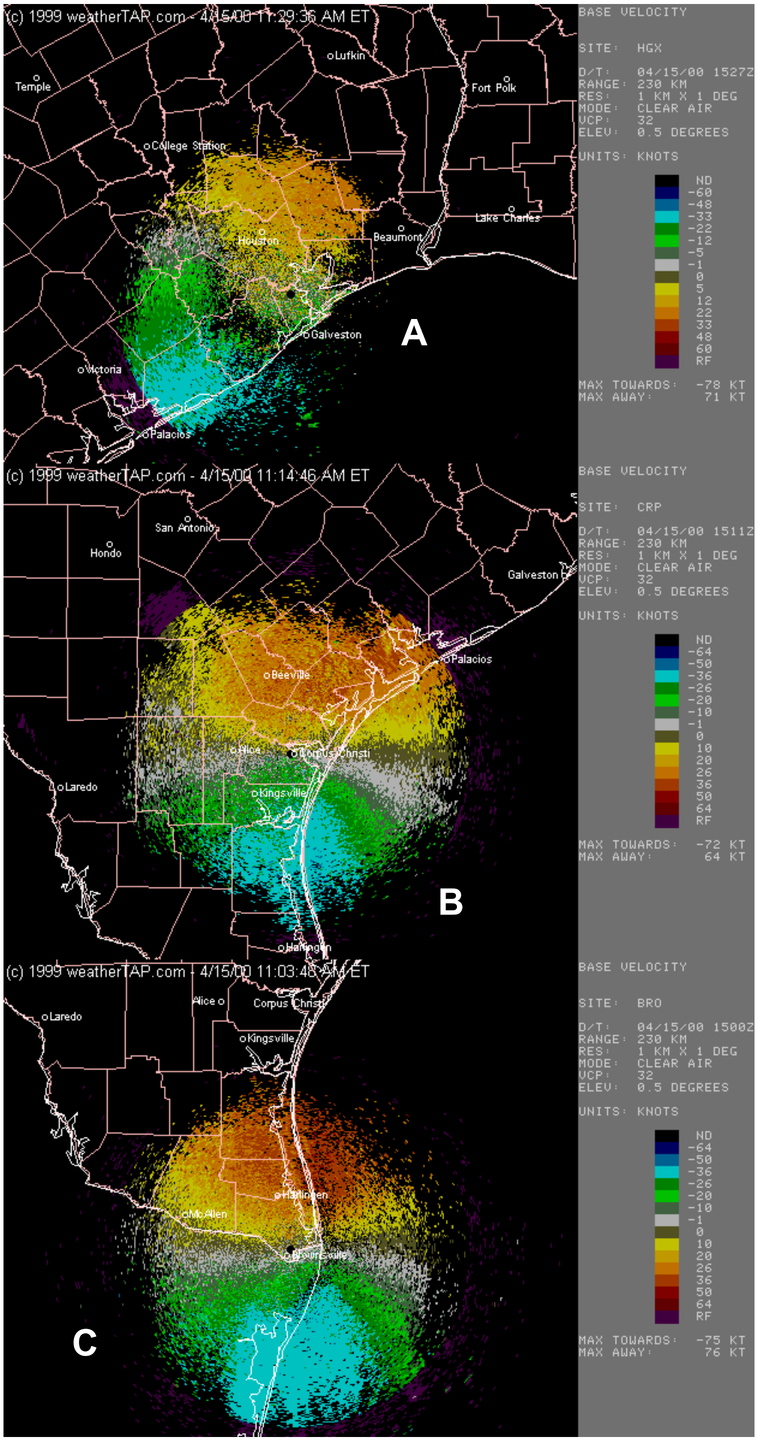

Figure 7.4. NEXRAD base velocity images corresponding to the reflectivity images for April 15 in Figure 7.2. A. Houston NEXRAD (HGX). B. Corpus Christi NEXRAD (CRP). C. Brownsville NEXRAD (BRO). Yellows and browns indicates movement away from the radar site and greens and blues indicate movement toward the radar. Radar scans were obtained in clear-air mode at an elevation of 0.5°. Images are courtesy of TAP Publishing Company.

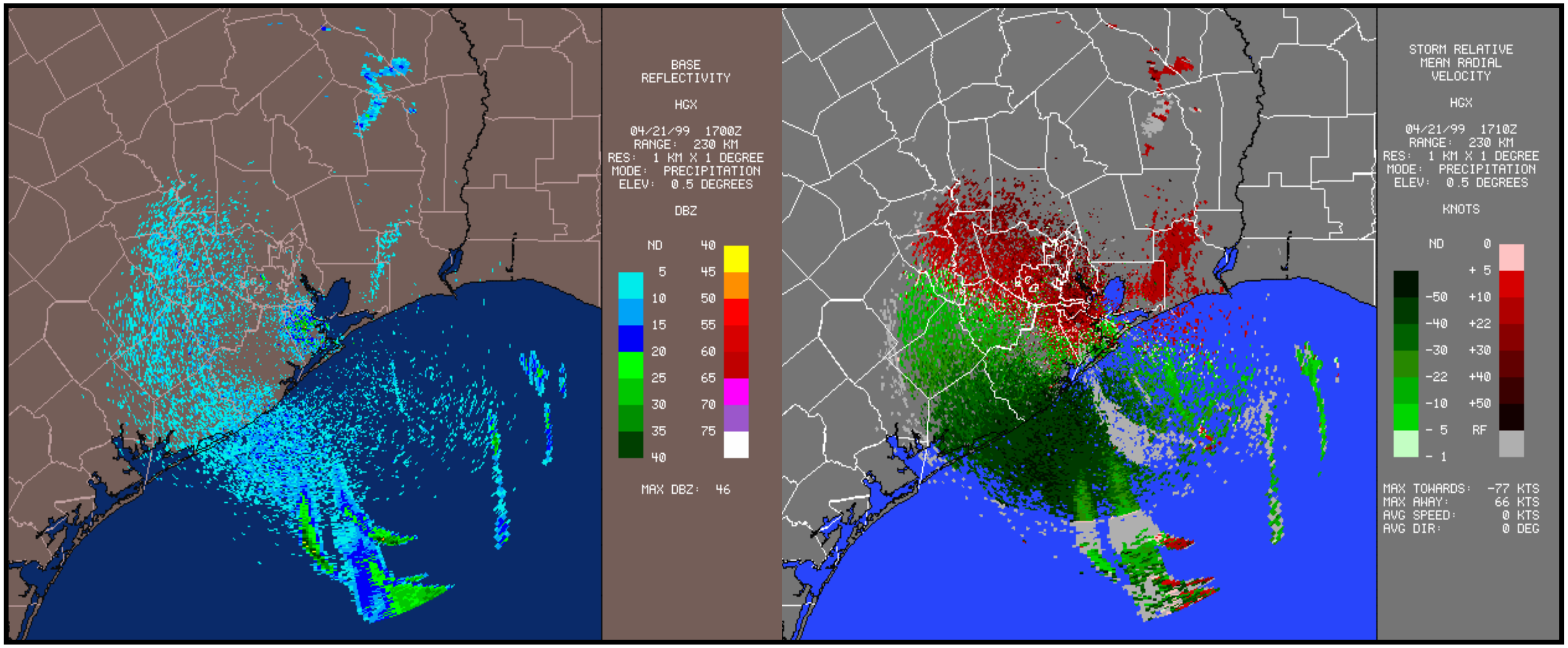

Figure 7.5. NEXRAD images from the Houston site (HGX) showing the arrival of migrating birds on the Upper Texas Coast from the SSW at 17:00 Z (12:00 CDT) on April 21, 1999. Synoptic weather for this flight was classified as **GH**. Left: Reflectivity image showing the distribution of birds. The "half-donut" shape of the radar echoes is due to the fact that the radar beam scans at a slight upward angle (0.5°) and thus intersects the "layer" of high-altitude migrants at some distance from the radar site. Right: Corresponding velocity image showing direction of movement. Red indicates movement away from the radar site and green indicates movement toward the radar. The tube-like features offshore may be streams of chaff from Air Force meteorological experiments. Radar scans were obtained in precipitation mode at an elevation of 0.5°. Images are courtesy of WSI Corporation.

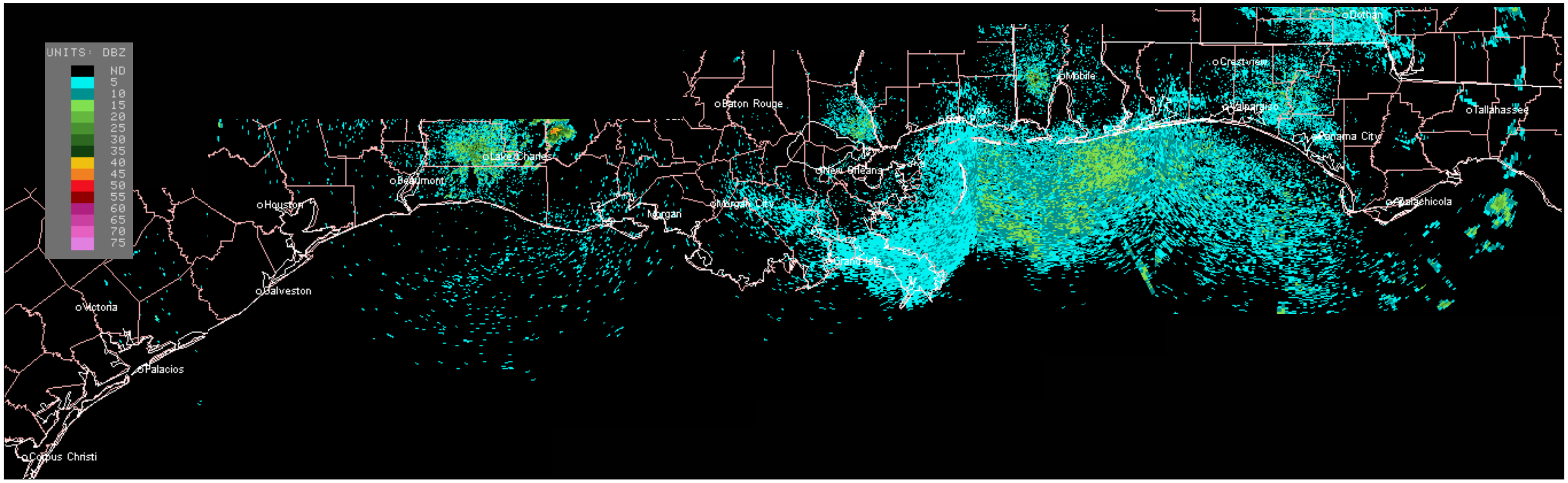

Figure 7.6. Composite NEXRAD image showing base reflectivity along the Gulf Coast on the morning of March 29, 2000, at 16:00 Z (10:00 CST). Synoptic weather for this flight was classified as **BH**. All radar scans were obtained in precipitation mode at an elevation of 0.5°. Images are courtesy of TAP Publishing Company.

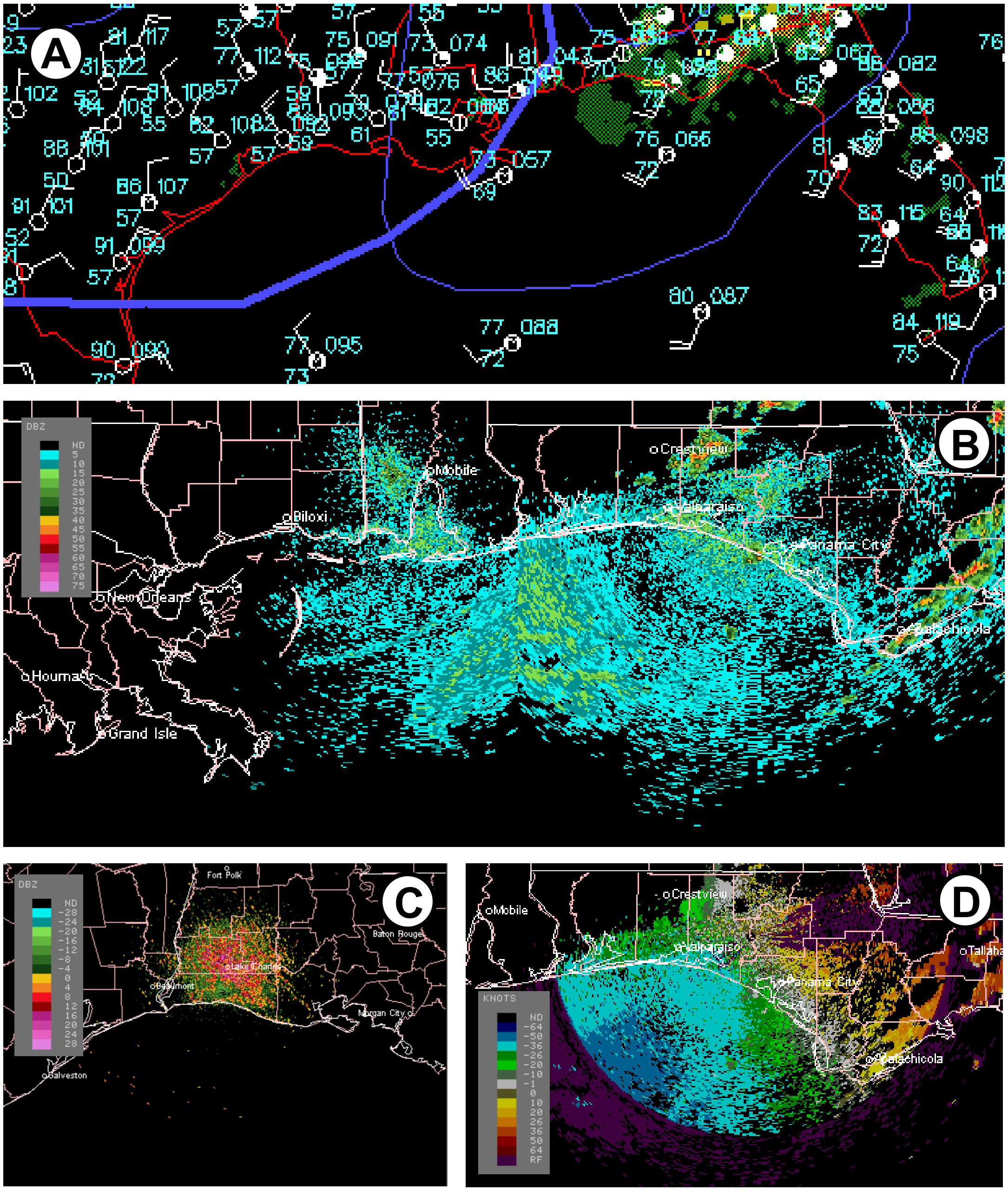

Figure 7.7. Eastward displacement of trans-Gulf migration by a cold front on April 24, 2000. A. Synoptic weather map showing surface wind vectors and position of cold front at 20:00 Z. Image is courtesy of Unisys Corporation. B. Composite NEXRAD image (MOB and EVX) showing base reflectivity along the northeastern Gulf Coast at 19:30 Z (14:30 CDT). C. NEXRAD image from Lake Charles (LCH) showing the absence of reflectivity off Louisiana at 19:30 Z (14:30 CDT). D. NEXRAD base velocity image from Red Bay (EVX) corresponding to the reflectivity image in B. Darker blues indicate faster movement toward the radar. Radar scans were obtained in precipitation mode (B, D) and clear-air mode (C) at an elevation of 0.5°. All radar images are courtesy of TAP Publishing Company.

When winds across the northwestern Gulf were unfavorable for trans-Gulf migrants — but not so unfavorable as to induce a large-scale displacement of the migration stream (e.g., Figure 7.7), the usual pattern of clockwise travel was absent. Most of the migrants that did undertake the crossing on such days apparently opted for a more direct route toward the Texas coast, where they could be seen in radar images arriving from the SSE (e.g., Figure 7.8) instead of continuing on toward the NNE or NE (Figures 7.4, 7.5).

On most days, radar imagery clearly showed that most or all trans-Gulf migrants proceeded variable distances inland upon landfall along the northern Gulf Coast. However, on some occasions, large numbers of migrants “fell out” along the immediate coastline. These fallouts yielded distinctive radar signatures (e.g., Figure 7.9) and corresponded to reports of excellent birdwatching along the coast.

Although not a focus of this study, another important phenomenon noted regularly in radar imagery was the nightly migration of birds from Cuba to the Florida Keys and the south Florida peninsula. On some occasions, this Cuban flight “leaked” into the Gulf of Mexico (e.g., Figure 7.10) and could have been the source for some of the “Caribbean vagrants” recorded on the platforms (Table 6.8, Chapter 11).

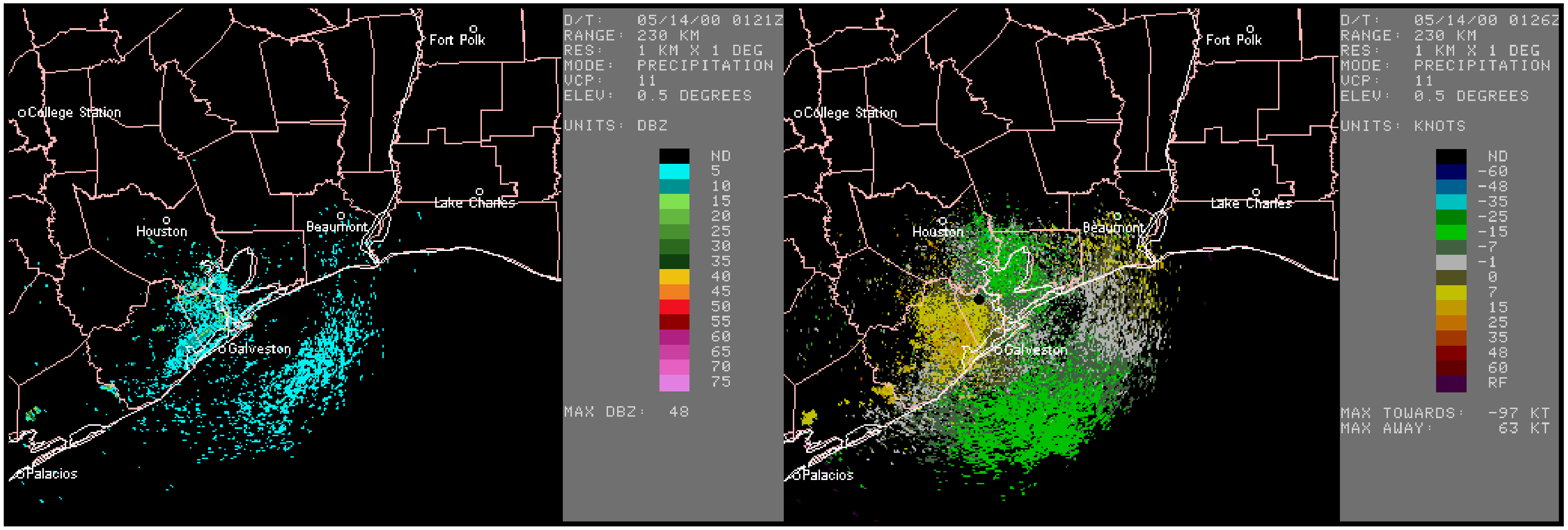

Figure 7.8. NEXRAD images from the Houston site (HGX) showing the arrival of migrating birds on the Upper Texas Coast from the SSE at 01:21 Z on May 14, 2000 (20:21 CDT on May 13). Synoptic weather for this flight was classified as **GF**. Left: Base reflectivity image showing the distribution of birds. Right: Corresponding base velocity image showing direction of movement. Yellows and oranges indicate movement away from the radar site and greens indicate movement toward the radar. Radar scans were obtained in precipitation mode at an elevation of 0.5°. Images are courtesy of TAP Publishing Company.

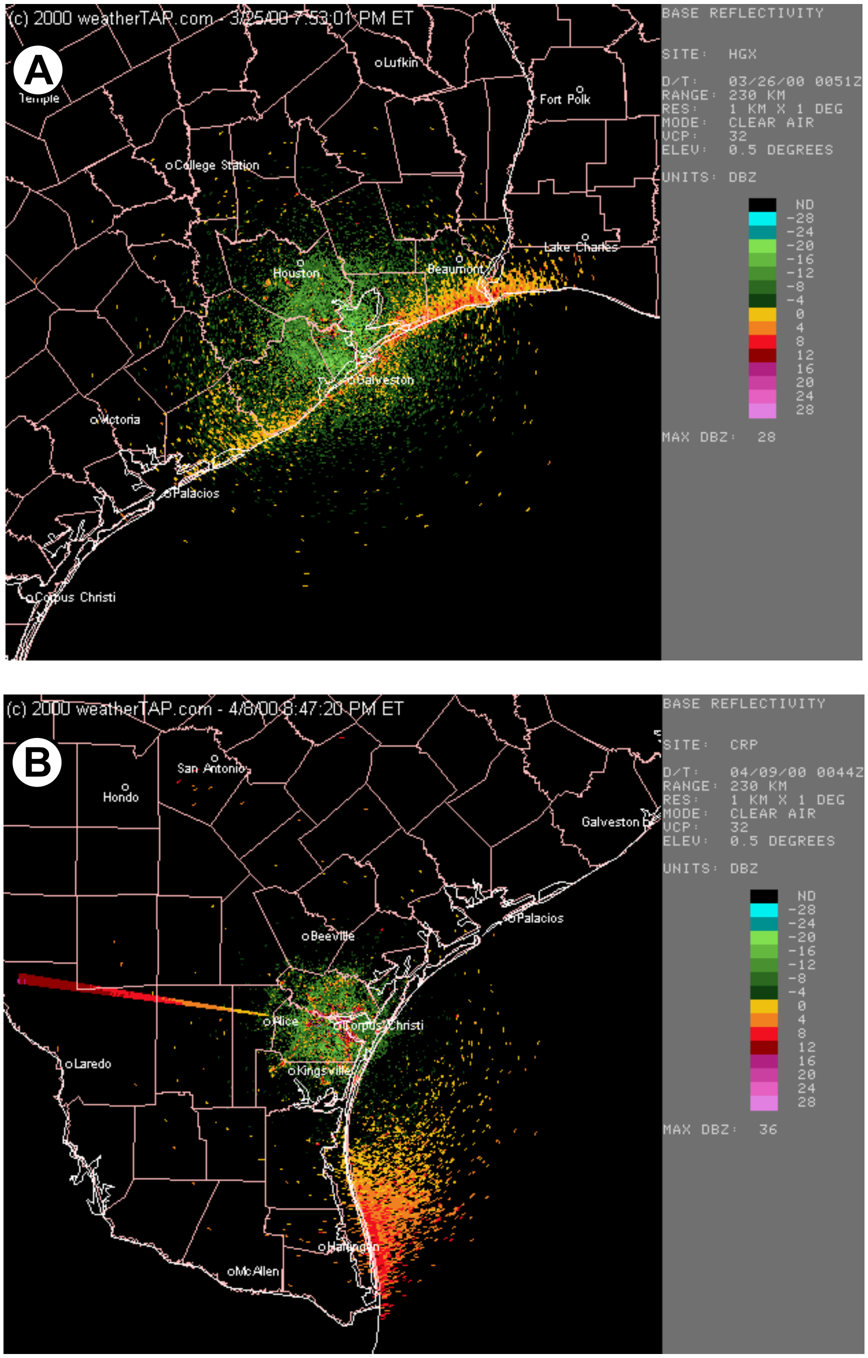

Figure 7.9. Examples of radar-observed evening fallouts of trans-Gulf migrants along the Texas coast. A. Base reflectivity image from Houston NEXRAD (HGX) for March 26, 2000, at 00:51 Z (March 25 at 18:53 CST). Synoptic weather was classified as **ECH** for March 25. B. Base reflectivity image from Corpus Christi NEXRAD (CRP) for April 9, 2000, at 00:44 Z (April 8 at 19:47 CDT). Synoptic weather was classified as **GF** for April 8. Both radar scans were obtained in clear-air mode at an elevation of 0.5°. Images are courtesy of TAP Publishing Company.

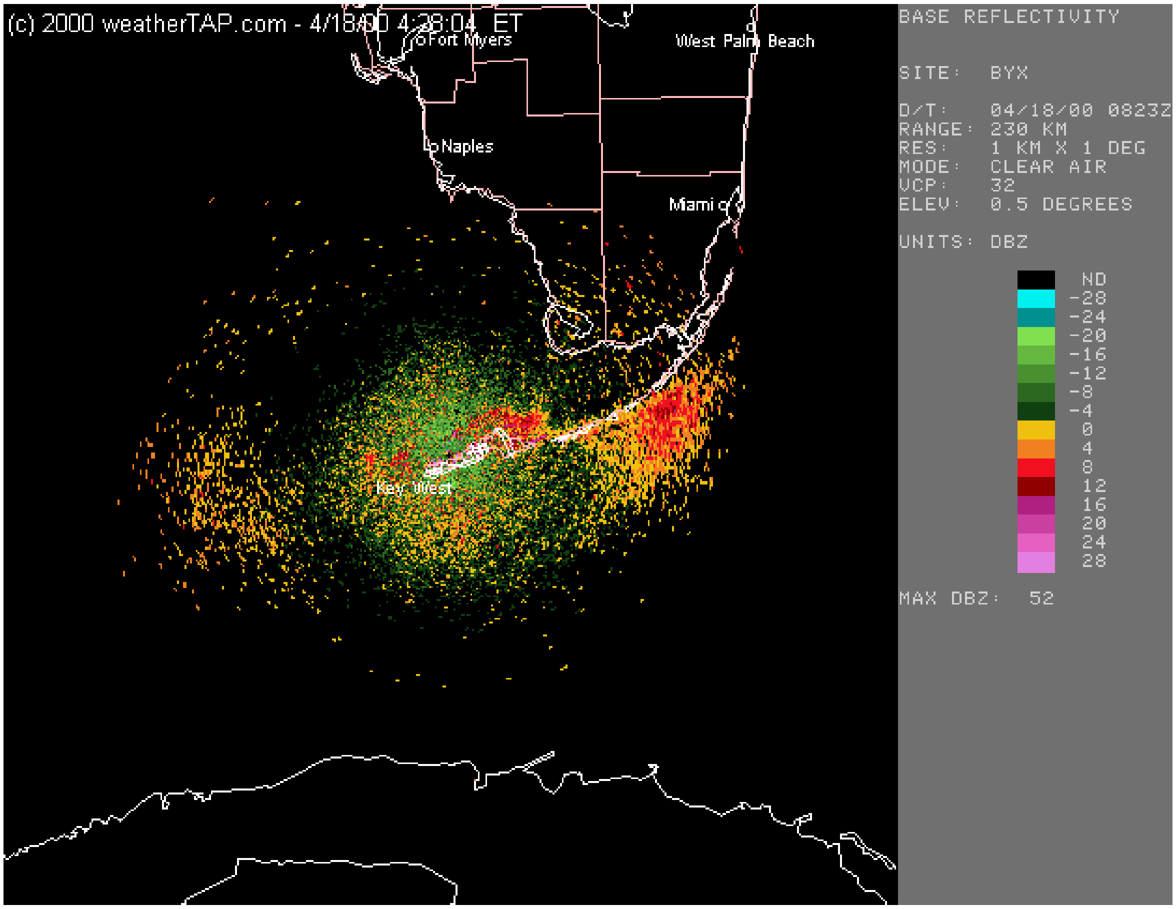

Figure 7.10. Example of radar-observed nocturnal fallout along the Florida Keys of trans-Caribbean migrants from Cuba, and "leakage" of some Cuban migrants into the Gulf of Mexico. Base reflectivity image is from Key West NEXRAD (BYX) on April 18, 2000, at 08:23 Z (04:23 EDT). Radar scan was obtained in clear-air mode at an elevation of 0.5°. Image is courtesy of TAP Publishing Company.

7.3 RELATIONSHIP BETWEEN SYNOPTIC WEATHER AND THE LOCATION OF LANDFALL

Inspection of daily radar images suggested that the portion of the northern Gulf Coast on which migrants made landfall varied dramatically from day to day (Chapter 7.2). To test the hypothesis that this variation was caused by synoptic weather, we tabulated the frequency of occurrence of landfall along different portions of the coast under different synoptic conditions (Table 7.1). This tabulation suggested that area of landfall was significantly related to synoptic weather pattern (with the two eastern geographic bins aggregated to avoid sparse cells: $G = 11.0$, $df = 4$, $P = 0.027$). Under synoptic weather conditions when winds over the Gulf typically had a strong westward component (**ECH**, **MCH**) or were weak (**GH**), trans-Gulf migrants usually made landfall along the western Gulf Coast. Under synoptic weather conditions when winds over the southern Gulf typically had a weaker westward component and winds over the northern Gulf often had an eastward component (**BH**), landfall was more frequent along the Upper Texas Coast and from Louisiana to the Florida Panhandle. On days when a cold front intruded over the Gulf (**GF**), radar-observed landfall tended to occur along the extreme portions of the study area: south Texas, southeastern Louisiana to Florida, or both.

There are several possible explanations for these patterns. First, the day-to-day shifts may be a function of the entire population of trans-Gulf migrants being "steered" by synoptic-scale winds. Second, the shifts may be caused by different species (or different individuals with a species) having different preferred flight routes, with each species (or individual) departing selectively on days when winds are more favorable with respect to its preferred route. These alternative causal explanations are examined further in Chapter 7.6.

Table 7.1.

Spatial patterns of spring trans-Gulf migration in relation to synoptic weather

The "stretch of coast with largest landfall" was defined as the region with the highest sustained radar-observed density of migrants (measured by dBZ_e) over the course of the day. The "Lower Texas Coast-Central Texas Coast" stretch was defined as the region covered by the Brownsville (BRO) and Corpus Christi (CRP) NEXRAD sites, north to Matagorda County, Texas. The "Upper Texas Coast-Southwestern Louisiana" stretch was defined as the region covered by the Houston (HGX) and Lake Charles (LCH) NEXRAD sites, from Brazoria County, Texas, east to Vermilion Parish, Louisiana. The "Southeastern Louisiana-Florida Panhandle" stretch was defined as the region covered by the New Orleans (LIX), Mobile (MOB), and Eglin Air Force Base (EVX) NEXRAD sites, east of Marsh Island, Louisiana. "Bimodal" indicates that two disjunct peaks of migration traffic were evident in southern Texas and the eastern area, with radar-observed migration absent or reduced in the intervening area. All data are from 2000.

	Stretch of Coast with Largest Landfall		
Synoptic Weather Type	Lower Texas Coast-Central Texas Coast	Upper Texas Coast-Southwestern Louisiana	Southeastern Louisiana-Florida Panhandle
MCH	5	0	0
ECH	11	2	0
GH	12	2	1
BH	9	7	3
GF	8	3	3

7.4 DIRECT OBSERVATIONS OF THE FLIGHT DIRECTIONS OF MIGRANTS

Flight directions of migrants detected visually from platforms varied among migrant categories, platforms, and weather types.

Ducks generally flew to the NNW, with little apparent influence of platform location or weather type (Table 7.2).

Flight behavior of herons was quite variable (Table 7.3), but they generally flew to the N, with little obvious influence of platform location or weather type. One exception to this generalization was that herons consistently flew to the west of due N on **GF** days in the western Gulf (i.e., at PN975, MI622, and HI561).

Samples sizes were small for shorebirds, but available data indicated that they generally flew to the N or NNW (Table 7.4). The one exception, as with herons, was that shorebirds consistently flew to the NW on **GF** days in the far western Gulf.

Aerial insectivores showed a clear pattern of more easterly flight directions farther east in the Gulf (Table 7.5). At PN975, they generally flew toward the NNW except on **BH** days, when they flew to the N. At MI622, they flew to the N on **ECH** days, to the NNW on **GF** days, and to the E on **BH** days. In the central portion of the study area, they generally flew to the N or NNW regardless of weather type. In the far eastern portion of the study area, they tended to fly east of due north.

Neotropical migrant landbirds also showed a clear pattern of more easterly flight directions farther east in the Gulf (Table 7.6). Vanishing bearings averaged NNW at PN975 and MI622, N in the central portion of the study area, and NNE toward the far east at SP89. Neotropical migrants also showed several clear patterns with respect to synoptic weather type. Flight directions were more eastward on **BH** days than on **ECH** days, except at PN975 and MI622 where the opposite pattern held. There was also an obvious pattern of more westerly flight directions (to the NW) in the western Gulf on **GF** days.

Insufficient data were available for a detailed analysis of the influence of geography and weather on the orientation of medium-distance migrants. However, the pooled sample of medium-distance migrants from all platforms and all weather types had a mean vanishing bearing to the NW ($\bar{x}$ = 320°; 95% CI = 307°-333°; r = 0.79; Rayleigh $P < 0.0001$; N = 34).

In general, most data are consistent with the hypothesis of a veering and diverging migration route across the Gulf for long-distance migrant landbirds (but not ducks, herons, or shorebirds), with flight directions more eastward at eastern platforms. The data are also consistent with the hypothesis that migration routes of landbirds (but not ducks, herons, or shorebirds) are flexible and subject to steering by synoptic-scale winds, with flight directions more eastward on **BH** days than on **ECH** days.

Several anomalies stand out and invite explanation. All taxa showed evidence of more westerly flight directions (i.e., to NW) on **GF** days in the western Gulf. This pattern suggests that, upon encountering a cold front, some migrants abandon the curvilinear flight route and instead opt for a more immediate landfall (e.g., Figure 7.8). Oddly, at PN975 and MI622, vanishing bearings were more westerly on **BH** days than on **ECH** days — despite the expectation that the main migration stream should occur farther east on **BH** days than on **ECH** days (Figure 7.6, Table 7.1). This anomaly suggests that on **BH** days, migrants occurring in the far western Gulf may be lower-quality individuals (i.e., on the periphery of the migration stream), which would be more likely to be fat-depleted and seeking immediate landfall.

Table 7.2.

Vanishing bearings of spring migrant ducks in relation to synoptic weather and position in the Gulf

All data are from spring 2000. The direction of movement is given by the direction of the mean vector for each sample ($\bar{x}$) along with a 95% confidence interval for $\bar{x}$. The length of the mean vector (r) is a measure of how tightly clustered the sample is around the mean direction. P indicates the significance level from a Rayleigh test (H_o = uniformity versus H_1 = unimodality). Sample size is given by N, which represents the number of independent observations and not the total number of individuals involved (e.g., a flock of five migrants counts for only one observation, not five).

		PN975	MI622	HI561	GB189	VR265	SM147	GC18	EW826	SP89
ECH	$\bar{x}$	345°	na	na	na	356°	na	319°	na	na
	95% CI	339°-352°	na	na	na	351°-2°	na	276°-1°	na	na
	r	0.94	na	na	na	0.99	na	0.84	na	na
	P	<0.0001	na	na	0.20	<0.0001	na	0.020	na	na
	N	31	0	0	3	12	0	5	0	1
GH	$\bar{x}$	338°	na	na	na	354°	na	302°	na	345°
	95% CI	na	na	na	na	350°-358°	na	285°-318°	na	322°-8°
	r	1.00	na	na	na	0.99	na	0.92	na	0.98
	P	0.007	na	0.14	na	<0.0001	na	<0.0001	na	0.039
	N	4	0	2	0	27	0	11	1	3
BH	$\bar{x}$	347°	na	343°	na	343°	na	319°	na	342°
	95% CI	343°-352°	na	314°-12°	na	335°-350°	na	302°-337°	na	281°-42°
	r	0.98	na	0.95	na	0.95	na	0.91	na	0.79
	P	<0.0001	na	0.015	na	<0.0001	na	<0.0001	na	0.074
	N	25	0	4	0	23	1	10	0	4
GF	$\bar{x}$	338°	na	na	353°	356°	359°	322°	na	351°
	95% CI	336°-340°	na	na	330°-15°	351°-2°	328°-30°	299°-344°	na	335°-6°
	r	0.99	na	na	0.93	0.98	0.91	0.87	na	0.96
	P	<0.0001	0.20	na	0.001	<0.0001	0.007	<0.0001	na	<0.0001
	N	48	2	1	6	17	5	10	1	7

Table 7.3.

Vanishing bearings of spring migrant herons in relation to synoptic weather and position in the Gulf

All data are from spring 2000. See Table 7.2 for explanation of notation.

		PN975	MI622	HI561	GB189	VR265	SM147	GC18	EW826	SP89
ECH	$\bar{x}$	347°	14°	39°	7°	1°	11°	29°	0°	350°
	95% CI	341°-354°	3°-25°	33°-45°	344°-29°	357°-5°	355°-26°	16°-41°	342°-18°	338°-2°
	r	0.91	0.87	0.96	0.81	0.96	0.83	0.76	0.97	0.96
	P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.002	<0.0001
	N	56	27	31	13	63	20	43	5	9
GH	$\bar{x}$	353°	na	354°	341°	2°	14°	354°	350°	353°
	95% CI	346°-1°	na	338°-10°	319°-3°	358°-6°	357°-31°	343°-4°	341°-359°	341°-6°
	r	0.98	na	0.93	0.85	0.97	0.92	0.97	0.98	0.95
	P	<0.0001	0.15	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	N	10	2	10	11	59	10	10	9	10
BH	$\bar{x}$	1°	14°	4°	357°	3°	5°	352°	353°	0°
	95% CI	351°-12°	2°-27°	354°-14°	335°-19°	356°-10°	342°-27°	330°-15°	341°-6°	350°-9°
	r	0.86641	0.79856	0.93617	0.78351	0.93004	0.81096	0.79706	0.95412	0.9003
	P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	N	34	37	17	15	39	13	14	10	31
GF	$\bar{x}$	330°	352°	345°	8°	356°	6°	356°	356°	3°
	95% CI	324°-336°	343°-2°	337°-353°	4°-11°	354°-358°	354°-18°	352°-359°	348°-5°	357°-9°
	r	0.89	0.86	0.79	0.86	0.95	0.77	0.93	0.90	0.93
	P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	N	92	42	86	289	288	45	123	36	54
MCH	$\bar{x}$	354°	30°	16°	28°	357°	348°	23°	na	0°
	95% CI	344°-5°	20°-40°	7°-26°	8°-48°	346°-9°	332°-5°	332°-73°	na	na
	r	0.96	0.90	0.95	0.85	0.91	0.94	0.71	na	1.00
	P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.042	na	<0.0001
	N	14	29	15	13	18	8	6	0	16

Table 7.4.

Vanishing bearings of spring migrant shorebirds in relation to synoptic weather and position in the Gulf

All data are from spring 2000. See Table 7.2 for explanation of notation.

		PN975 & MI622	HI561 & GB189	VR265 & SM147	GC18 & EW826 & SP89
ECH	$\bar{x}$	355°	0°	na	na
	95% CI	339°-11°	346°-14°	na	na
	r	0.80	0.96	na	na
	P	<0.0001	<0.0001	na	na
	N	21	8	1	1
GH	$\bar{x}$	na	351°	349°	326°
	95% CI	na	337°-5°	322°-16°	309°-342°
	r	na	0.98	0.91	0.94
	P	0.14	0.002	0.002	<0.0001
	N	2	5	6	8
BH	$\bar{x}$	348°	342°	342°	7°
	95% CI	318°-17°	303°-21°	321°-3°	344°-31°
	r	0.58	0.68	0.96	0.98
	P	0.002	0.031	0.003	0.039
	N	17	7	5	3
GF	$\bar{x}$	324°	357°	351°	355°
	95% CI	316°-332°	343°-10°	344°-358°	349°-1°
	r	0.87	0.86	0.93	0.95
	P	<0.0001	<0.0001	<0.0001	<0.0001
	N	54	22	38	34

Table 7.5.

Vanishing bearings of spring migrant aerial insectivores in relation to synoptic weather and position in the Gulf

All data are from spring 2000. See Table 7.2 for explanation of notation.

		PN975	MI622	HI561	GB189	VR265	SM147	GC18	EW826	SP89
ECH	$\bar{x}$	330°	353°	18°	na	353°	348°	8°	na	13°
	95% CI	294°-6°	325°-22°	337°-58°	na	343°-4°	334°-1°	332°-44°	na	358°-28°
	r	0.68	0.84	0.63	na	0.95	0.94	0.76	na	0.89
	P	0.019	0.001	0.035	0.15	<0.0001	<0.0001	0.006	na	<0.0001
	N	8	8	8	2	15	11	8	1	15
GH	$\bar{x}$	330°	na	347°	7°	0°	346°	346°	5°	6°
	95% CI	283°-17°	na	324°-9°	337°-37°	na	313°-20°	330°-3°	327°-43°	311°-61°
	r	0.93	na	0.95	0.88	1.00	0.75	0.94	0.91	0.74
	P	0.061	0.14	0.004	0.004	<0.0001	0.003	<0.0001	0.024	0.056
	N	3	2	5	6	11	9	8	4	5
BH	$\bar{x}$	353°	83°	0°	351°	353°	na	14°	353°	9°
	95% CI	343°-3°	56°-111°	na	306°-37°	341°-6°	na	351°-38°	307°-38°	347°-32°
	r	0.91	0.53	1.00	0.70	0.95	1.00	0.87	0.88	0.95
	P	<0.0001	<0.001	0.001	0.026	<0.0001	0.14	<0.001	0.034	0.004
	N	24	25	5	7	10	2	9	4	5
GF	$\bar{x}$	342°	344°	340°	356°	0°	358°	354°	349°	10°
	95% CI	328°-357°	305°-24°	325°-356°	345°-7°	348°-12°	331°-24°	350°-358°	331°-6°	353°-27°
	r	0.86	0.64	0.94	0.87	0.88	0.81	0.99	0.98	0.91
	P	<0.0001	0.031	<0.0001	<0.0001	<0.0001	<0.001	<0.0001	0.010	<0.0001
	N	17	8	9	28	21	10	23	4	11

Table 7.6.

Vanishing bearings of spring neotropical migrants in relation to synoptic weather and position in the Gulf

All data are from spring 2000. See Table 7.2 for explanation of notation.

		PN975	MI622	HI561	GB189	VR265	SM147	GC18	EW826	SP89
ECH	$\bar{x}$	342°	354°	315°	344°	350°	na	338°	na	8°
	95% CI	334°-350°	346°-3°	300°-331°	341°-347°	335°-4°	na	334°-342°	na	340°-37°
	r	0.95	0.88	0.75	0.98	0.92	0.59	0.97	na	0.79
	P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.18	<0.0001	na	<0.001
	N	21	44	29	47	13	5	46	1	10
GH	$\bar{x}$	324°	344°	358°	345°	354°	4°	352°	11°	20°
	95% CI	290°-357°	303°-25°	354°-2°	339°-352°	343°-5°	351°-18°	348°-356°	2°-21°	16°-25°
	r	0.86	0.79	0.99	0.94	0.90	0.86	0.98	0.97	0.96
	P	0.00564	0.01575	0	0	0	0	0	0	0
	N	6	6	21	37	23	21	38	12	54
BH	$\bar{x}$	334°	337°	354°	351°	352°	na	0°	na	29°
	95% CI	330°-339°	331°-343°	350°-358°	339°-4°	348°-356°	na	355°-5°	na	13°-45°
	r	0.89	0.86	0.97	0.76	0.94	0.61	0.93	0.42	0.83
	P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.100	<0.0001	0.530	<0.0001
	N	129	106	37	43	86	6	90	4	17
GF	$\bar{x}$	315°	304°	329°	334°	346°	12°	356°	21°	30°
	95% CI	303°-328°	295°-314°	317°-342°	328°-340°	339°-352°	3°-22°	355°-357°	11°-31°	27°-34°
	r	0.80	0.79	0.76	0.80	0.86	0.70	0.97	0.89	0.91
	P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	N	37	58	45	141	95	92	454	28	157

7.5 EFFECTS OF SYNOPTIC WEATHER ON PATTERNS OF ABUNDANCE ON PLATFORMS

Patterns of abundance across the platforms were compared among weather types. In spring 1998, migrants were most abundant on the westernmost platform studied (GB189) under all weather conditions (Figure 7.11). Patterns of abundance were less consistent in spring 1999, but migrants were still most abundant at GB189 under all weather conditions favorable for trans-Gulf migration, i.e., **BH**, **ECH**, and **GH** (Figure 7.12).

In spring 2000, when we operated on an extended array of platforms across the Gulf, patterns of abundance were clearly related to weather type (Figure 7.13). On **ECH** days, migrants were most abundant in the far western Gulf, i.e., on HI561 and PN975. However, on **BH** days, peak abundance occurred on GB189. This apparent eastward shift in the center of abundance on **BH** days (or westward shift on **ECH** days) is consistent with inferences from radar observations (Chapters 7.2, 7.3) as well as from direct observations of orientation (Chapter 7.4). All of this evidence, considered together, indicates that the main migration stream is at least partially "steered" by synoptic-scale winds.

Abundance was rather uniform across platforms on **GH** days, which is not surprising in light of the weak winds and lack of steering influence on such days. On **GF** days, abundance was greatest in the far western Gulf, especially at PN975. This pattern is consistent with the generally greater abundance of migrants over the western Gulf, together with the radar evidence and direct visual observations indicating that migrants turn toward the Texas coast when encountering a cold front (Figures 7.8, 7.9; Table 7.6).

Medium-distance migrants (Table 6.6) were most abundant in the far western Gulf on PN975 and MI622 under all weather conditions (Figure 7.14). Importantly, these species were fairly common on **ECH** days, i.e., under weather conditions favorable for trans-Gulf movement and inconsistent with offshore drift. This fact, together with the consistently NW vanishing bearings of medium-distance migrants (Chapter 7.4), suggests that some of these species may undertake an overwater route over the far western Gulf from the southernmost portions of their wintering range in Veracruz to the south Texas coast. However, it is not possible to disprove alternatives to the hypothesis that they are "intentional" overwater migrants and, indeed, it seems likely that at least some of the medium-distance migrants found themselves over water after drifting offshore during nocturnal circum-Gulf flights around the western Gulf Coast, and were simply attempting to regain land in the direction of the normal migration route.

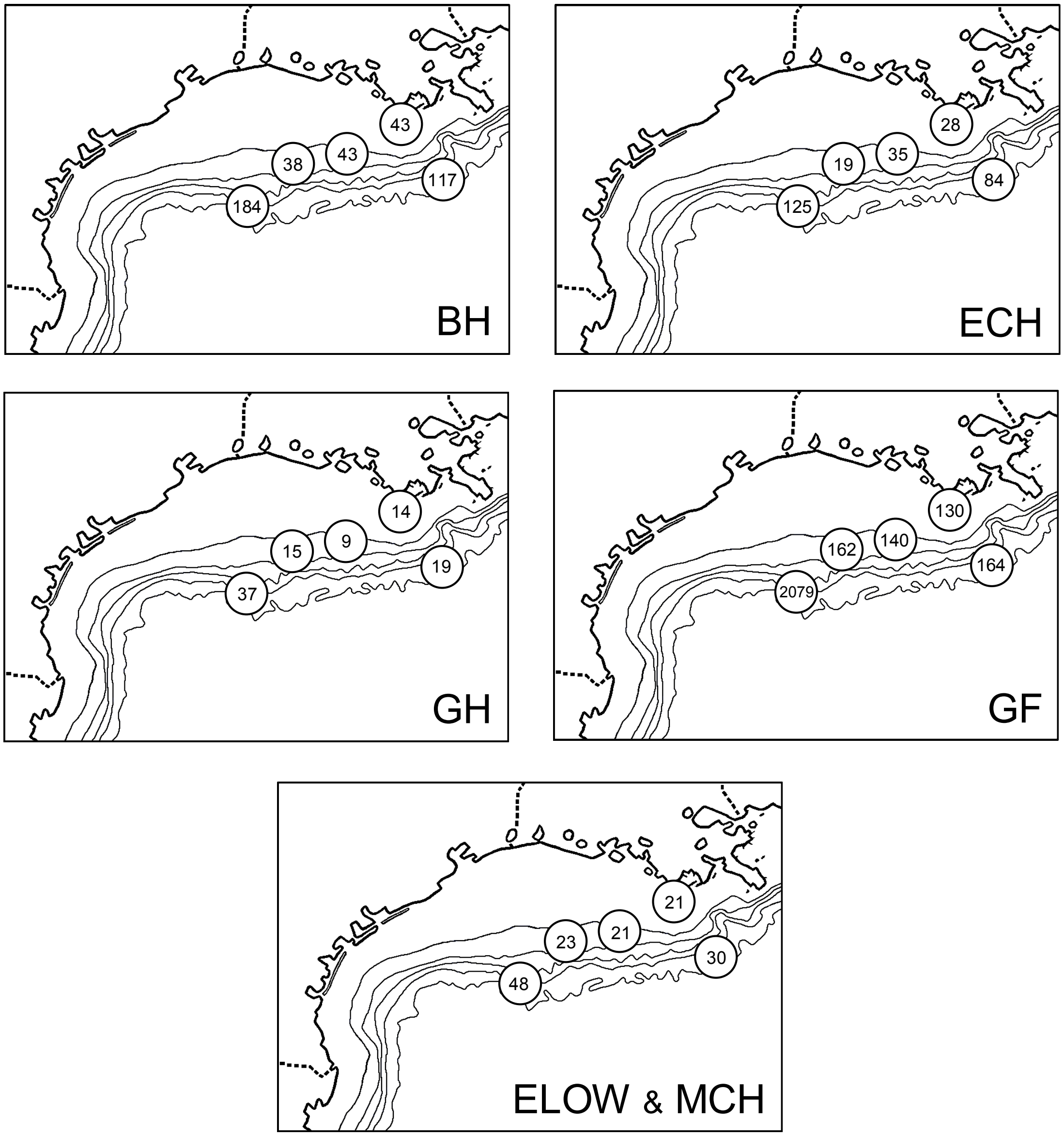

Figure 7.11. Patterns of abundance of long-distance migrant landbirds (aerial insectivores and neotropical migrants) on platforms in spring 1998 in relation to synoptic weather type. Numbers shown for a given weather type indicate total numbers of individuals initiating stopovers on each platform across all days characterized by that weather type.

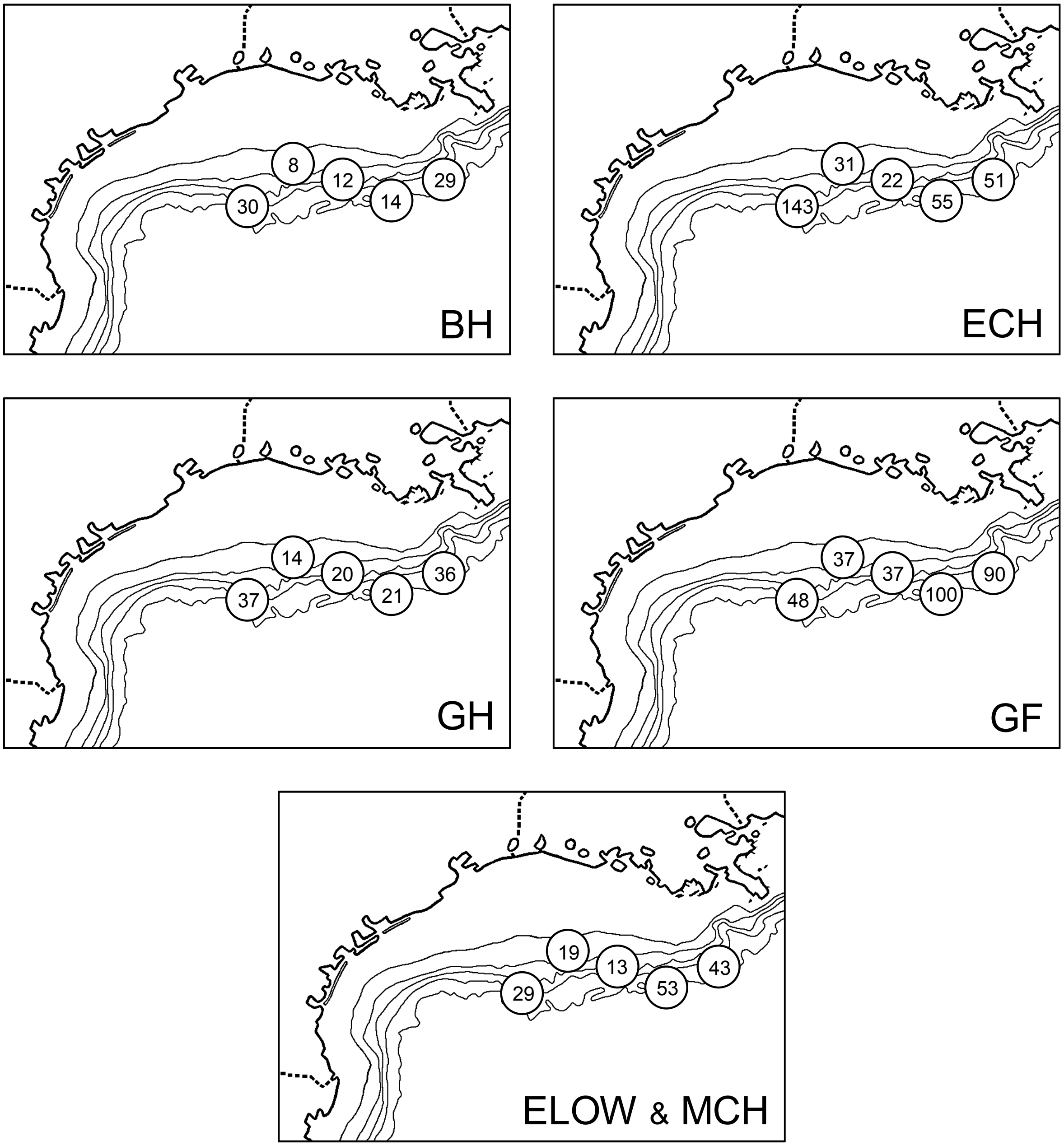

Figure 7.12. Patterns of abundance of long-distance migrant landbirds (aerial insectivores and neotropical migrants) on platforms in spring 1999 in relation to synoptic weather type. Numbers shown for a given weather type indicate total numbers of individuals initiating stopovers on each platform across all days characterized by that weather type.

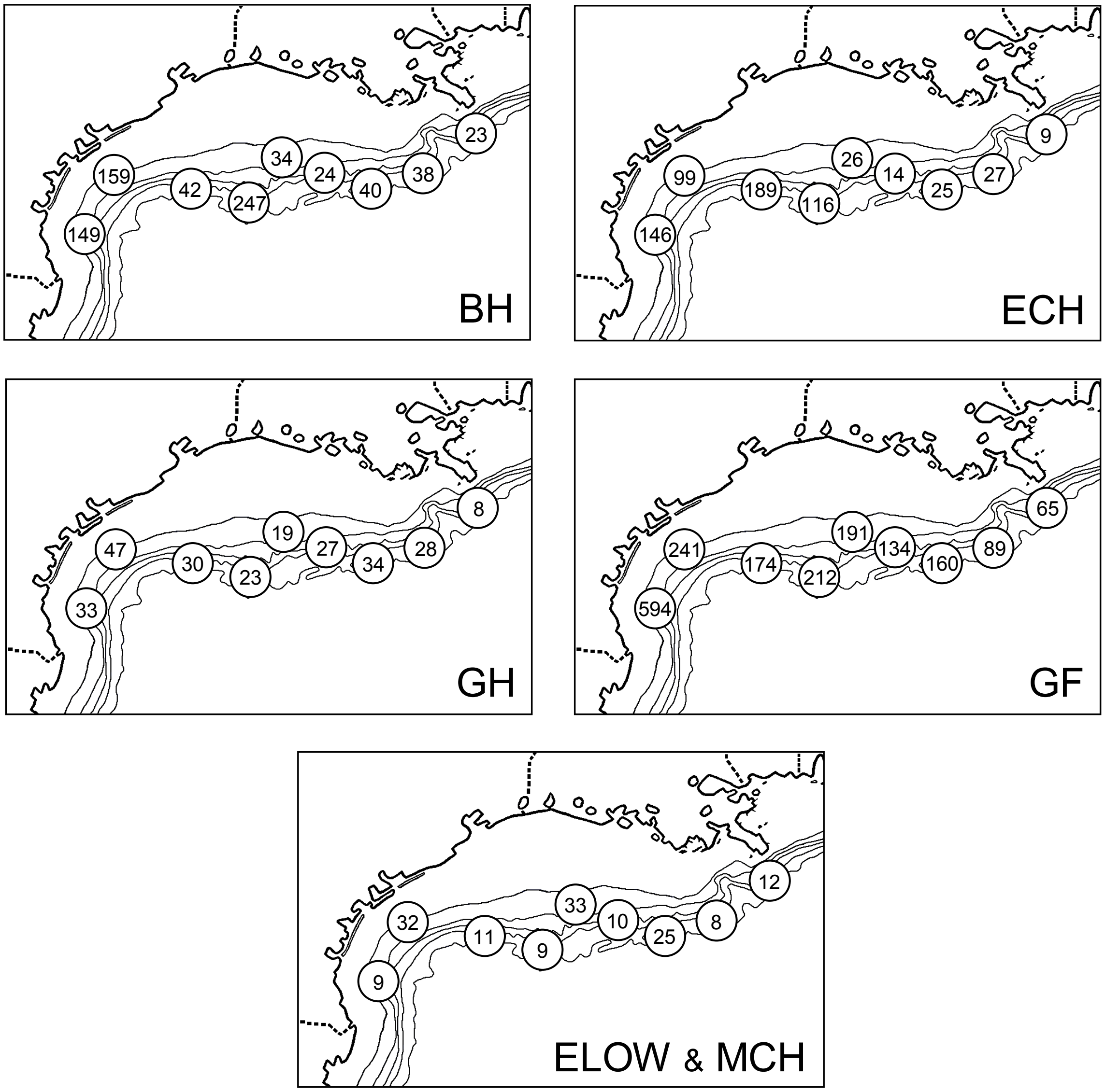

Figure 7.13. Patterns of abundance of long-distance migrant landbirds (aerial insectivores and neotropical migrants) on platforms in spring 2000 in relation to synoptic weather type. Numbers shown for a given weather type indicate total numbers of individuals initiating stopovers on each platform across all days characterized by that weather type.

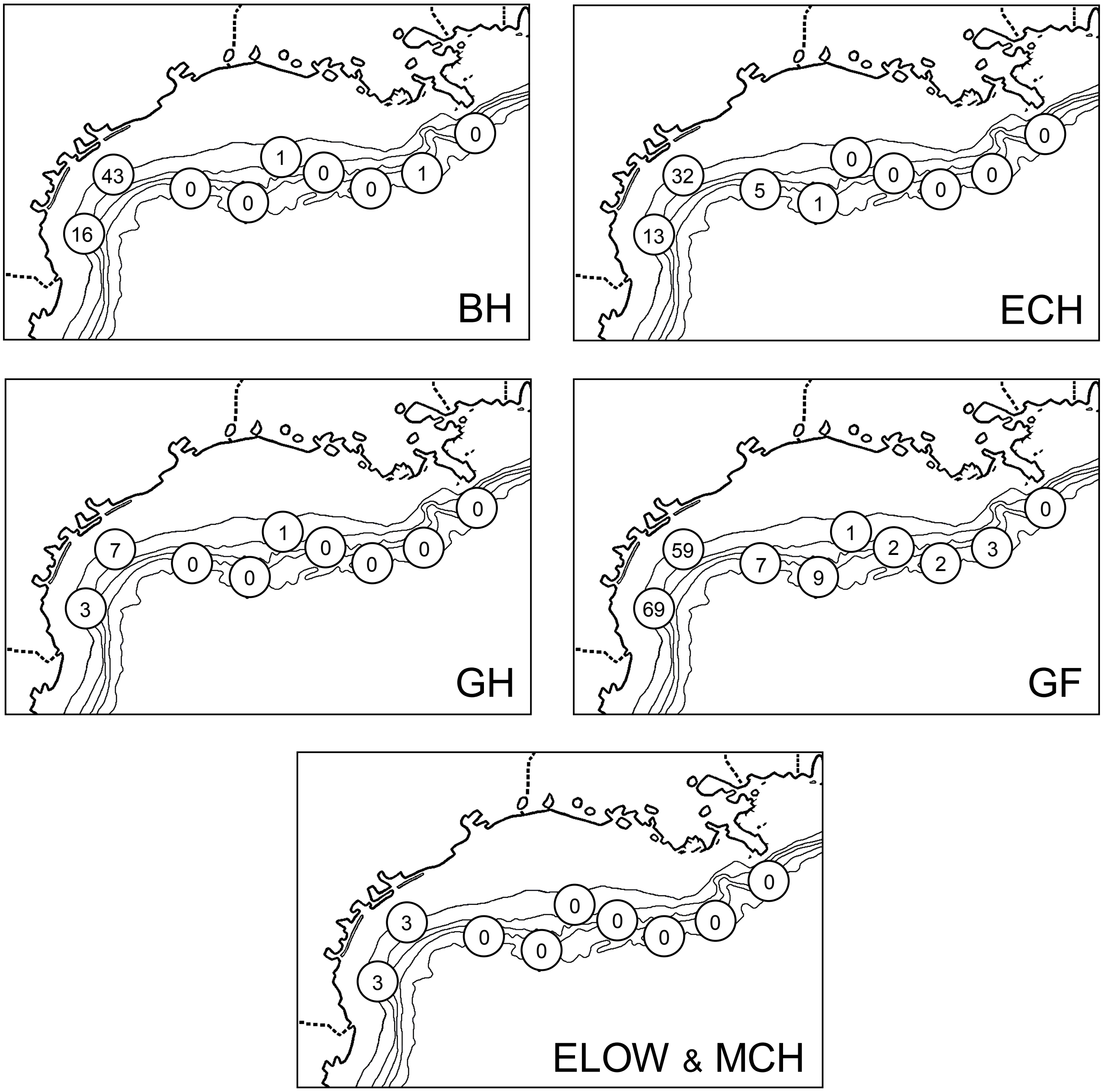

Figure 7.14. Patterns of abundance of medium-distance migrants on platforms in spring 2000 in relation to synoptic weather type. Numbers shown for a given weather type indicate total numbers of individuals initiating stopovers on each platform across all days characterized by that weather type.

7.6 INTERSPECIFIC VARIATION IN MIGRATION ROUTES

There were dramatic differences among species in patterns of abundance across the Gulf (Table 7.7), implicating species-specific migration routes. The frequency distribution of mean species-specific longitudinal positions is shown in Figure 7.15. Of special note is the fact that six of the eight species with the most western distributions were medium-distance migrants. Herons, falcons, and certain larger Neotropical migrants (Sora, Purple Gallinule, Chuck-Will's-Widow, and Belted Kingfisher) had more easterly distributions, implying a more direct route across the Gulf, which would be consistent with their larger body sizes (and concomitantly faster flight and reduced reliance on wind assistance). Otherwise, the distribution of mean species-specific positions for Neotropical migrants is tightly clustered over the western Gulf, peaking around the longitude of HI561. Only two species had mean positions east of SM147, with none as far east as GC18.

An important question is whether day-to-day shifts in the position of the migration stream (and resulting location of landfall; Chapters 7.2, 7.3) in response to varying synoptic weather are the result of individual migrants employing flexible tactics or differential wind selection by different populations of migrants.

In the first case ("flexible tactics"), an individual's route and destination along the northern Gulf Coast would be determined in part by the synoptic weather scenario prevailing at the time when the individual completed refueling at the point of origin and became ready to depart. As a result, the composition and overall size of the migration stream would be expected to be similar or identical under different synoptic weather scenarios, but the abundance of migrants at a given location would vary as a result of the varying location of the migration stream.

In the second case, individuals or species with differences in preferred route or point of landfall would await synoptic conditions appropriate to their preferences, and the composition of the migration stream would consequently vary dramatically under different weather scenarios. This potential phenomenon was first formally proposed by Evans (1966) and Nisbet and Drury (1967), and was later dubbed "pseudodrift" by Alerstam (1978).

One way to distinguish between these two possibilities ("flexible tactics" versus "pseudodrift") is to compare a species' distribution and abundance between different synoptic weather scenarios. In the case of flexible tactics, species-specific geographic patterns should vary in response to varying steering winds, but the overall abundance of the species should not. The opposite predictions can be made for pseudodrift: species-specific geographic patterns should NOT vary in response to steering winds, but overall abundance should.

We tested these predictions using data from **ECH** and **BH** days in spring 2000 for all species for which adequate data were available. The results are shown in Table 7.8. All species occurred farther to the east on **BH** days than on **ECH** days, as expected under the "flexible tactics" hypothesis. Single-species tests were significant only for Black-and-white Warblers and Hooded Warblers, but the fact that all seven comparisons yielded results in accordance with the predicted direction under the "flexible tactics" hypothesis was significant in itself (sign test, $P = 0.008$).

Proportionately more individuals of all species were recorded throughout the study area on **ECH** days than on **BH** days, and the difference was significant for all species except Common Yellowthroats. This suggests that these species preferred to depart on **ECH** days (when steering winds are more likely to result in landfall on the Texas coast than farther east), and is consistent with the hypothesis of differential wind selection or "pseudodrift."

The results are thus partly consistent with hypotheses of both flexible tactics and differential wind selection, and suggest that a blend of both phenomena may account for the observed patterns of spatiotemporal dynamics and response to wind. Further evaluation of the behavioral mechanisms underlying the observed patterns would require more focused study.

Table 7.7.

Comparative longitudinal distributions of spring trans-Gulf migrants

Numbers shown indicate numbers of individuals undertaking stopovers on each platform during spring 2000. Species are listed in order from most westerly distribution at top to most easterly distribution at bottom. Species with <5 stopovers are not included

	PN975	MI622	HI561	GB189	VR265	SM147	GC18	EW826	SP89	Total
Chipping Sparrow	13	7	0	0	0	0	0	0	0	20
Clay-colored Sparrow	15	16	1	1	0	0	0	0	0	33
Blue-winged Warbler	10	7	0	0	1	0	0	0	0	18
Brown-headed Cowbird	54	40	2	3	0	0	0	2	0	101
Grasshopper Sparrow	11	37	1	1	1	0	0	1	0	52
Yellow-breasted Chat	1	12	0	1	0	0	0	0	0	14
Lincoln's Sparrow	16	59	4	3	1	2	0	1	0	86
Lark Sparrow	3	11	0	1	1	0	0	0	0	16
Dickcissel	6	4	3	1	0	0	0	0	0	14
Magnolia Warbler	214	23	33	17	10	13	6	6	3	325
Tree Swallow	63	4	7	15	0	1	2	3	0	95
Mourning Dove	21	37	0	8	0	1	2	2	1	72
Northern Mockingbird	1	7	1	0	1	0	1	0	0	11
Vesper Sparrow	2	1	0	2	0	0	0	0	0	5
Savannah Sparrow	15	27	2	4	2	4	2	2	1	59
Blue Grosbeak	1	3	0	1	1	0	0	0	0	6
Common Yellowthroat	175	101	17	26	28	11	15	18	11	402
Painted Bunting	0	5	1	0	2	0	0	0	0	8
Blackburnian Warbler	27	1	7	5	0	5	1	0	3	49
Nashville Warbler	5	1	1	3	2	0	0	0	0	12
Baltimore Oriole	17	12	0	2	3	3	0	5	1	43
Black-and-white Warbler	68	14	40	6	10	5	10	4	4	161
Northern Waterthrush	8	5	6	3	2	0	2	1	0	27
Black-throated Green Warbler	26	2	2	6	0	2	5	3	2	48
Philadelphia Vireo	2	0	2	0	0	0	1	0	0	5
Northern Parula	19	12	10	6	7	1	4	2	2	63
Indigo Bunting	23	25	7	7	9	8	4	1	6	90
White-winged Dove	29	27	6	16	2	5	18	1	2	106
Worm-eating Warbler	5	2	4	1	2	1	1	1	0	17
Hooded Warbler	36	36	26	13	10	10	13	6	6	156
Yellow-throated Warbler	2	5	8	3	2	0	1	1	0	22
Kentucky Warbler	16	9	5	4	4	5	3	3	2	51
Eastern Wood-Pewee	3	11	2	6	4	3	2	0	0	31
White-eyed Vireo	1	8	4	0	3	3	0	0	1	20

Table 7.7.

Comparative longitudinal distributions of spring trans-Gulf migrants

Numbers shown indicate numbers of individuals undertaking stopovers on each platform during spring 2000. Species are listed in order from most westerly distribution at top to most easterly distribution at bottom. Species with <5 stopovers are not included

	PN975	MI622	HI561	GB189	VR265	SM147	GC18	EW826	SP89	Total
Common Moorhen	0	1	2	2	0	0	0	0	0	5
Myrtle Warbler	4	8	3	2	1	0	3	0	3	24
Scissor-tailed Flycatcher	4	3	0	0	1	1	4	0	0	13
Lesser Nighthawk	1	2	2	3	1	0	1	0	0	10
Yellow Warbler	9	6	10	2	4	2	2	3	2	40
Louisiana Waterthrush	5	3	17	1	0	1	2	2	2	33
Ovenbird	30	11	8	4	12	9	8	3	8	93
Cliff Swallow	4	3	0	8	0	1	1	2	0	19
Yellow-throated Vireo	0	1	12	0	0	0	1	0	1	15
Orchard Oriole	10	33	11	6	12	7	4	13	3	99
Purple Martin	27	21	70	129	8	9	9	2	2	277
Chimney Swift	4	0	0	2	1	3	1	0	0	11
Golden-winged Warbler	1	1	1	1	1	2	0	0	0	7
Chestnut-sided Warbler	11	2	4	3	2	3	4	0	4	33
Tennessee Warbler	24	8	25	11	9	10	12	3	5	107
Merlin	2	0	0	1	0	0	2	0	0	5
American Kestrel	1	4	1	2	1	0	1	0	2	12
Great Blue Heron	3	2	7	0	0	2	2	3	0	19
Eastern Kingbird	2	0	0	2	2	0	1	0	0	7
Snowy Egret	5	0	4	1	1	0	4	2	0	17
Least Bittern	0	3	1	1	2	1	0	0	1	9
American Redstart	17	12	12	14	8	3	8	7	8	89
Northern Rough-winged Swallow	1	2	2	3	0	4	0	1	0	13
Peregrine Falcon	8	13	4	13	4	4	8	5	4	63
Little Blue Heron	1	0	0	9	1	0	0	0	0	11
Yellow-bellied Sapsucker	1	1	1	0	0	1	1	1	0	6
Bobolink	0	2	1	4	0	0	1	0	1	9
Sora	1	8	12	0	7	2	6	4	1	41
Belted Kingfisher	4	10	3	7	3	2	11	5	1	46
Rose-breasted Grosbeak	0	2	0	0	2	0	2	0	0	6
Bay-breasted Warbler	2	1	7	126	1	12	1	0	1	151
Yellow-crowned Night-Heron	3	0	3	1	0	1	6	0	0	14
Great Egret	4	4	1	2	0	1	3	2	4	21
Wood Thrush	0	3	0	0	2	0	2	0	1	8
Barn Swallow	37	9	32	82	3	22	27	47	6	265
Ruby-throated Hummingbird	6	4	4	9	14	11	5	2	2	57
Summer Tanager	0	2	2	2	3	0	1	1	1	12

Table 7.7.

Comparative longitudinal distributions of spring trans-Gulf migrants

Numbers shown indicate numbers of individuals undertaking stopovers on each platform during spring 2000. Species are listed in order from most westerly distribution at top to most easterly distribution at bottom. Species with <5 stopovers are not included

	PN975	MI622	HI561	GB189	VR265	SM147	GC18	EW826	SP89	Total
Cattle Egret	33	58	28	245	48	24	86	55	24	601
Yellow-billed Cuckoo	1	12	3	6	8	5	8	7	3	53
Red-eyed Vireo	2	6	1	2	3	5	13	0	2	34
Bank Swallow	2	0	0	3	1	1	4	1	0	12
Green Heron	16	39	3	13	35	15	25	35	23	204
Gray Catbird	12	26	12	23	87	19	42	17	10	248
Swainson's Warbler	1	0	0	1	0	0	3	0	0	5
Chuck-Will's-Widow	2	1	1	3	1	1	9	2	0	20
Blackpoll Warbler	4	1	4	7	7	4	12	4	4	47
Acadian Flycatcher	0	2	0	1	2	2	1	2	1	11
Purple Gallinule	0	1	1	3	7	2	2	2	1	19
Scarlet Tanager	0	1	0	6	1	1	1	2	2	14
Prothonotary Warbler	0	3	0	2	1	0	2	3	3	14
Western Palm Warbler	0	1	0	1	2	1	2	1	1	9
Cerulean Warbler	0	0	1	2	1	0	3	0	1	8
Least Flycatcher	0	0	0	2	0	1	1	0	1	5

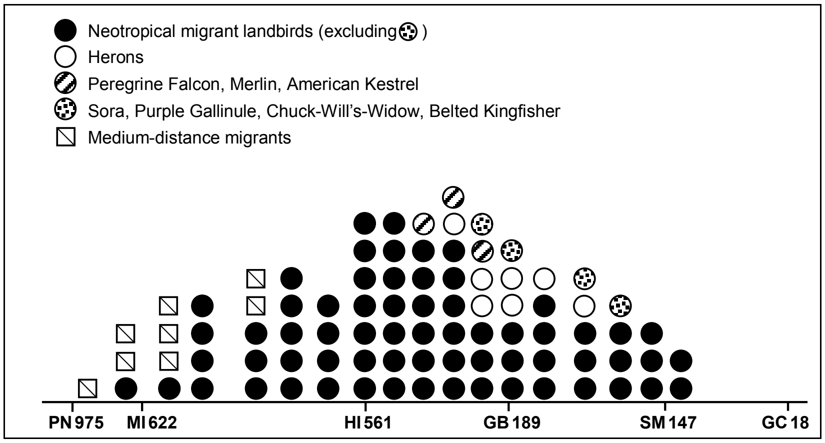

Figure 7.15. Frequency distribution of mean species-specific longitudinal positions in spring 2000. Each symbol indicates the mean position calculated from the entire sample of stopovers (i.e., all weather types) for one of the species listed in Table 7.7. Longitude is indicated by reference to the relative positions of selected study platforms.

Table 7.8.

Comparisons of geographic distribution and abundance between **ECH** and **BH** days for selected species

"Median platform" indicates the median longitudinal position of individuals from the combined sample of **ECH** and **BH** days. "Proportion east of median platform" compares the proportion of individuals recorded east of the median platform between **ECH** and **BH** days; total sample sizes for the two weather types are indicated in parentheses. P values indicate significance levels from single degree-of-freedom log-likelihood ratio tests for independence between geographic distribution and synoptic weather type. "Abundance ratio" compares the total abundance of a species across all platforms on **ECH** days versus **BH** days. The expected ratio was calculated for April and May, when most individuals of these species were recorded (9 **ECH** days and 22 **BH** days, i.e., 9 ÷ 22 = 0.41). P values indicate significance levels from single degree-of-freedom chi-square tests for deviations between observed and expected abundances under the null expectation that total abundance was unrelated to synoptic weather.

	Median	Proportion East of Median Platform (N)				Abundance Ratio (ECH:BH)			
Species	Platform	ECH days	BH days	G	P	Observed	Expected	χ^2	P
Common Yellowthroat	MI622	0.24 (41)	0.27 (95)	0.1	0.72	0.43	0.41	0.1	0.77
Black-and-white Warbler	HI561	0.04 (50)	0.85 (13)	36.2	<0.0001	3.85	0.41	77.6	<0.0001
White-winged Dove	MI622	0.40 (25)	0.56 (25)	1.3	0.26	1.00	0.41	10.7	0.001
Hooded Warbler	HI561	0.15 (26)	0.56 (18)	8.0	0.005	1.44	0.41	19.3	<0.0001
Purple Martin	HI561	0.44 (132)	0.50 (46)	0.5	0.48	2.87	0.41	176.3	<0.0001
Barn Swallow	GB189	0.24 (86)	0.35 (48)	1.8	0.18	1.79	0.41	80.5	<0.0001
Gray Catbird	GB189	0.37 (19)	0.52 (25)	1.0	0.32	0.76	0.41	4.3	0.038

7.7 MALE-BIASED SEX RATIOS

Over the course of the study it became obvious that we were seeing considerably more males than females in sexually dichromatic species that could be identified to sex in the field. Sex ratios for these species are summarized in Table 7.9, which shows that 28 out of 31 species (90%) had male-biased sex ratios.

Fisher (1930) seems to have been the first to have taken an interest in the evolution of sex ratio. He showed that natural selection should favor the maintenance of 1:1 sex ratios because of the advantage of investing in offspring of the rarer sex. An influential hypothesis during the early years of behavioral ecology proposed that natural selection should result in the ability of animals to manipulate the sex ratio of their offspring adaptively in accordance with environmental circumstances (Trivers and Willard 1973). However, to date, there has been little evidence of offspring sex-ratio manipulation or skewed sex ratios in nature, except in association with atypical ecological circumstances such as cooperative breeding (e.g., Komdeur et al. 1997), polygyny (e.g., Westerdahl et al. 2000), etc. In fact, most longer-term studies of passerines (reviewed by Wheelwright and Seabury 2003) find stable 1:1 offspring sex ratios in support of Fisherian theory.

In light of the theoretical and empirical evidence indicating that population-level sex ratios should be close to 1.0, the extreme male bias we observed begs explanation.

First, it is possible that the extreme sex ratios we observed are accurate representations of population structure. A considerable body of evidence has accumulated indicating that in several species of neotropical migrant warblers, males and females are spatially segregated on the wintering grounds (e.g., Lynch et al. 1985; Wunderle 1992; Parrish and Sherry 1994) and that this sexual segregation is due to behavioral dominance of males (Morton et al. 1987; Morton 1990; Stutchbury 1994; Marra 2000). Recently, Marra and Holmes (2001) showed that such dominance behavior and the resulting differential habitat segregation has consequences for the physical condition and survival of excluded individuals. Thus, it is possible that sexual segregation on the wintering grounds may cause reduced overwinter survivorship of females, resulting in skewed sex ratios during spring migration and on the breeding grounds. In fact, it is well known that breeding populations of many neotropical migrant landbirds contain large pools of unmated "floater" males (e.g., Rappole et al. 1977).

Table 7.9.

Sex ratios of sexually dichromatic species during spring 2000

Numbers given are the totals from all nine study platforms. Only species with total N ≥ 10 are included. Species are listed in descending order of male bias.

	♂	♀	♂♂:♀♀
Magnolia Warbler	1,128	38	29.7
Prothonotary Warbler	17	1	17.0
Chestnut-sided Warbler	41	3	13.7
Kentucky Warbler	36	4	9.0
Blackburnian Warbler	68	11	6.2
Baltimore Oriole	157	33	4.8
Indigo Bunting	219	47	4.7
Yellow-throated Warbler	9	2	4.5
Golden-winged Warbler	8	2	4.0
Yellow Warbler	38	11	3.5
Brown-headed Cowbird	82	26	3.2
Northern Parula	47	15	3.1
Blue Grosbeak	9	3	3.0
Black-throated Green Warbler	44	15	2.9
Hooded Warbler	143	49	2.9
Blue-winged Warbler	11	4	2.8
Common Yellowthroat	328	133	2.5
Scarlet Tanager	29	13	2.2
Blackpoll Warbler	36	19	1.9
Black-and-white Warbler	113	60	1.9
Bay-breasted Warbler	98	53	1.8
Tennessee Warbler	51	28	1.8

Table 7.9.

Sex ratios of sexually dichromatic species during spring 2000

Numbers given are the totals from all nine study platforms. Only species with total N ≥ 10 are included. Species are listed in descending order of male bias.

	♂	♀	♂♂:♀♀
Cerulean Warbler	7	4	1.8
Rose-breasted Grosbeak	28	17	1.6
Summer Tanager	20	13	1.5
American Redstart	60	46	1.3
Purple Martin	147	133	1.1a
Orchard Oriole	67	62	1.1
Ruby-throated Hummingbird	36	48	0.8
Belted Kingfisher	17	33	0.5
Myrtle Warbler	2	9	0.2

[a] Excludes 59 individuals that were either females or second-year males.

Second, it is possible that the sex ratios we observed were biased by differential propensities of males versus females to drop out of the airspace and be detected by the platform observers. Such a difference could result if females are more efficient fliers than males. Indeed, it seems reasonable to expect that competitive disadvantages on the wintering grounds must be balanced by some sort of compensatory survival advantage in another aspect of their life history. In one of the most well-studied cases of such a balance between competition and compensation, Carpenter et al. (1993a,b) found that female Rufous Hummingbirds are competitively disadvantaged along their migration corridor because they are behaviorally subordinate to males, and less likely to obtain high-quality flower territories with which to replenish migratory energy stores. However, females have a variety of exploitative advantages over males, including more energetically efficient flight and superior skills in thieving nectar. The females' exploitative advantages appeared to compensate completely for their competitive disadvantages, since there were no demonstrable differences in overall migration performance between the sexes. Unfortunately, analogous information concerning possible compensatory advantages of female trans-Gulf migrants is not available. Elkins (1988) suggested that females appear to be more resilient to the effects of sudden adverse weather changes encountered during migration, but did not elaborate.

Finally, it is possible that the skewed sex ratios we observed might result from some sort of differential route selection by the sexes. To evaluate this possibility, we examined geographic patterns of sex ratio. The results (Table 7.10) indicate that sexual segregation of migration route does occur in some species.

Magnolia Warblers, Bay-breasted Warblers, Black-and-white Warblers, and American Redstarts showed a pattern of increasing male bias toward the west. This pattern could result if females take a more direct route across the Gulf, and would therefore be consistent with the idea that females may compensate for their competitive disadvantages in part via more efficient migratory flight. However, the data do not support the idea that differential route selection can account for the highly skewed sex ratios we observed; the only portion of the migratory population that we did not sample was a possible circum-Gulf component, and the observed trends suggest that such a component (if it exists) is likely to be even more extremely male-biased.

Curiously, all of the non-warblers (Orchard Oriole, Baltimore Oriole, Indigo Bunting) showed a pattern of male bias increasing toward the east. This pattern could be consistent with differential route selection as an explanation for male-biased sex ratios over the Gulf if females in these species are more likely to undertake a circum-Gulf migration. Unfortunately, relevant data concerning circum-Gulf migration are not available.

Table 7.10.

Geographic variation in sex ratio of sexually dichromatic species in spring 2000

Sex ratios are computed from pooled samples from three longitudinal strata: “West” = PN975 + MI622 + HI561; “Central” = GB189 + VR265 + SM147; “East” = GC18 + EW826 + SP89. Significance levels are from G-tests (df = 2) of the null hypothesis that sex ratio was independent of region. Data are shown only for species for which meaningful G-tests could be conducted. Species are listed in order starting with those showing a trend toward stronger male bias in the west, and concluding with species showing stronger male bias toward the east.

	Sex Ratio (♂♂:♀♀)					
	West	Central	East	N	G	P
Magnolia Warbler	38.85	8.50	6.43	1,166		
Bay-breasted Warbler	7.50	1.64	1.00	151		
Black-and-white Warbler	2.09	1.63	1.11	173		
American Redstart	1.65	1.17	0.93	106		
Common Yellowthroat	2.39	2.42	3.00	461		
Hooded Warbler	2.93	2.17	4.14	192		
Orchard Oriole	0.94	1.07	1.40	129		
Baltimore Oriole	2.42	8.20	14.50	190		
Indigo Bunting	2.79	2.15	36.33	266		

Chapter 8

Timing and Magnitude of Spring Trans-Gulf Migration and Platform Use

Robert W. Russell and Sidney A. Gauthreaux, Jr.

8.1. DIEL TIMING OF SPRING MIGRATION

The diel timing of spring trans-Gulf migration followed a predictable pattern that was evident both in radar imagery and from direct visual observations on the platforms. Figure 8.1 shows a typical progression of radar images over the course of a spring day. On this day, the first migrants began arriving on the northern Gulf Coast at around 10 AM local time; migration was extremely heavy by the afternoon, and was essentially over by 9 PM (the final image primarily depicts nocturnal insect migrants). On this particular day, roughly 25 million migrant birds were estimated to have arrived on the northern Gulf coast, most having departed from the Yucatan Peninsula the night before. The pattern of migration indicated in the radar imagery was mirrored in our observations on the platforms: landing of migrants on platforms began at around 10 AM, peaked in the afternoon, and was finished by early evening.

Although this pattern of diel timing seemed remarkably consistent, there were minor differences from day to day that appeared to be related to seasonal and weather factors. An analysis of covariance of radar-observed arrival time (with **ELOW** and **MCH** days excluded due to insufficient samples) showed that at Lake Charles (LCH) in spring 1998, the arrival of incoming trans-Gulf migrants began significantly later as the season progressed, but arrival time did not vary among days of different weather type. Time of peak trans-Gulf migration traffic detected at Lake Charles also occurred significantly later as the season progressed, and differences among weather types were nearly significant. Duration of radar-observed trans-Gulf migration at Lake Charles averaged 8.5 h and did not vary with date or among weather types.

An analysis of covariance (with **ELOW** and **MCH** days excluded due to insufficient samples) of radar-observed arrival time showed that at New Orleans in spring 1998, TGM arrival time did not vary with date, but did vary significantly and dramatically among days of different weather type. Similarly, time of peak TGM at New Orleans did not vary with date, but varied significantly and dramatically among weather types. Duration of TGM at New Orleans did not vary with date but varied significantly and dramatically among weather types.

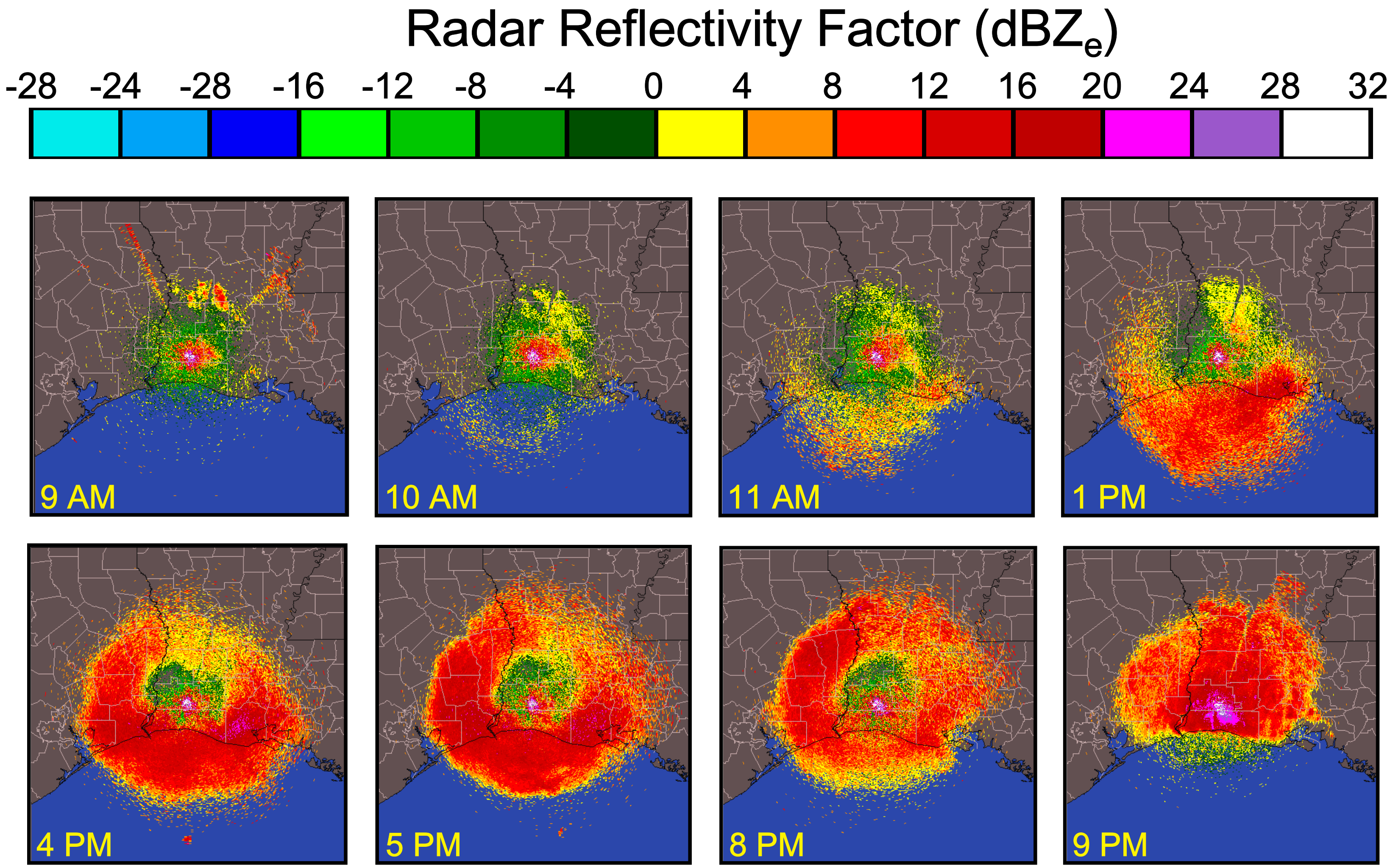

Figure 8.1. Time series showing the progressive arrival of trans-Gulf migrants on the northern Gulf Coast on May 13, 1998. Synoptic weather for this flight was classified as **ECH**. Times indicated are in local time (CDT). Radar scans were obtained in clear-air mode at an elevation of 0.5°. Images are courtesy of WSI Corporation.

On **BH** days in spring 1998 when TGM was detected by radar at both Lake Charles and New Orleans, TGM started significantly earlier at New Orleans, peaked significantly earlier at New Orleans, and lasted longer at New Orleans. Paired samples were of insufficient size for statistical testing on **ECH** (n = 7) and **GH** (n = 6) days.

Analysis of covariance (with **ELOW** and **MCH** days excluded due to insufficient samples) of radar-observed arrival time showed that at Lake Charles in spring 1999, TGM started significantly later as the season progressed, but arrival time did not vary among days of different weather type. Time of peak TGM also occurred significantly later as the season progressed, and differences among weather types were nearly significant. Duration of TGM at Lake Charles averaged 8.2 h and did not vary with date or among weather types.

Analysis of covariance (with **ELOW** and **MCH** days excluded due to insufficient samples) of radar-observed arrival time showed that at New Orleans in spring 1999, TGM started significantly earlier as the season progressed but arrival time did not vary among days of different weather type. Similarly, time of peak TGM at New Orleans started significantly earlier as the season progressed and arrival time did not vary among days of different weather type. Duration of TGM at New Orleans averaged 7.7 h and did not vary with date or among weather types.

On **BH** days in spring 1999 when TGM was detected by radar at both Lake Charles and New Orleans, there were no differences between the two in TGM arrival time, TGM peak, or TGM duration. On **ECH** days in spring 1999 when TGM was detected at both Lake Charles and New Orleans, TGM arrival was significantly earlier at Lake Charles. However, there was no significant difference in time of peak TGM. Duration of TGM duration was longer at Lake Charles and the difference was nearly significant. Paired samples were of insufficient size for statistical testing on **GH** days (n = 8).

In summary, radar-observed migration over the northern Gulf began between early morning and early afternoon, peaked 3-4 h after first detection, and continued until 7-12 h after first detection. Variability in diel timing was related in a complex way to location, weather, year, and time of year. These relationships are summarized in Table 8.1a-c.

Time of first daily arrival of TGM was unrelated to weather type in three out of four comparisons. In the case where earliest TGM detection was related to weather type (New Orleans 1998), first arrival was earliest on **BH** days (12:22 UTC) and averaged more than five hours later on **ECH** and **GH** days (17:33-18:04 UTC). Time of peak TGM was related to weather type in three out of four comparisons, but these differences were confounded with geographic differences and not consistent between years. At Lake Charles, TGM peaked earliest on **GF** and **GH** days in 1998 but on **ECH** and **BH** days in 1999. At New Orleans, TGM peaked 4-6 h earlier on **BH** and **GF** days than on **ECH** and **GH** days in 1998, but no effect of weather type was detected in 1999. In 1998, both first arrival and peak TGM occurred 2-3 h earlier at New Orleans than at Lake Charles on **BH** days, and peak TGM occurred 2-5 h earlier at Lake Charles on **ECH**, **GH**, and **GF** days. Diel timing also averaged earlier at New Orleans on **BH** days in 1999, though this difference could not be demonstrated statistically. On **ECH** days in 1999, first arrival occurred 1.5 h earlier at Lake Charles than at New Orleans, but there was no detectable difference in time of TGM peak. In summary, to the extent that differences were detected, TGM tended to occur earliest at New Orleans on **BH** days and earliest at Lake Charles on **ECH**, **GH**, and **GF** days.

The pattern of TGM tending to arrive earlier at New Orleans than at Lake Charles on **BH** days, but earlier at Lake Charles on **ECH**, **GH**, and **GF** days, is consistent with a strong synoptic steering influence on migration routes across the Gulf. On **BH** days, migrants traveling with the geostrophic flow should follow a straighter, more direct route to the northern Gulf Coast from the Yucatan Peninsula and adjacent Mexican shores. In contrast, migrants exploiting the geostrophic flow on **ECH** and **GH** days would follow a more curvilinear route, with the western flank skirting the Texas coast and the northern vanguard approaching from a more westerly bearing.

Table 8-1a.

Spring radar-observed trans-Gulf migration time of initial arrival on the northern Gulf Coast (CST)

	1998		1999	
	Lake Charles	New Orleans	Lake Charles	New Orleans
Seasonal Trend	Significant, Progressively later	Not Significant	Significant, Progressively later	Significant, Progressively Earlier
	Beta = 0.0027	---	Beta = 0.0022	Beta = 0.0020
	$F_{1,45} = 10.91$	$F_{1,40} = 0.62$	$F_{1,52} = 6.92$	$F_{1,42} = 4.46$
	P = 0.0019	P = 0.44	P = 0.011	P = 0.041
Variation among synoptic weather types	Not Significant	Significant	Not Significant	Not Significant
	$F_{3,45} = 1.10$	$F_{3,40} = 9.24$	$F_{3,52} = 1.48$	$F_{3,42} = 1.26$
	P = 0.36	P = 0.0001	P =0.23	P = 0.30
Overall x (CST)	9:06 AM ± 0:25 SE	---	10:37 AM ± 0:25 SE	9:48 AM
Bermuda High (CST)	---	6:22 AM	---	---
East Continental High (CST)	---	11:33 AM	---	---
Gulf High (CST)	---	12:04 PM	---	---
Gulf Front (CST)	---	7:41 AM	---	---
Paired comparison on Bermuda High Days	Significant Lake Charles (8:02 AM CST) > New Orleans (6:29 AM CST)		Not significant Lake Charles (11:02 AM CST) = New Orleans	
	T = 2.38 DF = 16 P = 0.03		T = 0.86 DF = 16 P = 0.40	
Paired comparison on East Continental High days	Not measured		Significant Lake Charles (11:02 CST) > New Orleans (10:36 AM CST) T = 7.43 DF = 11 P = 0.0001	

Table 8-1b.

Spring radar-observed trans-Gulf migration time of the peak in number of birds arriving on the northern Gulf Coast (CST)

	1998		1999	
	Lake Charles	New Orleans	Lake Charles	New Orleans
Seasonal trend	Significant	Not significant	Significant	Significant
	Beta = 0.0033	---	Beta = 0.0025	Beta = 0.0023
	F1,45 = 7.58	F1,40 = 0.81	F1,50 = 9.63	F1,41 = 5.35
	P = 0.0085	P = 0.37	P = 0.0031	P = 0.026
Variation among synoptic weather types	Significant	Significant	Nearly Significant	Not Significant
	F3,45 = 2.77	F3,40 = 5.88	F3,50 = 2.58	F3,41 = 1.22
	P = 0.052	P = 0.002	P =0.064	P = 0.31
Overall x (CST)	---	---	---	12:27 PM
Bermuda High (CST)	12:58 PM	10:08 AM	1:51 PM	---
East Continental High (CST)	1:36 PM	3:28 AM	1:10 PM	---
Gulf High (CST)	11:25 AM	4:08 PM	3:59 PM	---
Gulf Front (CST)	8:55 AM	11:03AM	3:32 PM	---
Paired comparison on Bermuda High Days	Significant		Not Significant	
	T = 2.99		T = 0.41	
	DF = 16		DF = 10	
	P = 0.009		P = 0.69	
	Lake Charles (12:20 PM CST) > New Orleans (10:26 PM CST)		Lake Charles (12:41 PM CST) = New Orleans	
Paired comparison on East Continental High days	Not measured		T = 0.75	
			Lake Charles (12:47 PM CST) = New Orleans	
			DF = 10	
			P = 0.055	

Table 8-1c.

Spring radar-observed trans-Gulf migration duration of arrival period (hr) on the northern Gulf Coast

	1998		1999	
	Lake Charles	New Orleans	Lake Charles	New Orleans
Seasonal Trend	Not significant F1,45 = 0.64 P = 0.13	Not Significant F1,40 = 1.84 P = 0.18	Significant F1,52 = 6.92 P = 0.011	Not Significant F3,41 = 1.05 P = 0.31
Variation among synoptic weather types	Not significant F3,.45 = 2.01 P = 0.13	Significant F3,40 6.08 P = 0.0016	Not significant F3,52 = 0.74 P = 0.53	Not significant F3,41 = 0.49 P = 0.69
Overall x (hr)	8.5 hr + 0.42 SE		8.2 hr + 0.41 SE	7.7 hr + 0.42 SE
Bermuda High (hr)		11.7 hr		
East Continental High (hr)		8.0 hr		
Gulf High (hr)		6.7 hr		
Gulf Front (hr)		9.3 hr		
Paired comparison on Bermuda High Days	Significant T = 2.61 DF = 16 P = 0.019 Lake Charles (9.9 hr) < New Orleans (11.8 hr)		Not Significant T = 0.86 DF = 16 0.40 Lake Charles (8.7 hr) = New Orleans	
Paired comparison on East Continental High days	Not tested		Not significant	
	`		T = 7.43 DF = 11 P = 0.055 Lake Charles (9.2 hr) > New Orleans (7.2 hr)	

The radar-observed pattern in daily duration of TGM (i.e., 2 h longer at New Orleans than at Lake Charles on **BH** days, and 2 h longer at Lake Charles than at New Orleans on **ECH** days) mirrored the patterns of TGM arrival (i.e., longer daily durations were associated with earlier arrivals), suggesting that radar-observed duration is usually bounded by nightfall (presumably because migrants descend in altitude at nightfall). This finding indicates that duration of radar-observed TGM is probably not a useful comparative parameter, and more importantly, that a portion of spring TGM is probably missed by radar, even on favorable weather days.

Lake Charles showed a consistent pattern in seasonal trend of diel timing, with both TGM arrival and peak TGM occurring later as the season progressed in both years. This pattern can be explained simply as a result of increasing daylength during the spring. As spring progresses, nightfall on the Yucatan Peninsula or other departure points occurs progressively later. Therefore, migrants departing shortly after nightfall should arrive over the northern Gulf later on the following day as the season progresses, all else being equal. The findings from Lake Charles were thus consistent with the null expectation. However, diel migration timing at New Orleans was *earlier* as the season progressed in 1999, independent of any influences of synoptic weather type. A seasonal trend toward shorter trans-Gulf transit times is particularly unexpected because a number of studies have shown that late migrants tend to be lower-quality individuals, which should be less efficient in transiting the Gulf. One possible explanation for this discrepancy is that the late-season flights recorded by New Orleans NEXRAD may be dominated by shorebirds, which fly faster than landbirds and rarely stop on platforms.

Most comparisons indicated that the diel timing of TGM over the northern Gulf averaged 1-3 h later in 1999 than in 1998, even after accounting for synoptic weather type. The reason for this difference is not clear, though the most obvious candidate explanation would be persistently stronger winds aloft in 1998. Regardless of the causality, an important implication of substantial interannual variation in transit times is that the condition of arriving migrants on the northern Gulf Coast should be expected to vary among years (due to the very high energetic cost of powered flight).

8.2. RADAR-BASED ESTIMATES OF ABSOLUTE BIRD MIGRATION TRAFFIC

To estimate the total daily number of trans-Gulf migrants detected by radar during spring 1998 and spring 1999, we necessarily made a number of assumptions. We assumed that changes in species composition over the course of the season can be characterized by the daily variation in mean body mass of the pool of migrants stopping over on and flying past our study platforms. Daily average radar cross section was then estimated using equation 4.12, and estimated migration fluxes were calculated using equation 4.7 and the actual NEXRAD data. Migrants were assumed to travel uniformly in an altitudinal band from 300-1300 m, and to arrive across a 900-km swath from the central Texas coast to around Mobile Bay, Alabama. The NEXRAD results from LCH were assumed to be applicable uniformly to the western 500 km of the arrival front, and the LIX results were assumed to be applicable uniformly to the eastern 400 km (roughly from South Marsh Island eastward). Radar cross section calculations for the western area were based on observations from GB189 and VR265, and calculations for the eastern area were based on SM66 (1998), SM147 (1999), PL10 (1998), GC18 (1999), and EW826. In cases where trans-Gulf migration was observed by radar before or after our field seasons, we based radar cross section calculations on the average of the first two days or last two days of the field season.

These calculations yielded total seasonal estimates of 316 million trans-Gulf migrants in spring 1998 (68% arriving west of South Marsh Island) and 147 million trans-Gulf migrants in spring 1999 (67% arriving west of South Marsh Island).

8.3. SEASONAL TIMING OF SPRING MIGRATION

8.3.1 Phenology of the Migration in Aggregate

The volume of trans-Gulf migration varied dramatically from day to day, both in terms of radar estimates and actual numbers observed on platforms.

“Small” trans-Gulf flights (>1 million migrants estimated from radar) occurred between March 25 and May 24. “Moderate” flights (>5 million migrants) occurred between April 2 and May 15. “Megaflights” (>25 million migrants) occurred between April 22 and May 13.

Radar-observed migration was characterized by a series of pulses and tended to be “all-or-nothing”, i.e., either significant trans-Gulf migration was evident on radar or else it was essentially entirely absent (Figure 8.2). Interestingly, the peaks of the pulses seemed to conform to a smooth pattern in each year. In 1999, migration peaks seemed to be approximately Gaussian and symmetric around the peak date of

April 22. In contrast, radar-observed migration peaked much later in 1998 and the overall pattern was highly skewed to the left.

Patterns of migrant abundance detected from platforms showed less of the “all-or-nothing” character than did radar-observed migration, but at the same time showed more extreme peaking (Figure 8.3).

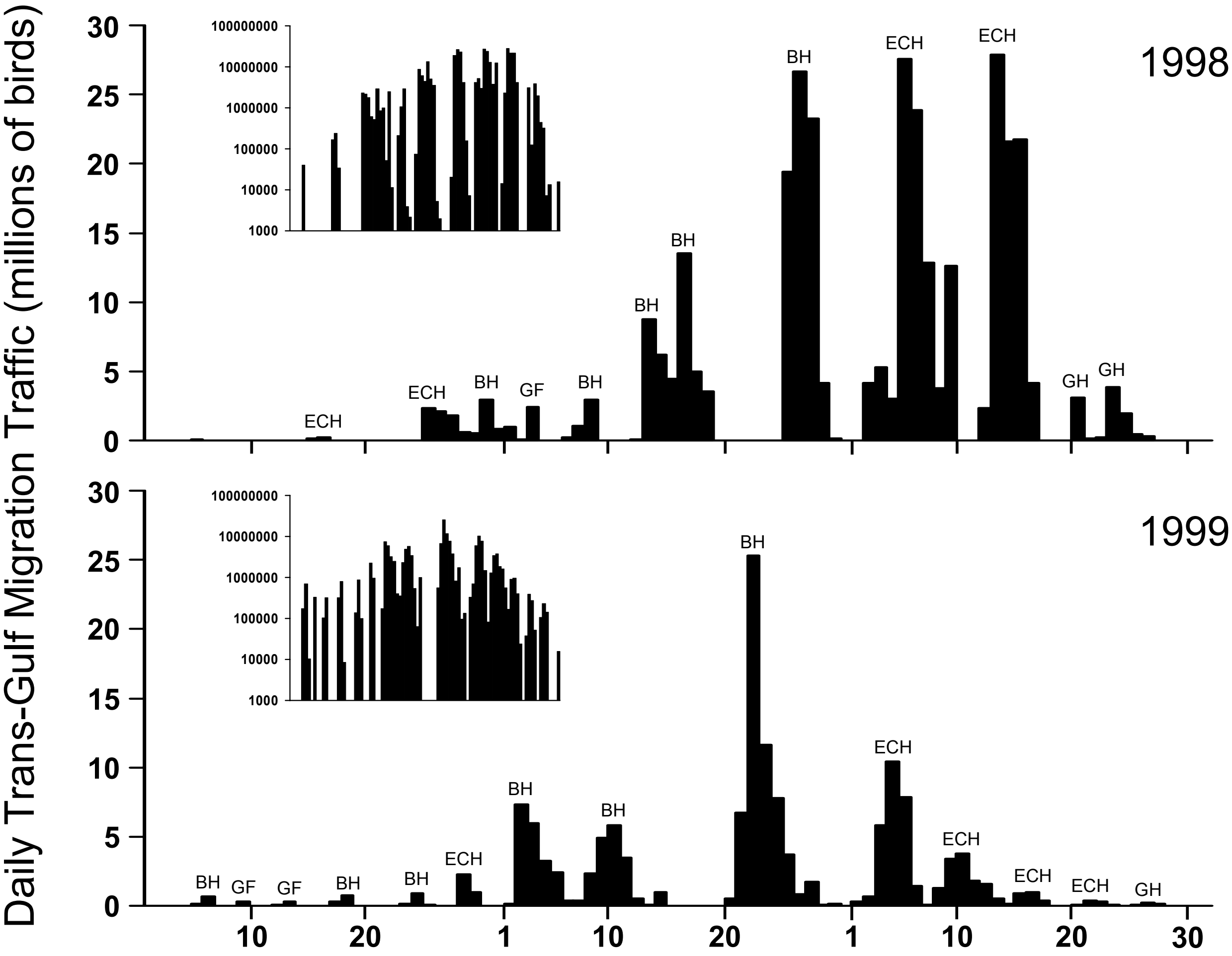

Figure 8.2. Phenology of radar-observed spring migration in 1998 and 1999. The inset figures show the same data (x+1)-transformed on a logarithmic scale for perspective. Synoptic weather types are indicated above intraseasonal migration peaks.

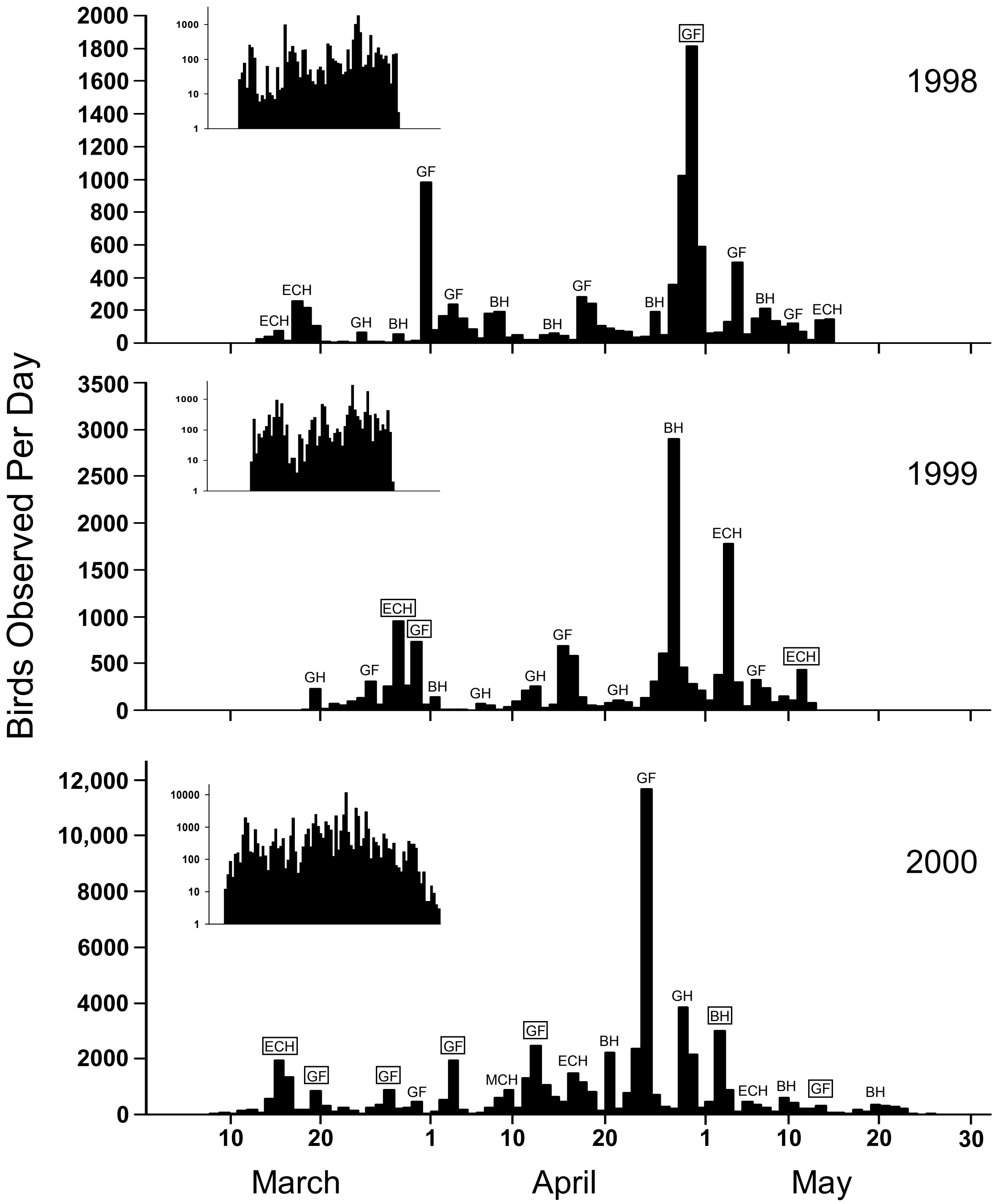

Figure 8.3. Phenology of platform-observed spring migration in 1998-2000. The inset figures show the same data (x+1)-transformed on a logarithmic scale for perspective. Synoptic weather types are indicated above intraseasonal migration peaks, and inside a box on days with rain.

8.3.2 Weather Influences

Trans-Gulf migration was often completely absent on radar for prolonged periods, even around the expected seasonal peak of migration (Figure 8.2: e.g., April 9-12, April 19-24, and April 29-May 1 in 1998, and April 15-19 and April 28-May 1 in 1999). These dramatic hiatuses were always associated with strong cold fronts that penetrated deep into Mexico and set up persistent northerly winds over most of the Gulf. Conversely, radar-observed migration peaks were almost strictly associated with **ECH** and **BH** days, though minor peaks sometimes occurred on **GF** days in March-early April and on **GH** days in late May (Figure 8.2).

The influence of synoptic weather on the occurrence of radar-observed migration was similar but not identical between the Lake Charles and New Orleans NEXRAD sites (Table 8.2). Trans-Gulf migration was almost always detected by NEXRAD on **BH** days. In spring 1998, TGM was detected at Lake Charles on all **BH** days except March 7 and April 2, and at New Orleans on all **BH** days except March 5, March 7, March 26, and April 7. In spring 1999, TGM was detected on all **BH** days at both Lake Charles and New Orleans.

There was an interesting difference between Lake Charles and New Orleans in the frequency of radar detection of TGM on **ECH** days. In spring 1998, TGM was detected at Lake Charles on 71% of **ECH** days (all except March 4, March 6, March 13, March 14, and March 18), whereas TGM was detected on just 41% of **ECH** days at New Orleans (not detected on the same days as Lake Charles as well as on March 15, March 16, March 17, May 25, and May 26). The pattern was nearly identical in 1999. In spring 1999, TGM was detected at Lake Charles on 75% of **ECH** days (all except March 4, March 8, March 16, March 27, March 29, May 29, and May 30) but on just 48% of **ECH** days at New Orleans (absent on the same days as Lake Charles except on March 29, when TGM was detected at New Orleans but not at Lake Charles; also absent on March 5, April 29, May 17, May 18, May 20, May 21, May 22, and May 31). The bias toward detection at Lake Charles on **ECH** days presumably reflects the general steering influence of synoptic winds on the broad-scale trajectory of migration (Chapter 7).

Table 8.2.

Influence of synoptic weather on the occurrence of radar-observed trans-Gulf migration in spring 1998 and 1999

	Spring 1998				Spring 1999			
	Lake Charles		New Orleans		Lake Charles		New Orleans	
Weather Type	TGM	No TGM	TGM	No TGM	TGM	No TGM	TGM	No TGM
BH	20	2	18	4	18	0	18	0
ECH	12	5	7	10	21	7	13	14
GH	10	9	8	11	12	6	9	9
GF	8	8	12	4	7	11	7	10
MCH	0	9	2	7	1	4	0	5
ELOW	0	8	2	6	0	4	0	4

TGM was detected by radar on roughly half of **GH** days. In spring 1998, TGM was detected at Lake Charles on 53% of **GH** days (absent on March 23, March 24, May 17, May 18, May 19, May 21, May 22, May 29, and May 30). At New Orleans, TGM was detected on 41% of **GH** days (absent on the same days as Lake Charles except May 21 and May 22, when TGM was detected at New Orleans but not at

Lake Charles; also absent on April 24, May 1, May 28, and May 31). The pattern was similar in 1999. In spring 1999, TGM was detected at Lake Charles on 67% of **GH** days (absent on March 1, March 2, March 19, April 19, May 24, and May 28). At New Orleans, TGM was detected on 50% of **GH** days (absent on the same days as Lake Charles except March 19, when TGM was detected at New Orleans but not at Lake Charles; also absent on April 20, May 23, May 25, and May 27).

TGM was rarely detected by radar on **MCH** and **ELOW** days, and when it was it was only trace amounts. Radar detection on **GF** days was highly variable. At least in 1998, TGM was detected more frequently on **GF** days at New Orleans than at Lake Charles, presumably due to eastward displacement of the main migration stream by the fronts (e.g., Figure 7.7).

The largest flights observed from platforms were often on **GF** days, but platform-observed migration peaks also occurred on **BH**, **ECH**, and **GH** days (Figure 8.3). Contrary to popular expectation, platform-observed migration was not strictly associated with precipitation. Indeed, in 1998 only one significant migration event was associated with precipitation. Association with precipitation was more prevalent in 1999 and, especially, in 2000; however, the largest platform-observed migration events in those years occurred on precipitation-free days (Figure 8.3).

Broad temporal patterns of platform-observed migration generally followed the radar patterns, but relatively more birds seemed to be detected from platforms in March and relatively fewer migrants seemed to be detected in May. These biases probably reflect the high early-season frequency of weather events unfavorable for trans-Gulf migrants and the generally benign weather toward the end of the season (Figure 5.2).

A comparison of platform counts with radar estimates in relation to synoptic weather is provided in Table 8.3 (1998) and Table 8.4 (1999). In general, **BH** and **ECH** days tended to yield large radar-observed events and relatively small platform-observed events. This association was not universal since, as previously mentioned, significant platform events did sometimes occur on such "fair-weather" days. On **GF** days, migration was usually absent or minor on radar, but often spectacular on platforms.

Table 8.3.

Comparison of daily platform counts and radar-observed migration traffic in relation to synoptic weather in spring 1998

Date	Synoptic Type	Radar-Observed Migration Traffic	Platform Counts
1-Mar	ELOW	0	na
2-Mar	ELOW	0	na
3-Mar	MCH	0	na
4-Mar	ECH	0	na
5-Mar	BH	39,919	na
6-Mar	ECH	0	na
7-Mar	BH	0	na
8-Mar	GF	0	na
9-Mar	ELOW	0	na
10-Mar	MCH	0	na
11-Mar	MCH	0	na
12-Mar	MCH	0	na
13-Mar	ECH	0	25
14-Mar	ECH	0	40

Table 8.3.

Comparison of daily platform counts and radar-observed migration traffic in relation to synoptic weather in spring 1998

Date	Synoptic Type	Radar-Observed Migration Traffic	Platform Counts
15-Mar	ECH	167,252	78
16-Mar	ECH	238,151	14
17-Mar	ECH	34,340	256
18-Mar	ECH	0	218
19-Mar	GF	0	108
20-Mar	ELOW	0	9
21-Mar	ELOW	0	5
22-Mar	MCH	0	8
23-Mar	GH	0	6
24-Mar	GH	0	63
25-Mar	ECH	2,306,963	10
26-Mar	BH	2,150,481	8
27-Mar	BH	1,797,596	6
28-Mar	BH	623,348	57
29-Mar	BH	520,190	12
30-Mar	BH	2,956,739	14
31-Mar	GF	849,083	984
1-Apr	GF	1,005,184	81
2-Apr	BH	52,663	164
3-Apr	GF	2,453,045	237
4-Apr	GF	11,397	152
5-Apr	MCH	517	84
6-Apr	ECH	208,480	29
7-Apr	BH	1,063,162	183
8-Apr	BH	2,942,194	190
9-Apr	GF	3,939	35
10-Apr	ELOW	2,182	49
11-Apr	MCH	0	22
12-Apr	ECH	74,205	18
13-Apr	BH	8,732,527	49
14-Apr	BH	6,199,372	59
15-Apr	BH	4,485,806	47
16-Apr	BH	13,512,286	18
17-Apr	GF	5,020,577	281
18-Apr	GF	3,585,184	242
19-Apr	GF	5,221	104
20-Apr	MCH	1,953	89
21-Apr	MCH	0	78
22-Apr	ELOW	781	73
23-Apr	ELOW	0	36
24-Apr	GH	20,695	42
25-Apr	BH	19,423,956	189
26-Apr	BH	26,682,504	50

Table 8.3.

Comparison of daily platform counts and radar-observed migration traffic in relation to synoptic weather in spring 1998

Date	Synoptic Type	Radar-Observed Migration Traffic	Platform Counts
27-Apr	BH	23,278,464	359
28-Apr	GF	4,179,621	1,025
29-Apr	GF	157,679	1,814
30-Apr	GF	7,201	589
1-May	GH	0	59
2-May	GH	4,118,728	68
3-May	BH	5,261,354	132
4-May	GF	3,055,877	494
5-May	ECH	27,566,460	57
6-May	BH	23,881,607	152
7-May	BH	12,840,200	213
8-May	BH	3,764,298	134
9-May	BH	12,628,122	100
10-May	GF	0	123
11-May	GF	14,350	73
12-May	ECH	2,306,692	19
13-May	ECH	27,891,872	139
14-May	ECH	21,574,463	145
15-May	GH	21,730,740	2
16-May	GH	4,133,416	na
17-May	GH	0	na
18-May	GH	0	na
19-May	GH	0	na
20-May	GH	3,126,921	na
21-May	GH	125,156	na
22-May	GH	240,092	na
23-May	GH	3,857,084	na
24-May	GH	1,946,344	na
25-May	ECH	444,565	na
26-May	ECH	324,916	na
27-May	ND	7,200	na
28-May	GH	13,554	na
29-May	GH	0	na
30-May	GH	0	na
31-May	GH	15,738	na

Table 8.4.

Comparison of daily platform counts and radar-observed migration traffic in relation to synoptic weather in spring 1999

	Synoptic type	Radar-observed migration traffic	Platform Counts
1-Mar	GH	0	na
2-Mar	GH	0	na
3-Mar	GF	0	na
4-Mar	ECH	0	na
5-Mar	ECH	171,425	na
6-Mar	BH	695,082	na
7-Mar	GF	10,167	na
8-Mar	ECH	0	na
9-Mar	GF	336,908	na
10-Mar	GF	0	na
11-Mar	GF	0	na
12-Mar	GF	102,003	na
13-Mar	GF	322,958	na
14-Mar	ELOW	0	na
15-Mar	ELOW	0	na
16-Mar	ECH	0	na
17-Mar	BH	320,542	na
18-Mar	BH	787,340	8
19-Mar	GH	8,560	225
20-Mar	GF	0	16
21-Mar	GF	0	73
22-Mar	MCH	0	55
23-Mar	GH	137,642	93
24-Mar	BH	869,919	132
25-Mar	GF	100,488	307
26-Mar	GF	0	63
27-Mar	ECH	0	258
28-Mar	ECH	2,234,816	954
29-Mar	ECH	957,955	266
30-Mar	GF	0	728
31-Mar	ND	0	65
1-Apr	BH	171,457	143
2-Apr	BH	7,351,551	7
3-Apr	BH	5,938,882	11
4-Apr	ECH	3,261,131	11
5-Apr	BH	2,439,647	3
6-Apr	GH	402,674	69
7-Apr	ECH	357,003	50
8-Apr	BH	2,326,992	8
9-Apr	BH	4,909,449	32
10-Apr	BH	5,846,485	97
11-Apr	GH	3,446,789	210

Table 8.4.

Comparison of daily platform counts and radar-observed migration traffic in relation to synoptic weather in spring 1999

	Synoptic type	Radar-observed migration traffic	Platform Counts
12-Apr	GH	537,339	257
13-Apr	ECH	64,459	29
14-Apr	ECH	991,489	61
15-Apr	GF	0	689
16-Apr	ELOW	0	578
17-Apr	ELOW	0	144
18-Apr	MCH	0	54
19-Apr	GH	0	40
20-Apr	GH	554,514	77
21-Apr	GH	6,735,496	109
22-Apr	BH	25,332,693	84
23-Apr	BH	11,667,590	29
24-Apr	GH	7,759,154	132
25-Apr	GH	3,724,672	307
26-Apr	BH	831,125	606
27-Apr	BH	1,744,102	2,900
28-Apr	GF	95,605	457
29-Apr	ECH	133,093	279
30-Apr	MCH	0	211
1-May	MCH	332,029	109
2-May	ECH	695,177	382
3-May	ECH	5,856,132	1,781
4-May	ECH	10,407,673	300
5-May	BH	7,825,020	41
6-May	GF	1,452,163	330
7-May	GF	81,571	239
8-May	GF	1,296,378	92
9-May	ECH	3,382,813	147
10-May	ECH	3,783,530	103
11-May	ECH	1,843,354	429
12-May	ECH	1,600,698	83
13-May	GF	553,457	1
14-May	BH	167,619	na
15-May	BH	901,284	na
16-May	ECH	978,990	na
17-May	ECH	407,363	na
18-May	ECH	23,823	na
19-May	MCH	0	na
20-May	ECH	37,834	na
21-May	ECH	395,288	na
22-May	ECH	276,390	na
23-May	GH	52,762	na
24-May	GH	0	na

Table 8.4.

Comparison of daily platform counts and radar-observed migration traffic in relation to synoptic weather in spring 1999

	Synoptic type	Radar-observed migration traffic	Platform Counts
25-May	GH	108,364	na
26-May	GH	233,555	na
27-May	GH	142,276	na
28-May	GH	0	na
29-May	ECH	0	na
30-May	ECH	0	na
31-May	ECH	15,695	na

8.3.3 Interspecific Variation in Migration Schedules

Data on species-specific spring migration schedules are tabulated in Table 8.5 and summarized graphically in Figure 8.4. Waterfowl and herons peaked by early April. Shorebirds had widely varying migration schedules, with different species peaking as early as mid-March and as late as the end of May. Landbird migrants showed peaks throughout the season, but a majority of species peaked in the second half of April.

Table 8.5.

Species-specific timing of spring trans-Gulf migration in 2000

Species are listed in order from earliest to latest migrants (based on mean date). Sample sizes indicate total numbers of individuals of each species recorded over the entire season, including both stopovers and flyby migrants. 95% confidence intervals are calculated only for sample sizes ≥ 5.

Species	First Date	95% CI Lower Bound	Mean Date	95% CI Upper Bound	Last Date	N
Greater White-fronted Goose	---	---	11-Mar	---	---	1
Blue-headed Vireo	---	---	14-Mar	---	---	1
Common Snipe	14-Mar	---	14-Mar	---	15-Mar	2
Yellow-throated Vireo	13-Mar	14-Mar	14-Mar	15-Mar	15-Mar	7
Ring-necked Duck	---	---	15-Mar	---	---	1
White-faced Ibis	---	---	15-Mar	---	---	1
Wilson's Plover	---	---	15-Mar	---	---	1
Killdeer	11-Mar	13-Mar	15-Mar	17-Mar	19-Mar	11
Green-winged Teal	16-Mar		16-Mar		16-Mar	2
Northern Pintail	15-Mar	29-Feb	16-Mar	1-Apr	11-Apr	5
Lesser Scaup	12-Mar	6-Mar	16-Mar	27-Mar	3-Apr	12
Pied-billed Grebe	9-Mar	6-Mar	17-Mar	28-Mar	3-Apr	6
Yellow-crowned Night-Heron	11-Mar	12-Mar	17-Mar	22-Mar	29-Apr	61
Louisiana Waterthrush	14-Mar	12-Mar	18-Mar	24-Mar	24-Apr	23
Cinnamon Teal	---	---	19-Mar	---	---	1
Eastern Meadowlark	11-Mar	---	19-Mar	---	28-Mar	4
Red-winged Blackbird	---	---	20-Mar	---	---	1
Black-crowned Night-Heron	15-Mar	1-Mar	20-Mar	7-Apr	1-May	10
unid. Meadowlark	16-Mar	15-Mar	22-Mar	28-Mar	30-Mar	6
White Ibis	12-Mar	14-Mar	22-Mar	30-Mar	21-Apr	15
Redhead	---	---	23-Mar	---	---	1
Burrowing Owl	10-Mar	---	23-Mar	---	5-Apr	2
American Wigeon	15-Mar	29-Feb	23-Mar	14-Apr	16-Apr	6
Myrtle Warbler	10-Mar	19-Mar	23-Mar	27-Mar	22-Apr	32

Table 8.5.

Species-specific timing of spring trans-Gulf migration in 2000

Species are listed in order from earliest to latest migrants (based on mean date). Sample sizes indicate total numbers of individuals of each species recorded over the entire season, including both stopovers and flyby migrants. 95% confidence intervals are calculated only for sample sizes ≥ 5.

Species	First Date	95% CI Lower Bound	Mean Date	95% CI Upper Bound	Last Date	N
Swallow-tailed Kite	14-Mar	---	24-Mar	---	13-Apr	4
Tree Swallow	9-Mar	22-Mar	24-Mar	27-Mar	21-May	151
Yellow-throated Warbler	10-Mar	18-Mar	24-Mar	31-Mar	22-Apr	21
Northern Parula	15-Mar	21-Mar	25-Mar	28-Mar	22-May	69
Purple Martin	8-Mar	22-Mar	25-Mar	28-Mar	19-May	214
Black Rail	---	---	26-Mar	---	---	1
Song Sparrow	---	---	26-Mar	---	---	1
Violet-Green Swallow	---	---	26-Mar	---	---	1
Ruby-crowned Kinglet	26-Mar	---	26-Mar	---	27-Mar	2
American Robin	11-Mar	---	27-Mar	---	13-Apr	3
American Bittern	15-Mar	---	27-Mar	---	7-Apr	3
Black-and-white Warbler	9-Mar	24-Mar	28-Mar	31-Mar	25-May	174
White-eyed Vireo	14-Mar	21-Mar	28-Mar	4-Apr	29-Apr	22
Great Blue Heron	8-Mar	24-Mar	28-Mar	2-Apr	21-May	203
Clapper Rail	---	---	29-Mar	---	---	1
Marsh Wren	---	---	29-Mar	---	---	1
Great Egret	7-Mar	25-Mar	29-Mar	1-Apr	26-May	320
Little Blue Heron	7-Mar	25-Mar	29-Mar	3-Apr	22-May	317
American Golden Plover	14-Mar	15-Mar	30-Mar	13-Apr	2-May	20
Fulvous Whistling Duck	19-Mar	6-Feb	30-Mar	22-May	12-Apr	5
Savannah Sparrow	11-Mar	27-Mar	30-Mar	3-Apr	9-May	63
Western Meadowlark	29-Mar		31-Mar		2-Apr	2
American Coot	14-Mar	25-Mar	1-Apr	8-Apr	1-May	16
Eastern Phoebe	---	---	2-Apr	---	---	1
Willet	10-Mar	13-Mar	2-Apr	21-Apr	24-Apr	9
Belted Kingfisher	11-Mar	29-Mar	2-Apr	6-Apr	20-May	58
Hooded Warbler	14-Mar	31-Mar	2-Apr	5-Apr	21-May	174
Lazuli Bunting	---	---	3-Apr	---	---	1
Virginia Rail	---	---	3-Apr	---	---	1
Reddish Egret	7-Mar	27-Feb	3-Apr	9-May	2-May	5
Short-eared Owl	29-Mar	---	4-Apr	---	10-Apr	2
Northern Shoveler	15-Mar	15-Mar	4-Apr	23-Apr	22-Apr	13

Table 8.5.

Species-specific timing of spring trans-Gulf migration in 2000

Species are listed in order from earliest to latest migrants (based on mean date). Sample sizes indicate total numbers of individuals of each species recorded over the entire season, including both stopovers and flyby migrants. 95% confidence intervals are calculated only for sample sizes ≥ 5.

Species	First Date	95% CI Lower Bound	Mean Date	95% CI Upper Bound	Last Date	N
Slate-colored Junco	---	---	5-Apr	---	---	1
Sora	11-Mar	31-Mar	5-Apr	10-Apr	2-May	51
Least Bittern	16-Mar	28-Mar	6-Apr	14-Apr	3-May	11
Blue-gray Gnatcatcher	26-Mar	21-Mar	6-Apr	22-Apr	5-May	6
Yellow-bellied Sapsucker	26-Mar	24-Mar	6-Apr	19-Apr	25-Apr	6
Tricolored Heron	10-Mar	31-Mar	6-Apr	13-Apr	20-May	87
Worm-eating Warbler	15-Mar	29-Mar	7-Apr	15-Apr	17-May	17
Pectoral Sandpiper	15-Mar	15-Mar	7-Apr	30-Apr	10-May	28
Black-necked Stilt	19-Mar	7-Mar	7-Apr	8-May	28-Apr	11
Snowy Egret	8-Mar	4-Apr	8-Apr	12-Apr	24-May	131
Lesser Nighthawk	15-Mar	3-Apr	8-Apr	13-Apr	20-May	35
Blue-winged Teal	8-Mar	1-Apr	8-Apr	15-Apr	2-May	226
Prothonotary Warbler	15-Mar	4-Apr	9-Apr	14-Apr	24-Apr	26
Upland Sandpiper	14-Mar	22-Mar	9-Apr	27-Apr	21-May	18
Grasshopper Sparrow	16-Mar	5-Apr	9-Apr	13-Apr	19-May	53
Cassin's Sparrow	30-Mar	---	10-Apr	---	21-Apr	2
Northern Rough-winged Swallow	15-Mar	3-Apr	10-Apr	16-Apr	7-May	20
Yellow-breasted Chat	27-Mar	6-Apr	11-Apr	15-Apr	24-Apr	19
Osprey	15-Mar	4-Apr	11-Apr	18-Apr	28-May	35
Varied Bunting	---	---	12-Apr	---	---	1
Ash-throated Flycatcher	3-Apr	---	12-Apr	---	21-Apr	2
Lincoln's Sparrow	16-Mar	9-Apr	12-Apr	15-Apr	12-May	85
Cliff Swallow	18-Mar	7-Apr	12-Apr	17-Apr	21-May	50
Orchard Oriole	16-Mar	10-Apr	12-Apr	14-Apr	21-May	126
Western Palm Warbler	18-Mar	28-Mar	12-Apr	27-Apr	12-May	9
Common Moorhen	22-Mar	30-Mar	12-Apr	25-Apr	3-May	8
Green Heron	7-Mar	10-Apr	12-Apr	15-Apr	29-May	301
Northern Waterthrush	14-Mar	4-Apr	12-Apr	21-Apr	22-May	26
Brewster's Warbler	---	---	14-Apr	---	---	1
Carolina Wren	---	---	14-Apr	---	---	1
Blue-winged Warbler	30-Mar	10-Apr	14-Apr	18-Apr	28-Apr	18

Table 8.5.

Species-specific timing of spring trans-Gulf migration in 2000

Species are listed in order from earliest to latest migrants (based on mean date). Sample sizes indicate total numbers of individuals of each species recorded over the entire season, including both stopovers and flyby migrants. 95% confidence intervals are calculated only for sample sizes ≥ 5.

Species	First Date	95% CI Lower Bound	Mean Date	95% CI Upper Bound	Last Date	N
Lark Sparrow	2-Apr	9-Apr	14-Apr	19-Apr	24-Apr	16
American Kestrel	29-Mar	10-Apr	15-Apr	20-Apr	14-May	18
Lesser Yellowlegs	14-Mar	5-Apr	16-Apr	27-Apr	5-May	39
Black-bellied Plover	27-Mar	---	16-Apr	---	24-Apr	4
Kentucky Warbler	16-Mar	13-Apr	16-Apr	18-Apr	6-May	65
Scissor-tailed Flycatcher	29-Mar	10-Apr	16-Apr	22-Apr	21-May	29
Cattle Egret	7-Mar	15-Apr	17-Apr	19-Apr	29-May	945
Greater Yellowlegs	14-Mar	29-Mar	17-Apr	5-May	2-May	19
Wood Thrush	19-Mar	10-Apr	17-Apr	24-Apr	29-Apr	14
Aplomado Falcon	---	---	18-Apr	---	---	1
Eurasian Starling	---	---	18-Apr	---	---	1
White-throated Sparrow	---	---	18-Apr	---	---	1
Northern Mockingbird	26-Mar	7-Apr	18-Apr	28-Apr	20-May	12
Purple Gallinule	15-Mar	13-Apr	18-Apr	23-Apr	8-May	27
Chipping Sparrow	29-Mar	10-Apr	18-Apr	26-Apr	24-Apr	13
Sanderling	14-Mar	---	18-Apr	---	2-May	3
Ruby-throated Hummingbird	15-Mar	16-Apr	18-Apr	21-Apr	20-May	116
Chimney Swift	18-Mar	15-Apr	18-Apr	22-Apr	29-May	122
Nashville Warbler	27-Mar	7-Apr	18-Apr	30-Apr	2-May	10
Barn Swallow	8-Mar	17-Apr	19-Apr	21-Apr	29-May	538
Brown-headed Cowbird	11-Mar	15-Apr	19-Apr	22-Apr	17-May	100
Clay-colored Sparrow	29-Mar	14-Apr	19-Apr	23-Apr	26-Apr	26
Eastern Kingbird	15-Mar	16-Apr	19-Apr	22-Apr	20-May	88
Blue Grosbeak	9-Apr	14-Apr	19-Apr	25-Apr	3-May	11
Swainson's Warbler	2-Apr	3-Apr	20-Apr	6-May	15-May	6
Prairie Warbler	2-Apr	6-Apr	20-Apr	4-May	3-May	5
Least Sandpiper	14-Mar	8-Apr	20-Apr	2-May	22-May	19
Acadian Flycatcher	11-Apr	16-Apr	20-Apr	25-Apr	29-Apr	11
Summer Tanager	27-Mar	16-Apr	20-Apr	25-Apr	6-May	23
Audubon's Warbler	17-Apr	---	21-Apr	---	25-Apr	2
House Wren	18-Apr	---	21-Apr	---	24-Apr	2
unid. dowitcher	13-Mar	---	21-Apr	---	2-May	4

Table 8.5.

Species-specific timing of spring trans-Gulf migration in 2000

Species are listed in order from earliest to latest migrants (based on mean date). Sample sizes indicate total numbers of individuals of each species recorded over the entire season, including both stopovers and flyby migrants. 95% confidence intervals are calculated only for sample sizes ≥ 5.

Species	First Date	95% CI Lower Bound	Mean Date	95% CI Upper Bound	Last Date	N
Vesper Sparrow	3-Apr	15-Apr	21-Apr	27-Apr	24-Apr	8
Painted Bunting	12-Apr	17-Apr	21-Apr	25-Apr	29-Apr	13
Chuck-Will's-Widow	26-Mar	15-Apr	21-Apr	27-Apr	18-May	23
White-winged Dove	17-Mar	18-Apr	21-Apr	24-Apr	21-May	113
Mourning Dove	19-Mar	19-Apr	21-Apr	23-Apr	28-May	100
Merlin	3-Apr	18-Apr	21-Apr	25-Apr	4-May	19
Eastern Towhee	---	---	22-Apr	---	---	1
Inca Dove	---	---	22-Apr	---	---	1
Cerulean Warbler	14-Apr	18-Apr	22-Apr	25-Apr	2-May	11
Brown Thrasher	14-Apr	---	22-Apr	---	27-Apr	4
Indigo Bunting	26-Mar	20-Apr	22-Apr	23-Apr	21-May	173
Scarlet Tanager	9-Apr	19-Apr	23-Apr	26-Apr	2-May	29
Veery	14-Apr	15-Apr	23-Apr	1-May	2-May	5
Solitary Sandpiper	2-Apr	15-Apr	23-Apr	30-Apr	1-May	9
Warbling Vireo	18-Apr		23-Apr		30-Apr	4
Common Yellowthroat	10-Mar	21-Apr	23-Apr	25-Apr	26-May	397
Tennessee Warbler	7-Apr	22-Apr	23-Apr	25-Apr	21-May	111
Brewer's Blackbird	---	---	24-Apr	---	---	1
Loggerhead Shrike	---	---	24-Apr	---	---	1
Marbled Godwit	---	---	24-Apr	---	---	1
Northern Cardinal	---	---	24-Apr	---	---	1
Orange-crowned Warbler	---	---	24-Apr	---	---	1
Golden-winged Warbler	14-Apr	21-Apr	24-Apr	27-Apr	29-Apr	9
Whimbrel	8-Apr	16-Mar	24-Apr	3-Jun	21-May	5
Stilt Sandpiper	24-Apr	---	24-Apr	---	1-May	2
Baltimore Oriole	4-Apr	24-Apr	25-Apr	26-Apr	11-May	120
Gray Catbird	8-Apr	25-Apr	25-Apr	26-Apr	24-May	363
Black-throated Green Warbler	17-Mar	23-Apr	25-Apr	28-Apr	21-May	58
Band-tailed Pigeon	---	---	26-Apr	---	---	1
Common Grackle	---	---	26-Apr	---	---	1
Yellow-headed Blackbird	21-Apr	---	26-Apr	---	7-May	4

Table 8.5.

Species-specific timing of spring trans-Gulf migration in 2000

Species are listed in order from earliest to latest migrants (based on mean date). Sample sizes indicate total numbers of individuals of each species recorded over the entire season, including both stopovers and flyby migrants. 95% confidence intervals are calculated only for sample sizes ≥ 5.

Species	First Date	95% CI Lower Bound	Mean Date	95% CI Upper Bound	Last Date	N
Yellow Warbler	14-Apr	24-Apr	26-Apr	27-Apr	21-May	60
Bobolink	22-Apr	16-Apr	26-Apr	5-May	21-May	10
Buff-breasted Sandpiper	24-Apr	15-Apr	27-Apr	8-May	2-May	5
Cape May Warbler	21-Apr	20-Apr	27-Apr	3-May	3-May	5
Rose-breasted Grosbeak	12-Apr	23-Apr	27-Apr	1-May	10-May	26
Red-eyed Vireo	29-Mar	22-Apr	27-Apr	2-May	29-May	50
Philadelphia Vireo	14-Apr	22-Apr	28-Apr	3-May	6-May	8
Ovenbird	29-Mar	26-Apr	28-Apr	30-Apr	21-May	99
Dickcissel	20-Apr	25-Apr	28-Apr	1-May	15-May	31
Chestnut-sided Warbler	13-Apr	26-Apr	28-Apr	30-Apr	14-May	47
Great Crested Flycatcher	3-Apr	9-Apr	28-Apr	17-May	21-May	6
Yellow-billed Cuckoo	10-Apr	26-Apr	29-Apr	1-May	30-May	89
Peregrine Falcon	11-Mar	26-Apr	29-Apr	1-May	28-May	108
unid. *Catharus* thrush	13-Apr	24-Apr	29-Apr	5-May	14-May	44
Swainson's Thrush	16-Apr	21-Apr	29-Apr	8-May	6-May	8
Blackburnian Warbler	22-Apr	28-Apr	30-Apr	2-May	21-May	65
Baird's Sandpiper	---	---	1-May	---	---	1
Spotted Sandpiper	9-Apr	19-Apr	1-May	14-May	21-May	8
Bay-breasted Warbler	22-Apr	1-May	1-May	2-May	21-May	77
Magnolia Warbler	21-Apr	1-May	2-May	3-May	31-May	317
unid. *Empidonax* flycatcher	22-Apr	21-Apr	2-May	13-May	23-May	8
Rock Dove	---	---	3-May	---	---	1
Black-whiskered Vireo	---	---	4-May	---	---	1
American Pipit	8-Apr	---	4-May	---	30-May	2
Western Kingbird	25-Apr	---	4-May	---	23-May	3
American Redstart	30-Mar	1-May	4-May	7-May	24-May	112
Black-billed Cuckoo	22-Apr	23-Apr	4-May	15-May	21-May	8
Bank Swallow	28-Mar	1-May	5-May	9-May	22-May	58
Least Flycatcher	24-Apr	22-Apr	6-May	19-May	22-May	5
Blackpoll Warbler	19-Apr	3-May	6-May	9-May	31-May	57
unid. Cuckoo	13-Apr	3-May	6-May	9-May	23-May	89
Canada Warbler	24-Apr	---	7-May	---	20-May	2

Table 8.5.

Species-specific timing of spring trans-Gulf migration in 2000

Species are listed in order from earliest to latest migrants (based on mean date). Sample sizes indicate total numbers of individuals of each species recorded over the entire season, including both stopovers and flyby migrants. 95% confidence intervals are calculated only for sample sizes ≥ 5.

Species	First Date	95% CI Lower Bound	Mean Date	95% CI Upper Bound	Last Date	N
Ruddy Turnstone	1-May	---	7-May	---	14-May	3
Sharp-shinned Hawk	8-May	---	9-May	---	11-May	2
Hudsonian Godwit	---	---	10-May	---	---	1
Eastern Wood-Pewee	22-Apr	7-May	10-May	14-May	30-May	45
Common Nighthawk	3-Apr	8-May	11-May	15-May	27-May	114
Wilson's Phalarope	---	---	14-May	---	---	1
Mourning Warbler	---	---	18-May	---	---	1
Brown-crested Flycatcher	---	---	19-May	---	---	1
White-rumped Sandpiper	25-Apr	30-Apr	19-May	6-Jun	22-May	8
Alder Flycatcher	---	---	21-May	---	---	1
Couch's Kingbird	---	---	21-May	---	---	1
Western Sandpiper	---	---	21-May	---	---	1
Black-throated Blue Warbler	14-May	---	21-May	---	28-May	2
Traill's Flycatcher	21-May	---	21-May	---	22-May	3
Gray Kingbird	---	---	22-May	---	---	1

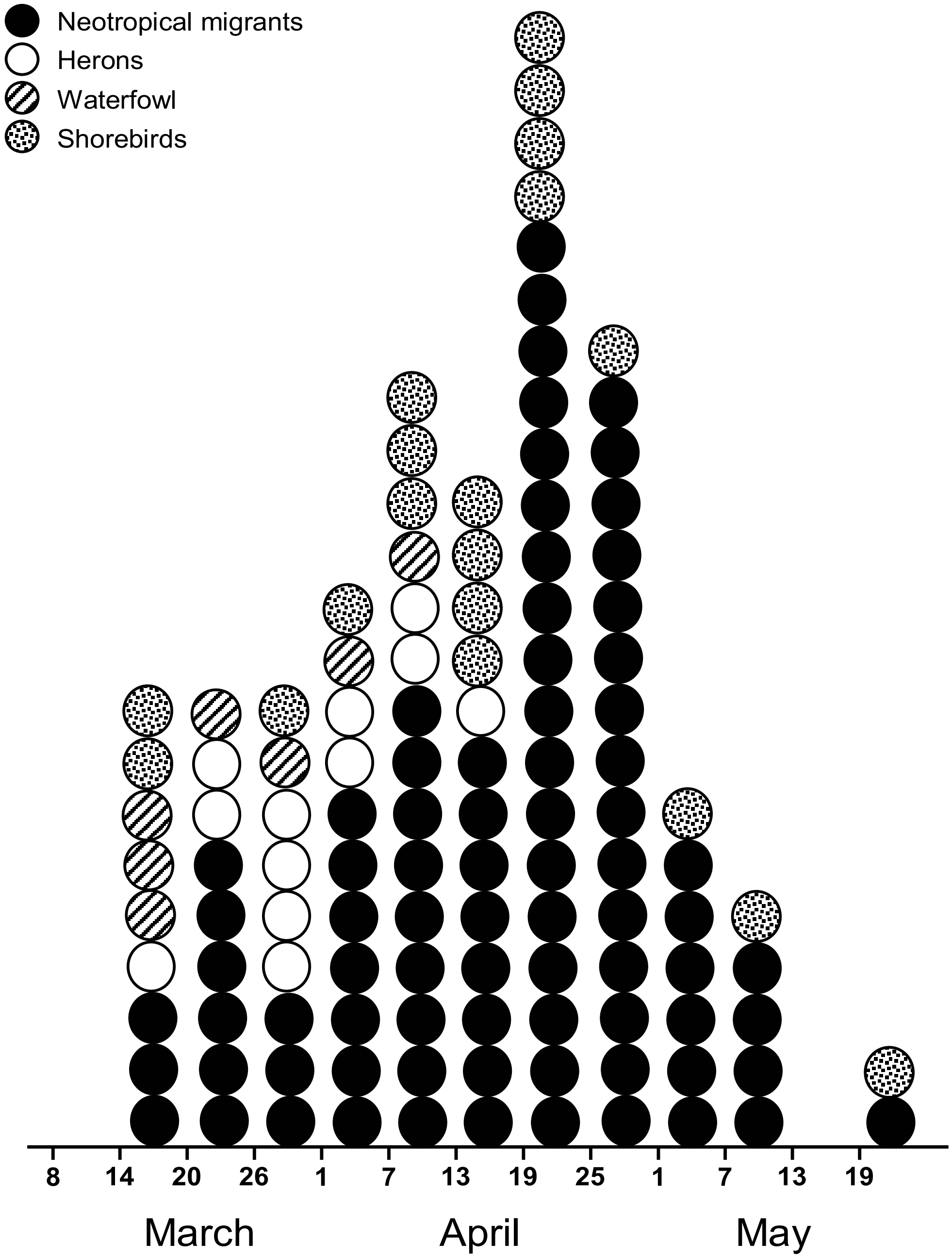

Figure 8.4. Frequency distribution of species-specific peak arrival times in spring 2000. Each symbol indicates the mean date of occurrence for one of the species listed in Table 8.5. "Neotropical migrants" includes aerial insectivores and diurnal raptors. Species represented by single observations are not included.

8.3.4 Sexual Differences in Migration Timing

In most sexually dichromatic species, males had earlier seasonal peaks than females (Table 8.6). Such differential migration has been documented widely and is generally believed to result evolutionarily from selective advantages accruing to early-arriving males that can secure the highest-quality territories. However, the mechanistic basis for differential migration (i.e., differences in onset versus rate of migration) remain poorly known (Woodrey and Chandler 1997).

Table 8.6.

Sexual differences in migration timing in spring 2000

Mean date is shown for each sex followed by the range of dates in parentheses. The difference between male and female peaks is given in the last column (positive for early males and negative for early females). Species are listed in descending order of magnitude of male-female difference.

Species	♂	♀	♂-♀ (days)
Yellow-throated Warbler	March 27 (March 10-April 14)	April 14 (na)	18
Prothonotary Warbler	April 6 (March 15-April 22)	April 21 (na)	15
Hooded Warbler	March 30 (March 14-April 26)	April 13 (March 16-May 21)	14
Blackpoll Warbler	May 2 (April 19-May 22)	14-May (April 28-May 31)	12
American Redstart	April 29 (March 30-May 21)	May 11 (April 14-May 24)	12
Ruby-throated Hummingbird	April 12 (March 15-May 3)	April 23 (March 21-May 20)	11
Blue Grosbeak	April 18 (April 9-25)	April 26 (April 14-May 3)	8
Black-and-white Warbler	March 28 (March 9-May 18)	April 5 (March 14-May 25)	8
Belted Kingfisher	March 29 (March 11-April 24)	April 6 (March 15-May 20)	8
Kentucky Warbler	April 13 (March 16-May 2)	April 20 (April 15-24)	7
Blackburnian Warbler	April 30 (April 22-May 21)	May 7 (April 24-May 21)	7
Black-throated Green Warbler	April 24 (March 17-May 5)	May 1 (April 22-May 21)	7
Common Yellowthroat	April 20 (March 10-May 26)	April 27 (March 16-May 25)	7
Summer Tanager	April 18 (March 27-May 6)	April 25 (April 24-May 2)	7
Magnolia Warbler	May 2 (April 21-May 22)	May 8 (April 25-May 31)	6
Rose-breasted Grosbeak	April 26 (April 12-May 6)	May 1 (April 24-May 10)	5
Orchard Oriole	April 10 (March 16-May 1)	April 15 (March 29-May 21)	5
Baltimore Oriole	April 25 (April 4-May 6)	April 29 (April 22-May 11)	4
Indigo Bunting	April 21 (March 26-May 2)	April 25 (April 12-May 21)	4
Yellow Warbler	April 25 (April 14-May 3)	April 29 (April 22-May 21)	4
Purple Martin	March 21 (March 8-May 6)	March 25 (March 11-May 19)	4
Chestnut-sided Warbler	April 27 (April 13-May 6)	April 30 (April 22-May 14)	3
Golden-winged Warbler	April 24 (April 14-29)	April 27 (April 25-28)	3
Scarlet Tanager	April 22 (April 9-May 2)	April 25 (April 9-May 2)	3
Brown-headed Cowbird	April 18 (March 11-May 13)	April 20 (March 12-May 17)	2
Tennessee Warbler	April 23 (April 14-May 17)	April 25 (April 13-May 13)	2
Bay-breasted Warbler	May 2 (April 22-May 13)	May 3 (April 30-May 21)	1
Cerulean Warbler	April 22 (April 14-May 2)	April 22 (April 15-25)	0
Northern Parula	March 26 (March 15-April 28)	March 23 (March 15-May 3)	-3
Blue-winged Warbler	April 14 (April 12-25)	April 7 (March 30-April 12)	-7
Myrtle Warbler	April 9 (April 8-9)	March 24 (March 10-April 17)	-16

Chapter 9

Ecology of Fall Trans-Gulf Migration

Robert W. Russell

9.1 INTRODUCTION

Cooke (1905) was the first to address meaningfully the possibility of fall trans-Gulf migration, postulating that the main route of long-distance neotropical migrants is from northwestern Florida across the Gulf. Since that time, there has been remarkably little progress in studying fall trans-Gulf migration, and knowledge on the subject has derived largely from occasional anecdotal reports from "ships of opportunity" (e.g., Paynter 1951, 1953; Siebenaler 1954) and a thesis that has remained unpublished (Buskirk 1968).

Several problems inhibit the study of fall trans-Gulf migration. A fundamental difference between spring and fall migration over the northern Gulf is proximity of origin and its consequences for diel timing. During the spring, migrants departing northward from the southern shores of the Gulf on a given night do not reach our study area until the following morning, and are therefore actively migrating through our study area during daylight hours. In contrast, during the fall, migrants departing southward from the northern shore of the Gulf are aloft over the study platforms primarily at night. This difference in timing of activity with respect to ambient light levels has implications for detectability of migrants as well as for the possible ways that platforms may attract or influence migrants.

In addition to the diel timing of migration, the abundance of migrating and dispersing insects during the fall is a significant problem hindering the quantitative study of fall trans-Gulf bird migration. Radar echoes over the Gulf in the spring can be interpreted unambiguously as birds (Chapters 7 and 8) for two main reasons. First, spring trans-Gulf migration by insects is rare and confined to just a handful of species (notably the green darner [*Anax junius*], spot-winged glider [*Pantala hymenaea*], and exposed bird-dropping moth [*Acontia aprica*]). Thus, the source population for any contribution to spring radar echoes by truly migratory insects on days favorable for northbound trans-Gulf migration is necessarily small. Second, classic spring radar patterns showing trans-Gulf arrivals (e.g., Figure 8.1) are confined to synoptic weather scenarios that are conducive to northbound trans-Gulf flight but completely prohibitive to passive advection southward over the Gulf. Although large advection events do sometimes occur in the spring (see Figure 13.4), they are strictly associated with frontal events and southward winds that are hostile to northbound migrants. On such days, both birds and drifted insects travel at low altitudes to minimize the impact of the unfavorable winds, and the low-altitude flight results in a near absence of any radar echoes of biological origin over the Gulf.

In other words, while aerial plankton is indeed common over the Gulf during the spring, it occurs only under circumstances that result in the absence of significant radar echoes of any sort over the Gulf, and therefore, questions about the source of radar echoes are moot.

Unfortunately, the above considerations do not apply similarly to the fall. During the fall, conditions favorable to both southward trans-Gulf bird migration and southward advection of aerial plankton coincide. In addition, very large numbers of dragonflies and noctuid and sphingid moths occur over the Gulf — in some cases, apparently intentionally — and these insects can have radar cross sections that approach those of migrant landbirds (Russell and Wilson 1997). Complicating the problem of evaluating the relative contributions of birds and insects to radar echoes in the fall is the fact that migrating birds and insects exhibit remarkably similar patterns of diel and seasonal flight activity (see Chapter 13).

9.2 RADAR EVIDENCE OF MIGRATION ROUTES

Understanding the relative contributions of birds and insects to radar echoes is an essential prerequisite for being able to interpret fall radar data quantitatively. Since we know of no method for objectively decomposing NEXRAD reflectivity data into bird and insect contributions, we decided not to attempt to interpret fall radar data quantitatively. Nonetheless, it is useful to review the qualitative types of radar patterns that we observed during the fall as a starting point for future efforts.

The most common pattern in the fall around the Gulf Coast is the "bull's-eye" or "exploding flower" pattern, in which reflectivity was greatest near the radar site and declined rapidly with distance from the radar site (e.g., Figure 9.1). This pattern can be characterized by a negative exponential function of the form $Z = a \bullet e^{-b \bullet d}$, where Z is reflectivity factor, d is distance from the radar site (or altitude above ground, which is proportional to distance), and b is a parameter that may be related to boundary-layer stability or other atmospheric conditions. This pattern differs dramatically from the "donut" pattern that characterizes major spring trans-Gulf bird migrations (Chapters 7, 8). This difference between spring and fall in the prevalence of the two types of radar signatures (i.e., donut vs. exploding flower) is a result of dramatic seasonal differences in the altitude of radar targets over the northern Gulf. In spring, radar profiles and direct observations from platforms and helicopters indicated that most migrants travel at altitudes from 300-1300 m on days with favorable flying conditions, and occasionally as high as 1900 m. In contrast, surveillance radar studies during September and October at Lake Charles showed that most nocturnal migrants were in the lowest altitudinal stratum (<300 m) with a rapid decline in density at higher altitudes (Able 1970).

Rapid transformations between donuts and exploding flowers at sunrise and sunset provide strong evidence that the prevalence of one or the other type of radar signature is primarily due to quantitative differences in flight altitude, rather than some other qualitative factor such as species composition. Nearly instantaneous transformations from donuts to exploding flowers occur predictably along the northern Gulf Coast in spring shortly after sunset, when migrants rapidly descend in altitude. Conversely, rapid transformations from exploding flowers to donuts can be seen predictably at sunrise in fall NEXRAD images from Brownsville and Key West, associated with a rapid ascent by overwater migrants to daytime flight altitudes.

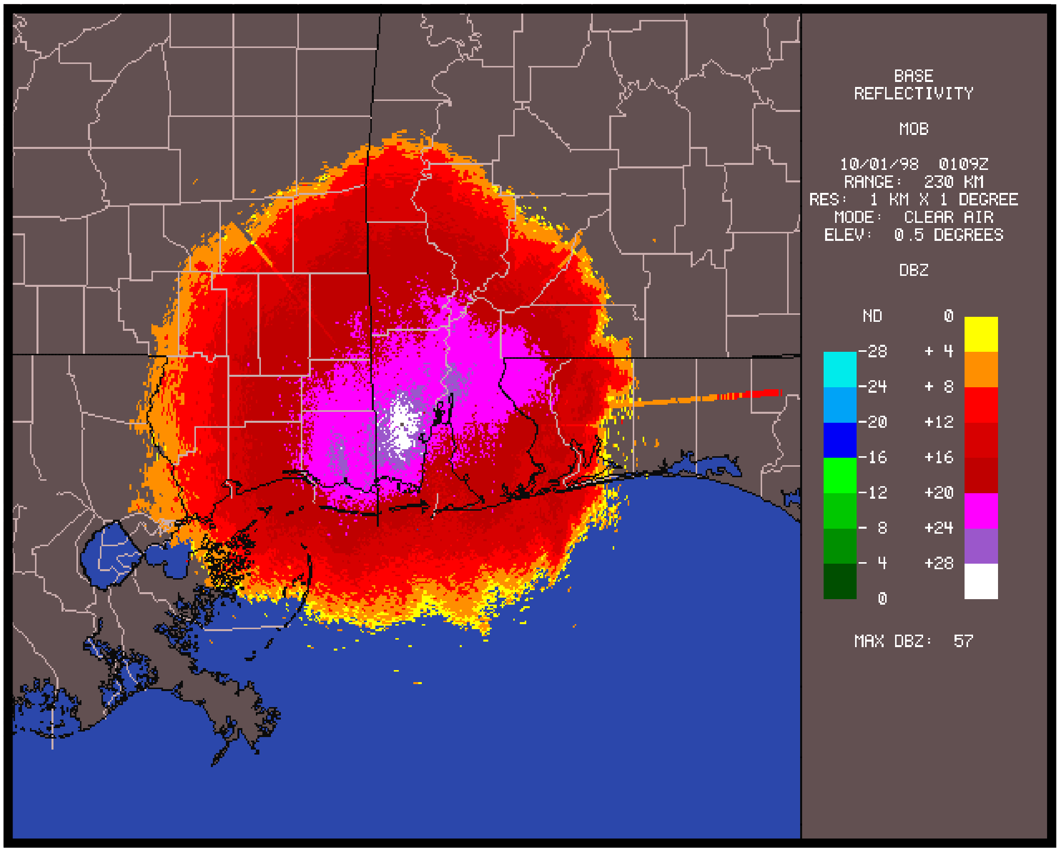

Figure 9.1. NEXRAD base reflectivity image from the Mobile site (MOB) showing a large movement of migrating birds and insects departing southward from the northeastern Gulf Coast shortly after nightfall on September 30, 1998. Synoptic weather for this flight was classified as **ELOW**. The radar scan was obtained in clear-air mode at an elevation of 0.5°. Image is courtesy of WSI Corporation.

The classic fall exploding flower begins shortly after sunset and reaches peak “bloom” within two hours (e.g., Figure 9.2). This temporal pattern corresponds closely with the known timing of departure by nocturnal bird migrants. Unfortunately (from the perspective of identifying the source of the radar echoes), the pattern also corresponds closely with the known timing of departure by nocturnal insect migrants. A number of previous studies along the northern Gulf Coast have shown that large numbers of insects — particularly noctuid moths — begin ascending into the airspace about a half hour after sunset (e.g., Beerwinkle et al. 1994).

Fall exploding flowers occurred in the study area from August through November, but seemed to be most intense (highest reflectivity) from late September through mid-October. This period corresponds roughly to the seasonal peak of passerine bird migration along the northern Gulf Coast. However, complicating matters of radar image interpretation is the fact that many migratory insects have fall activity patterns that are remarkably similar to those of migrating birds (reviewed by Russell et al. 1998). For example, studies in the Brazos River Valley of coastal Texas found fall peaks in the migration of corn earworm moths (*Heliothis zea*) around October 5 in one year and September 25 in another year (Beerwinkle et al. 1995).

Classic post-sunset exploding flowers (e.g., Figures 9.1, 9.2) were common during the fall along the northern Gulf Coast from Houston (HGX) to Tallahassee (TLH). At Corpus Christi (CRP), the pattern was characteristically truncated at the coast, with a wave of offshore radar echoes sweeping southward or southwestward as the night progressed (Figure 9.3)

At the Brownsville NEXRAD site (BRO), exploding flowers were rare and confined to November. Classic-looking post-sunset exploding flowers at Brownsville (e.g., Figure 9.4) were strictly associated with major insect dispersal events that brought large numbers of moths and butterflies to PN975. On other occasions, the principal radar signature was a "semi-donut" indicating an arrival of targets at high altitudes from the northeast during morning daylight hours (Figure 9.5). Similar to the spring, fallouts were occasionally evident along the lower Texas coast or on the coast of Tamaulipas (Figure 9.6).

Migrants that had departed from the northeastern Gulf Coast the previous evening were often visible heading south offshore from the west coast of the Florida Peninsula in morning NEXRAD images from the Tampa Bay (TBW) site, and this migration stream could often be seen in Key West (BYX) imagery making landfall in Cuba in late morning or early afternoon (Figure 9.7).

9.3 DIRECT OBSERVATIONS OF THE FLIGHT DIRECTIONS OF MIGRANTS

Direct studies of flight orientation were difficult during the fall since most migrants were aloft over the platforms during hours of darkness.

Platform lighting and other circumstances at VK786 permitted a series of visual studies from the helipad. The results of these studies are summarized in Table 9.1. Mean vanishing bearing varied from 136°-197° (SE-SSW). At the observed western extreme, migrants flying directly toward 197° would arrive in the eastern Bay of Campeche, with landfall near the Tabasco/Campeche border. At the observed eastern extreme, migrants flying directly toward 136° would make landfall in Cuba just west of Havana. Assuming the birds in these studies maintained their flight directions with no lateral drift, mean landfall would have been along the eastern Bay of Campeche in two cases, on the Yucatan in four cases, on the northern shore of Honduras in one case, and in western Cuba in two cases.

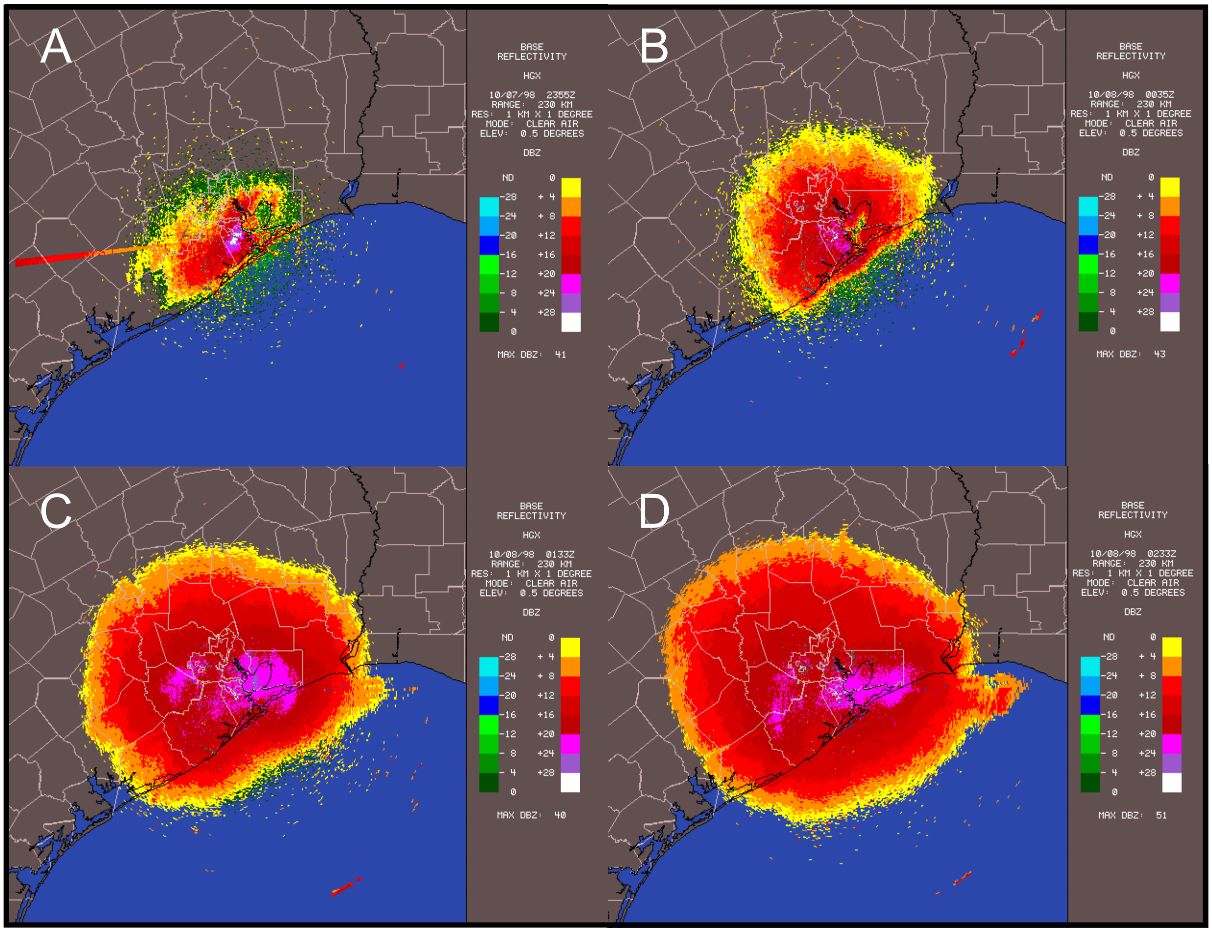

Figure 9.2. Time series of NEXRAD base reflectivity images from the Houston site (HGX) showing a large movement of migrating birds and insects departing the Upper Texas Coast after nightfall on October 7, 1998. Synoptic weather for this flight was classified as **ELOW**. A. Sunset. B. Sunset + 0.5 h. C. Sunset + 1.5 h. D. Sunset + 2.5 h. Radar scans were obtained in clear-air mode at an elevation of 0.5°. Images are courtesy of WSI Corporation.

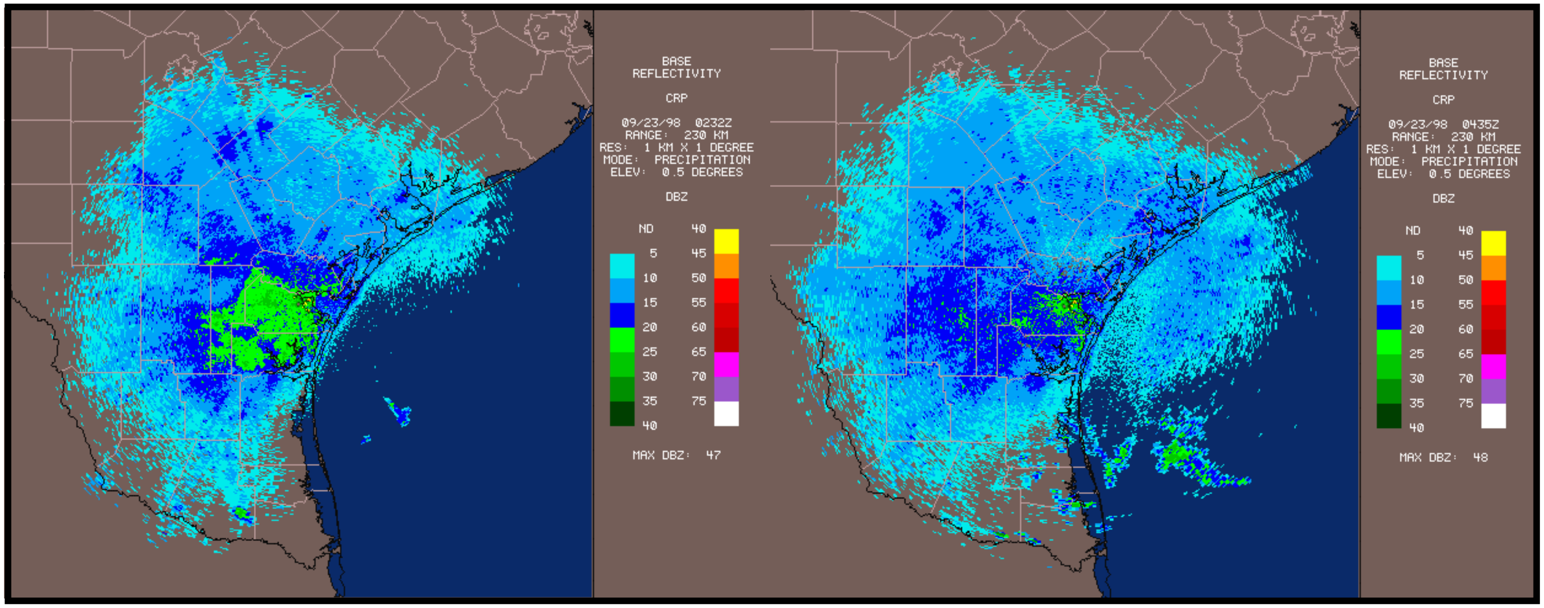

Figure 9.3. NEXRAD base reflectivity images from the Corpus Christi site (CRP) showing a large movement of presumed migrating birds traveling southwestward off the central Texas coast on the night of September 23-24, 1998. Synoptic weather for this flight was classified as **MCH**. Left: 02:32 Z (21:32 CDT). Right: 04:35 Z (23:35 CDT). Radar scans were obtained in precipitation mode at an elevation of 0.5°. Images are courtesy of WSI Corporation.

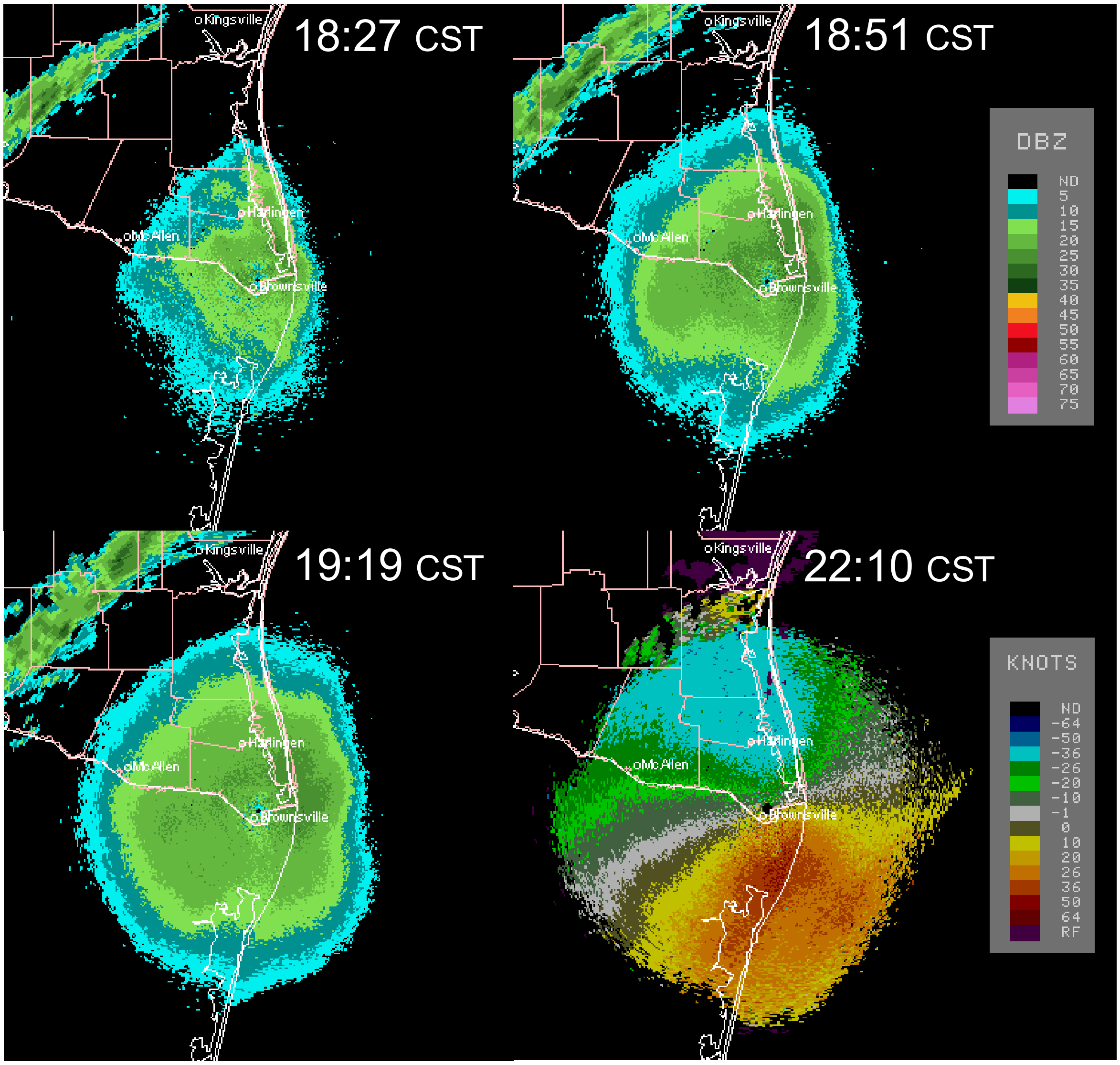

Figure 9.4. Time series of NEXRAD images showing the development of an "exploding flower" at Brownsville (BRO) after nightfall on November 8, 2000. Synoptic weather for this event was classified as **GF**/**ELOW**. Radar scans were obtained in precipitation mode at an elevation of 0.5°. Images are courtesy of TAP Publishing Company.

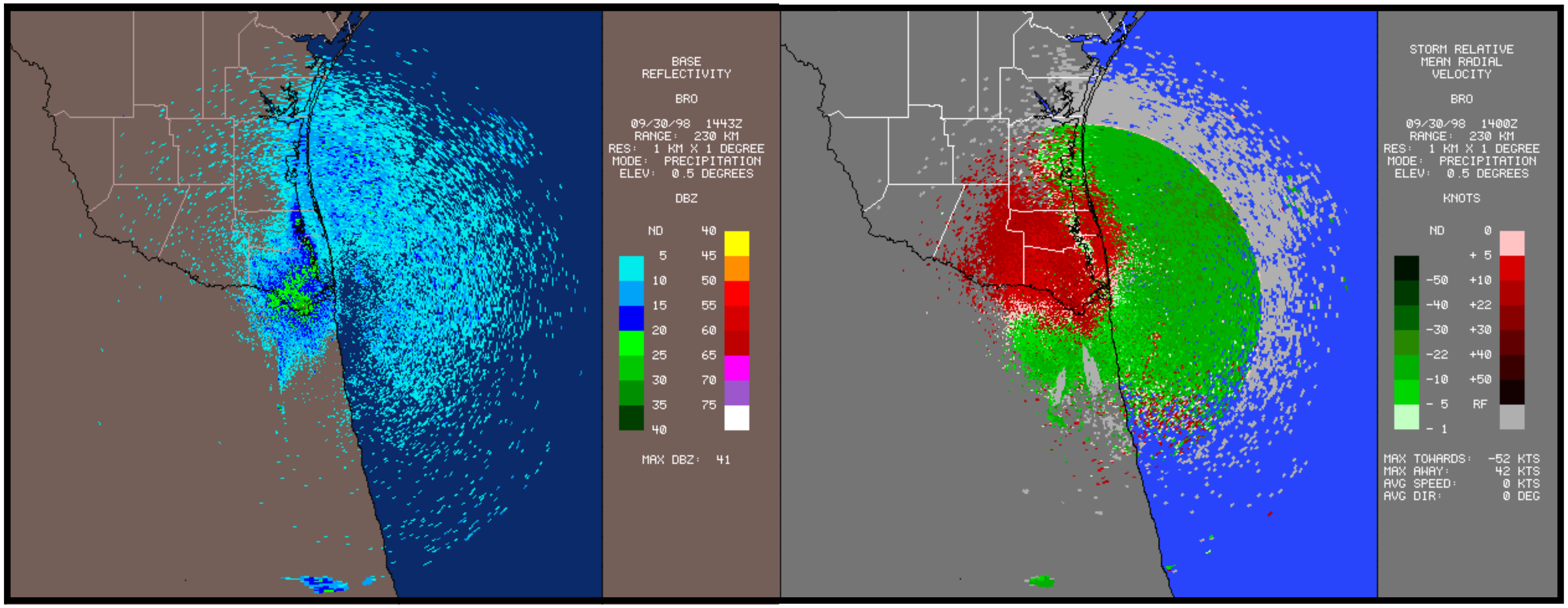

Figure 9.5. NEXRAD images from the Brownsville site (BRO) showing a large movement of migrating birds arriving on the lower Texas coast on the morning of September 30, 1998. Synoptic weather for this flight was classified as **TLOW**, though a high pressure system developed over the western Gulf overnight, resulting in ambient winds from the south in the radar coverage area at the time of the images. Left: Reflectivity image showing the arriving migrants just offshore. Right: Corresponding velocity image showing direction of movement. Red indicates movement away from the radar site and green indicates movement toward the radar. Note that the more intense echoes offshore were moving against the wind, generally toward the southwest. The sparse echoes over land were moving northward with the wind and probably were attributable to dispersing moths. Radar scans were obtained in precipitation mode at an elevation of 0.5°. Images are courtesy of WSI Corporation.

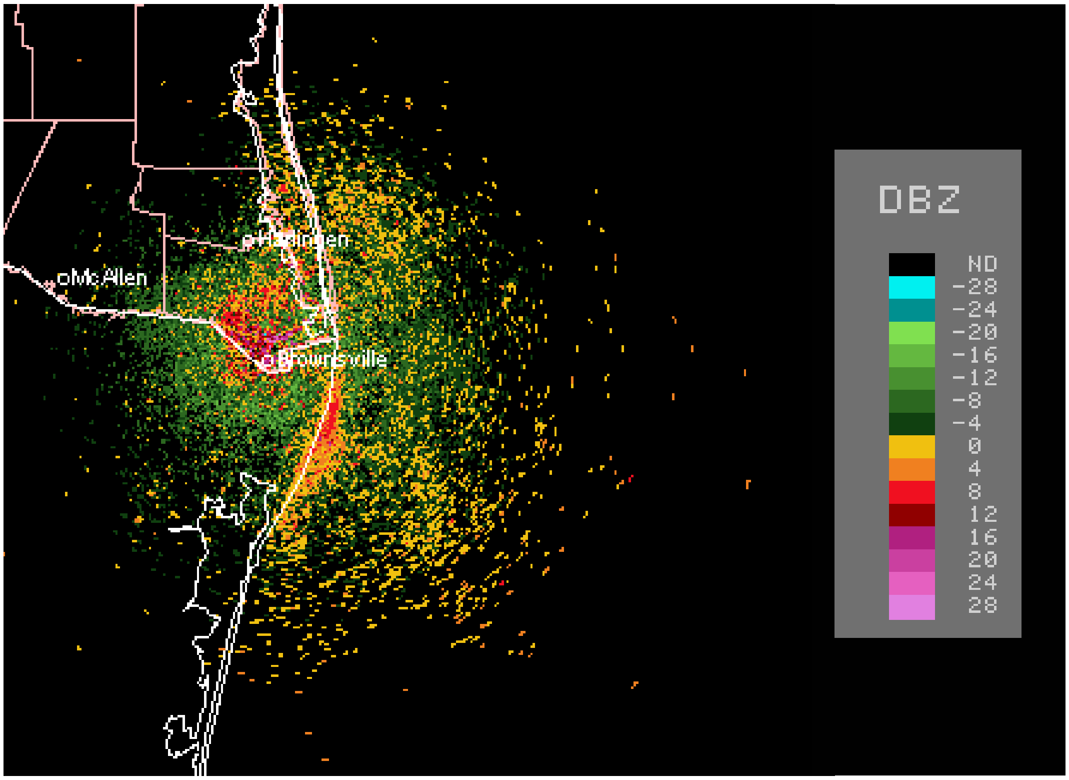

Figure 9.6. NEXRAD base reflectivity image from the Brownsville site (BRO) showing a fallout of migrants along the Tamaulipas coast on the morning of November 9, 2000 (14:22 Z). Synoptic weather for this event was classified as **GF/ELOW**. The radar scan was obtained in clear-air mode at an elevation of 0.5°. Image is courtesy of TAP Publishing Company.

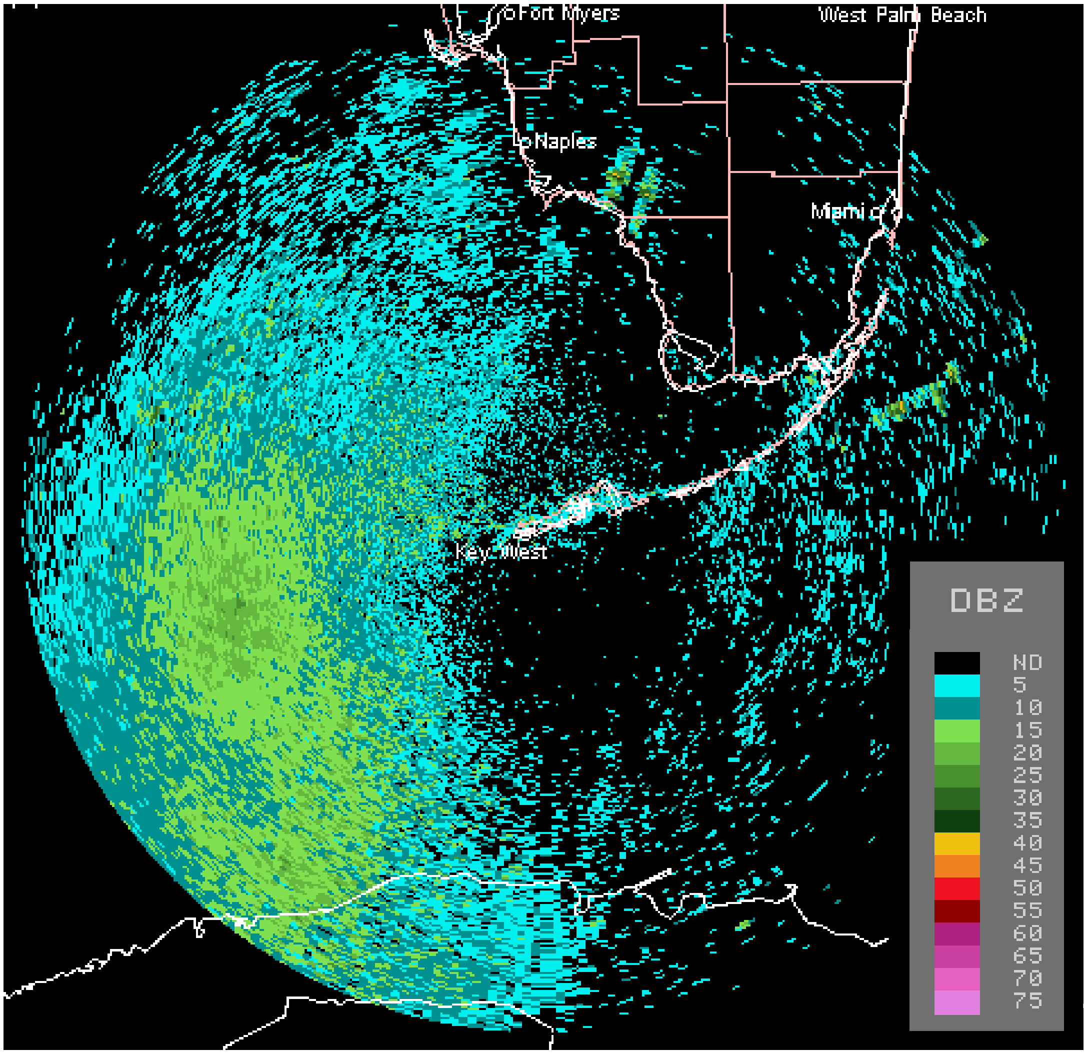

Figure 9.7. NEXRAD base reflectivity image from the Key West site (BYX) showing a large flight of migrants approaching Cuba from the NNW on the morning of October 8, 2000 (15:29 Z). Synoptic weather for this event was classified as **MCH**. The radar scan was obtained in precipitation mode at an elevation of 0.5°. Image is courtesy of TAP Publishing Company.

Table 9.1.

Summary of case studies of nocturnal flight direction at VK786 in fall 1999

		Aug 20-21	Aug 21-22	Sep 5-6	Sep 10-11 (early)	Sep 10-11 (late)	Sep 11-12	Sep 12-13	Sep 13-14	Sep 14-15
Wind Direction:		W	SW	WSW	N	NE	E	E	NNE/NE	N/NNE
Wind Speed (m/s):		4	2	7	4	7	7	7	10	13
Sky Condition:		Clear	P. cloudy	P. cloudy	Clear	Clear	Clear	Clear	Clear	Clear
Synoptic Weather Type:		GH	GH	GH	MCH	MCH	ECH	ECH	MCH	MCH
Number of vanishing bearings	NNE	0	0	1	0	0	0	0	0	0
	NE	0	0	0	0	0	0	0	0	0
	ENE	0	0	0	0	0	0	0	0	0
	E	0	0	0	0	0	0	0	0	0
	ESE	1	0	4	0	0	0	0	0	0
	SE	5	1	14	5	2	1	0	0	0
	SSE	2	4	6	14	2	0	1	2	2
	S	3	2	1	14	27	7	3	14	14
	SSW	1	0	0	2	11	10	4	12	4
	SW	0	0	0	2	2	4	2	1	0
	WSW	0	0	0	0	0	0	0	0	0
	W	0	0	0	0	0	0	0	0	0
	WNW	0	0	0	0	0	0	0	0	0
	NW	0	0	0	0	0	0	0	0	0
	NNW	0	0	0	0	0	0	0	0	0
	N	0	0	0	0	0	0	0	0	0
Mean Vector:		153°	161°	136°	169°	185°	197°	196°	189°	182°
N:		12	7	26	37	42	22	10	29	20
Length of Mean Vector (r):		0.90	0.97	0.91	0.93	0.95	0.94	0.94	0.97	0.98
Rayleigh P:		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

The regression equation relating mean vanishing bearing to the direction toward which the wind was blowing was VB = 135° + 0.23·wind ($r^2 = 0.84$, $P = 0.0005$). Setting VB = wind and solving the equation yields a wind direction for which migrants fly strictly downwind and do not compensate. This direction of no compensation is 175°, suggesting that the preferred flight direction of fall migrants over VK786 is slightly east of due south. Direct linear flight from VK786 toward 175° would take migrants to the eastern portion of the northern shore of the Yucatan Peninsula.

Variation in mean nightly flight directions in relation to the lateral wind component is depicted in Figure 9.8. The relationship was strong and clear, and fortuitous circumstances provided evidence that individual flight behavior was responsible for the pattern, as opposed to pseudodrift. On the night of September 10-11, there was a distinct shift in wind direction from N to NE after an adequate sample of vanishing bearings had already been obtained for analysis, and a second study was undertaken for comparison. Along with the shift in wind from N to NE, mean flight direction shifted from 169° to 185° (Table 9.1). This change between observation periods was highly significant (Watson-Williams test: $F_{1,77} = 12.8$, $P = 0.0006$). Because it is most unlikely that an entirely new assemblage of migrants materialized in the airspace over the course of several hours, it can be concluded that the flight behavior of individual migrants was being influenced over a short time period by the changing wind.

Over the course of the study we made numerous efforts to study nocturnal flight orientation using the “moonwatching” method. This technique involves watching for migrants passing in front of the face of the moon, recording their entry and exit points, and using spherical geometry along with data on the moon’s path to compute the migrants’ trajectories (Nisbet 1959). Most of our efforts were foiled by clouds or lack of adequate samples of bird targets due to synoptic weather circumstances. One successful and informative case study was undertaken at MI622 on the night of September 12-13, 2000 (Figure 9.9). Synoptic weather for this flight was classified as **ECH**. This study yielded a sample of 39 tracks with a mean angle of 209° (95% CI = 198°-220°, $r = 0.83$, Rayleigh $P < 0.0001$). Virtually all tracks were west of due S. Although based on just a single night, results from this study were consistent with our general impression based on many anecdotal observations and other lines of evidence that nocturnal movements in the far western Gulf in fall are usually toward the SW or SSW.

9.4 “OVERSHOOTING” OF THE GULF OF MEXICO BY NON-TRANS-GULF MIGRANTS

One of the interesting features of the fall migration offshore was the frequent occurrence of a variety of species that do not typically winter south of the northern Gulf Coast. These species were evidently mostly “overshoots” that inadvertently traveled past their intended destinations and found themselves unexpectedly over water at first light, or else circum-Gulf migrants that inadvertently drifted eastward over the Gulf during nocturnal flight. Accordingly, these species were often observed flying north or west during daylight hours, presumably trying to get back to land.

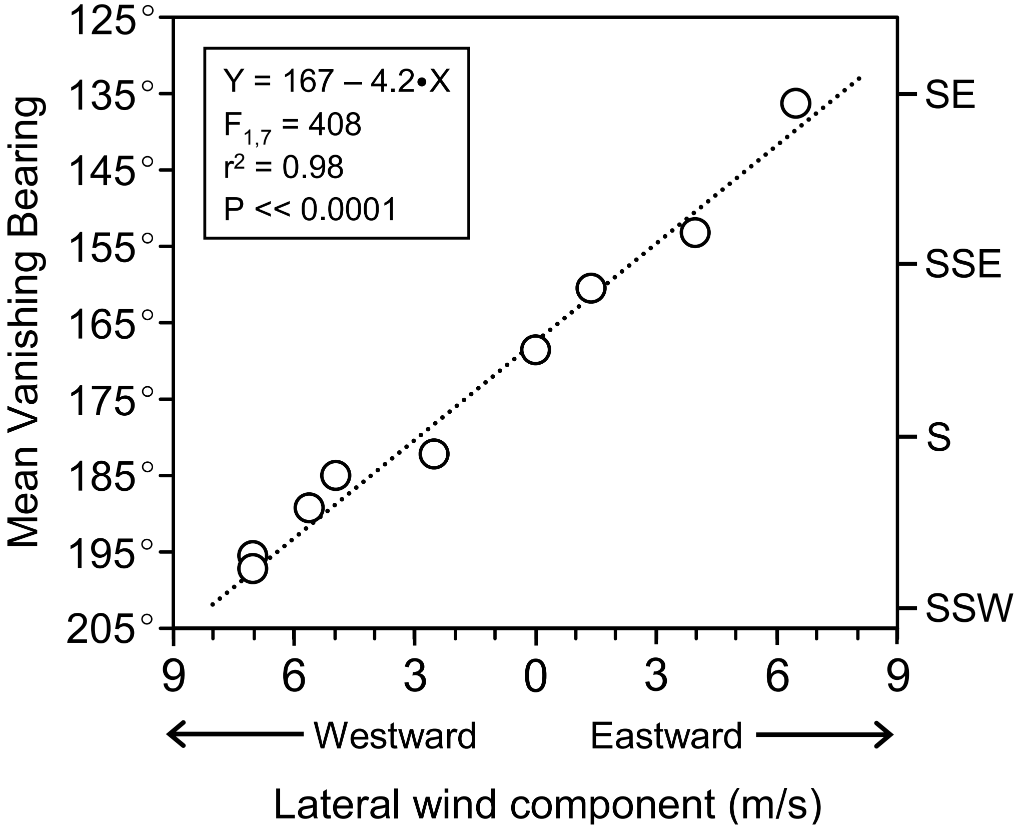

Figure 9.8. Relationship between lateral wind strength and the orientation of nocturnal migration at VK786 during fall 1999. Each point in the figure represents results from one night's study (Table 9.1).

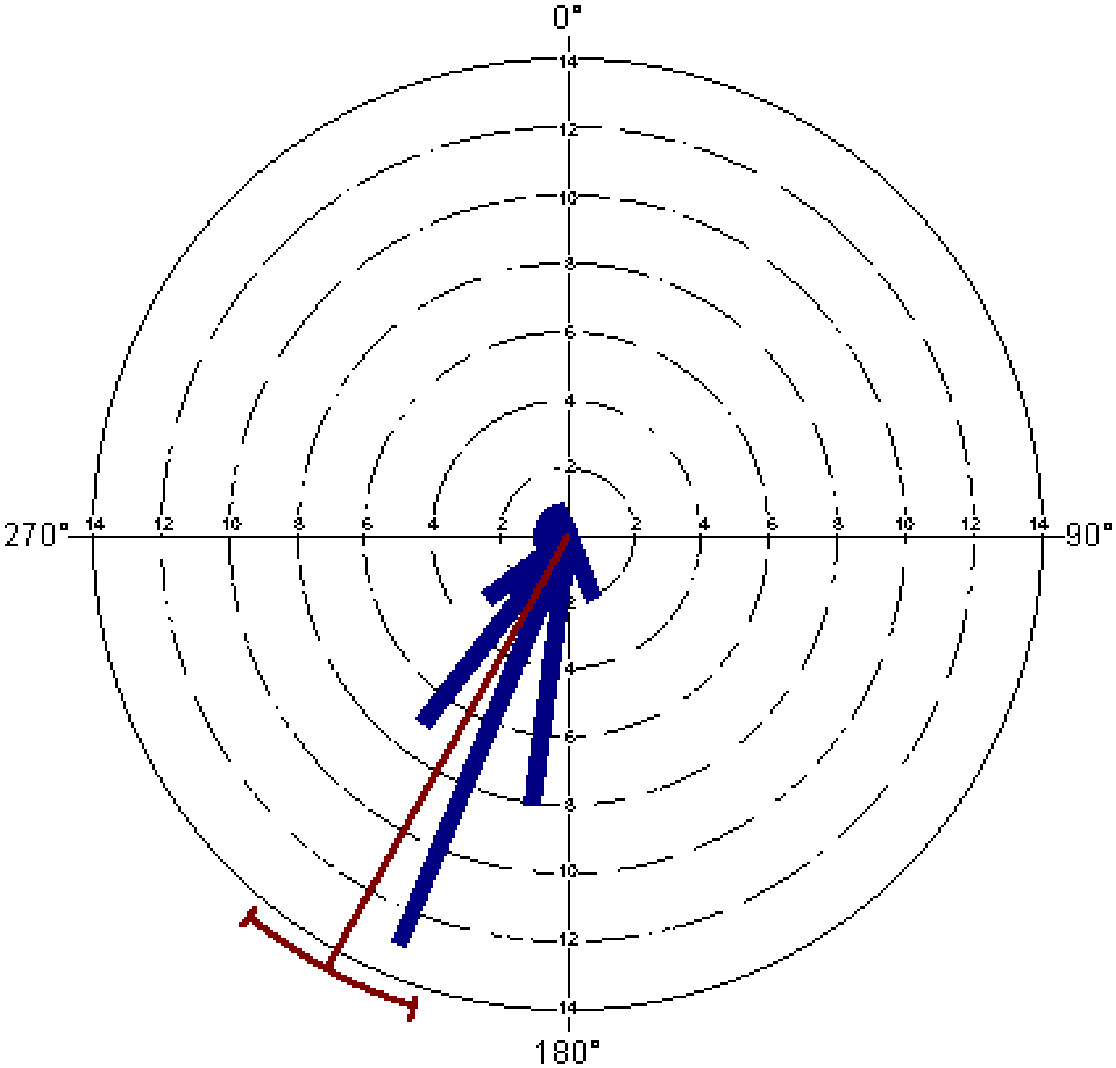

Figure 9.9. Frequency distribution of flight tracks from “moonwatching” at MI622 on the night of September 12-13, 2000. The radial line and arc indicate the circular mean and 95% confidence interval, respectively.

All species displaying behavior suggestive of overshooting were either medium-distance migrants (Table 6.6) or short-distance migrants (Table 6.7). Mean vanishing bearings for all medium- and short-distance migrants observed in flight during the fall are shown in Table 9.2. Among the species listed in Table 9.2, only three were also commonly observed during the spring migration ($N \geq 50$ individuals; Table 7.7), and therefore believed to be "intentional" trans-Gulf migrants. These three species (Lincoln's Sparrow, Grasshopper Sparrow, Brown-headed Cowbird) were classified as medium-distance migrants, and had vanishing bearings of ~SSW to S that were not unexpected for fall trans-Gulf migrants.

Among the presumed overshoot species, three species had adequate samples of vanishing bearings for separate analyses (Figure 9.10). These species showed significant orientation toward the WSW (House Wren), W (Marsh Wren), and NW (Ruby-crowned Kinglet). Intraspecifically, all three species showed some indication of bimodality in flight direction, with one group headed NW to NE and another group headed primarily W to WSW. Among these three, the short-distance migrant (Ruby-crowned Kinglet) was more likely to be seen heading in a northerly (as opposed to westerly) direction than the two medium-distance migrants (Marsh Wren and House Wren).

A comparison of vanishing bearings of all medium- versus short-distance migrant species is shown in Figure 9.11. Short-distance migrant species had a mean vanishing bearing that was more to the north ($\bar{x}$ = 303°, $r = 0.79$, Rayleigh $P = 0.004$) than medium-distance migrant species ($\bar{x}$ = 263°, $r = 0.71$, Rayleigh $P < 0.0001$). The difference between the two groups was statistically significant (Watson-Williams test: $F_{1,27} = 4.29$, $P = 0.048$).

In summary, among the medium- and short-distance migrant species, only Lincoln's Sparrow, Grasshopper Sparrow, and Brown-headed Cowbird showed indications of being intentional trans-Gulf migrants. All other species are presumed to have been over the Gulf inadvertently. Vanishing bearings of overshoots tended to cluster in the W-WSW and NW-NE sectors, with medium-distance migrants tending toward the former and short-distance migrants tending toward the latter.

The distinction between the westbound and northbound migrants could result either from facultative individual decisions or from inter-individual differences. In the case of facultative individual decisions, an overshoot migrant may "decide" whether to attempt to head back to the northern Gulf Coast based upon its body condition and remaining fat stores in relation to its assessment of the energy requirements needed to complete the corrective flight. Migrants lacking adequate energy stores for such corrective action may simply travel downwind (usually toward the WSW or SW in the fall) to maximize the amount of time before they deplete their energy stores. Alternatively, westbound birds may be individuals with intended winter destinations along the western (as opposed to northern) Gulf Coast. The fact that medium-distance migrants (which have more southerly wintering distributions) were more likely to be westbound than were short-distance migrants is consistent with the hypothesis of inter-individual variation. However, some short-distance migrants were observed traveling in directions that, if maintained until landfall, would have taken them to points well south of their species' normal wintering range (e.g., Figure 9.10), in support of the hypothesis of condition-dependence.

Table 9.2.

Mean vanishing bearings of medium-distance migrants (MDM) and short-distance migrants (SDM)

The value for each species represents the mean from fall 1998 and fall 1999 combined.

Species	MDM/SDM	$\bar{x}$	N
Brown Thrasher	SDM	348°	4
Pine Siskin	MDM	338°	2
Long-eared Owl	SDM	338°	1
Eastern Phoebe	MDM	326°	4
Ruby-crowned Kinglet	SDM	326°	14
Lark Sparrow	MDM	315°	1
Brewer's Blackbird	MDM	315°	1
White-throated Sparrow	SDM	315°	1
Common Grackle	SDM	315°	1
American Pipit	MDM	312°	3
Northern Mockingbird	MDM	304°	2
Vesper Sparrow	MDM	300°	3
Marsh Wren	MDM	280°	10
Yellow-shafted Flicker	MDM	275°	4
White-crowned Sparrow	MDM	270°	1
Golden-crowned Kinglet	SDM	270°	2
Eastern Towhee	SDM	270°	1
Clay-colored Sparrow	MDM	267°	3
House Wren	MDM	256°	13
Western Meadowlark	MDM	248°	4
Hermit Thrush	MDM	248°	3
Swamp Sparrow	MDM	225°	1
Sedge Wren	MDM	225°	1
Loggerhead Shrike	MDM	225°	1
Song Sparrow	SDM	225°	1
Brown-headed Cowbird	MDM	214°	2
Grasshopper Sparrow	MDM	202°	1
Orange-crowned Warbler	MDM	191°	2
Lincoln's Sparrow	MDM	180°	2

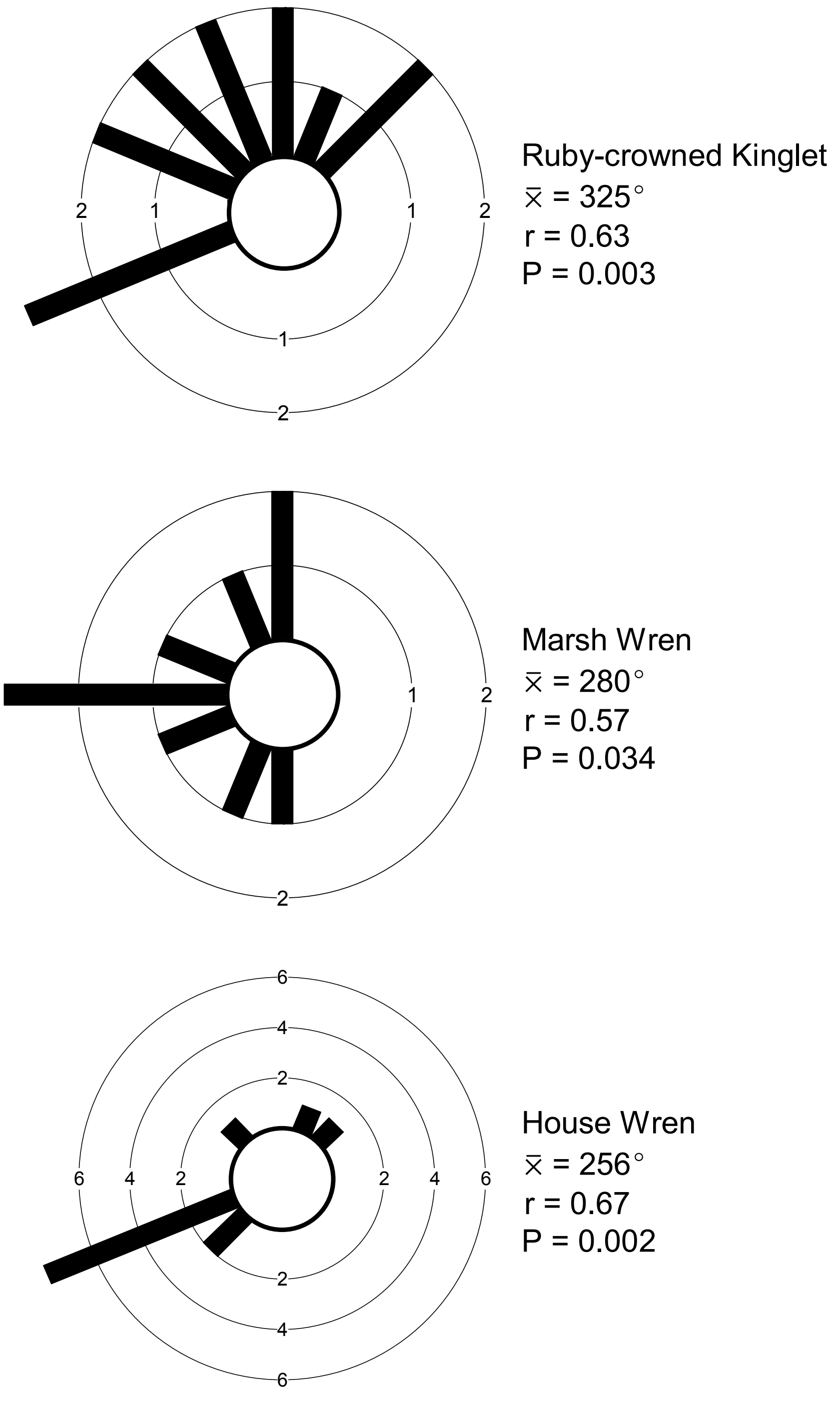

Figure 9.10. Distributions of vanishing bearings of Ruby-crowned Kinglets, Marsh Wrens, and House Wrens. Data are from fall 1998 and fall 1999 combined.

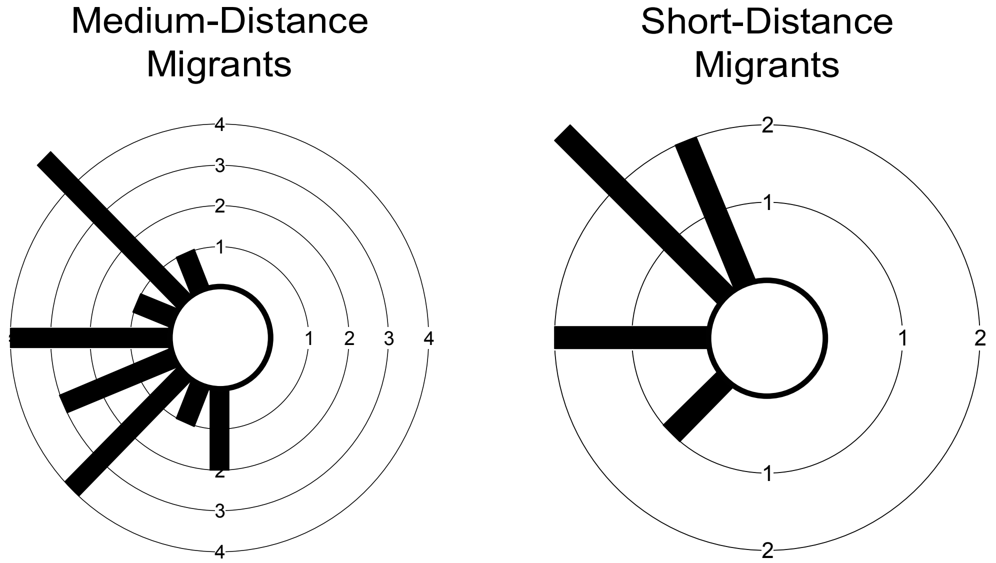

Figure 9.11. Comparison of vanishing bearings of medium-distance migrants and short-distance migrants. Each data point represents the mean for one species. Data are from fall 1998 and fall 1999 combined.

9.5 EFFECTS OF SYNOPTIC WEATHER ON PATTERNS OF ABUNDANCE ON PLATFORMS

Patterns of abundance across the platforms were compared among weather types in fall 1999. Long-distance migrants were most abundant on the easternmost platform studied (VK786) on **ECH**, **GH**, and **TLOW** days, which prevailed during the early part of the migration in August and September (Figure 9.12). A significant western component to the migration became evident during the latter half of the migration in October and November, when **MCH** and **ELOW** days prevailed, and migrants then showed a bimodal pattern of highest abundance in the far east and far west. Long-distance migrants were very scarce on **BH** days.

Medium- and short-distance migrants, which tended to have migration peaks later in the season, exhibited the bimodal geographic pattern on **MCH** and **ELOW** days, with peak abundance on the far eastern and far western platforms (Figures 9.13, 9.14). Medium-distance migrants and short-distance migrants were generally scarce under other weather conditions.

9.6 INTERSPECIFIC VARIATION IN MIGRATION ROUTES

There were dramatic differences among species in patterns of abundance across the Gulf (Table 9.3), implicating species-specific migration routes.

The frequency distribution of mean species-specific longitudinal positions is shown in Figure 9.15. It should be noted that peak abundance of many long-distance migrants occurred at VK786 (Table 9.3), implying that the true center of abundance for these species lies in the eastern Gulf where we were unable to sample due to absence of platforms (Figure 2.1). Thus, the “mean species-specific longitudinal positions” indicated in Figure 9.15 are severely biased toward the west for many species, and should only be interpreted relative to other species. Medium-distance migrants had more western peaks of abundance than both long- and short-distance migrants, consistent with the idea that some of these species may intentionally cross the western Gulf of Mexico (Chapter 9.4).

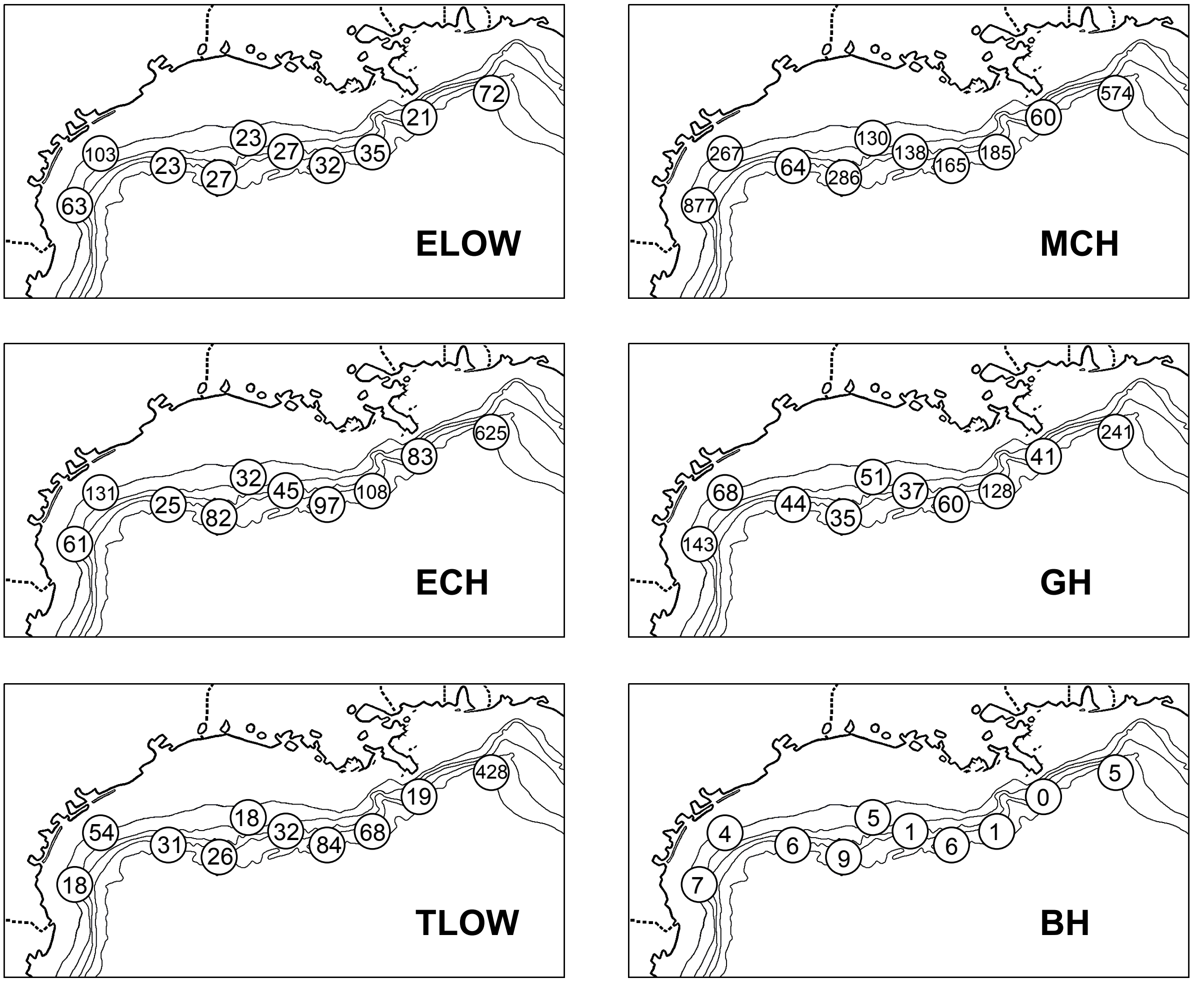

Figure 9.12. Patterns of abundance of long-distance migrant landbirds (aerial insectivores and neotropical migrants) on platforms in fall 1999 in relation to synoptic weather type. Numbers shown for a given weather type indicate total numbers of individuals initiating stopovers on each platform across all days characterized by that weather type.

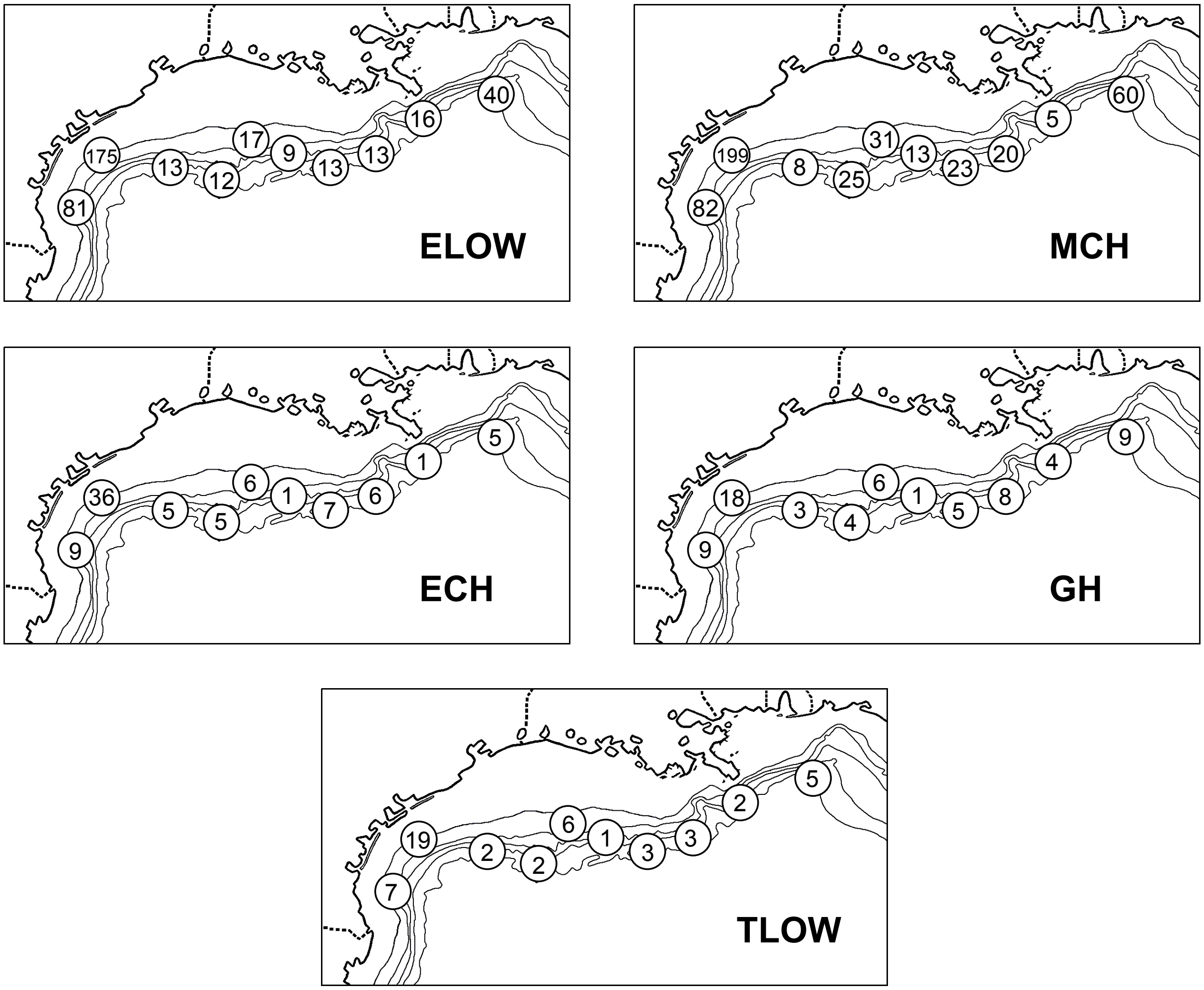

Figure 9.13. Patterns of abundance of medium-distance migrants on platforms in fall 1999 in relation to synoptic weather type. Numbers shown for a given weather type indicate total numbers of individuals initiating stopovers on each platform across all days characterized by that weather type.

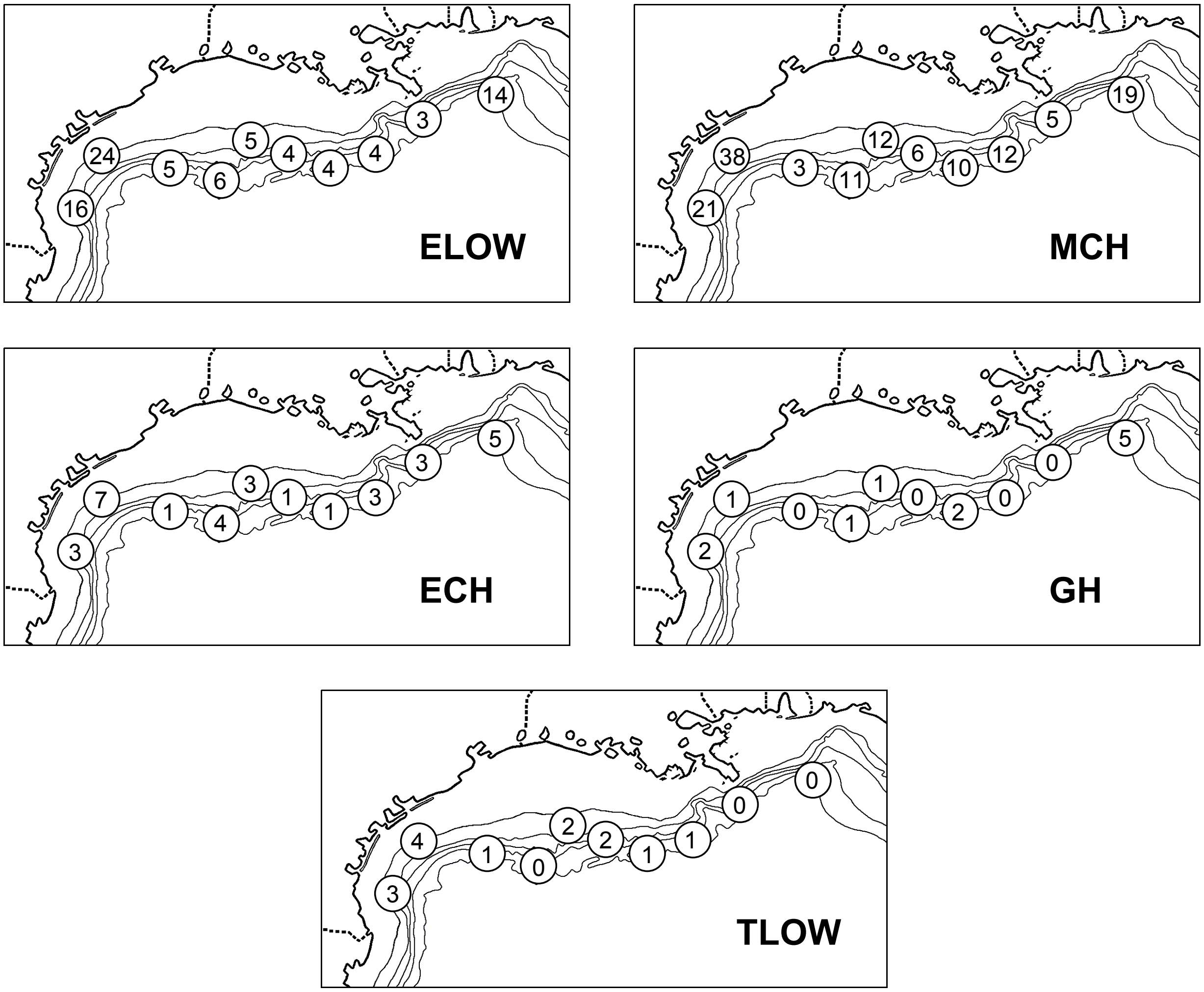

Figure 9.14. Patterns of abundance of short-distance migrants on platforms in fall 1999 in relation to synoptic weather type. Numbers shown for a given weather type indicate total numbers of individuals initiating stopovers on each platform across all days characterized by that weather type.

Table 9.3.

Comparative longitudinal distributions of fall trans-Gulf migrants

Numbers shown indicate numbers of individuals undertaking stopovers on each platform during fall 1999. Species are listed in order from most westerly distribution at top to most easterly distribution at bottom. Species with <5 stopovers are not included.

Species	PN975	MI622	HI561	GB189	VE265	SM147	GC18	EW826	SP89	VK786	Total
Western Meadowlark	23	31	0	0	0	0	0	0	0	0	54
Clapper Rail	2	4	0	0	0	0	0	0	0	0	6
Pyrrhuloxia	2	4	0	0	0	0	0	0	0	0	6
Scissor-tailed Flycatcher	24	16	0	3	0	0	0	0	0	0	43
Lincoln's Sparrow	53	138	4	2	4	0	0	2	3	4	210
Common Ground-Dove	14	9	0	2	1	0	0	0	0	1	27
Pied-billed Grebe	6	0	0	1	0	0	1	0	0	0	8
Yellow-shafted Flicker	0	4	0	0	0	1	0	0	0	0	5
Sora	30	0	1	2	0	0	0	0	0	5	38
Grasshopper Sparrow	16	48	1	1	1	3	3	3	2	2	80
Osprey	4	2	1	0	0	0	0	0	0	1	8
Wilson's Warbler	12	12	3	1	4	1	2	1	0	0	36
Burrowing Owl	2	2	0	1	0	0	1	0	0	0	6
Yellow-headed Blackbird	0	4	0	1	0	1	0	0	0	0	6
Barn Owl	2	2	0	0	0	0	0	0	0	1	5
House Wren	37	99	5	13	13	4	12	8	2	11	204
Traill's Flycatcher	0	22	2	0	0	1	2	0	2	2	31
Chipping Sparrow	6	21	1	1	2	0	1	4	1	2	39
Chuck-Will's-Widow	18	12	6	9	2	0	8	1	1	0	57
Great Blue Heron	9	0	0	0	1	0	3	0	0	1	14
Sedge Wren	1	10	0	1	1	2	0	1	0	1	17
Nashville Warbler	23	10	0	2	1	1	2	2	0	7	48
Indigo Bunting	205	15	5	14	0	4	9	6	1	63	322
Loggerhead Shrike	2	2	0	1	1	0	0	0	1	0	7
Mourning Warbler	6	9	2	3	0	0	2	0	0	3	25
Ruby-throated Hummingbird	22	32	8	5	6	5	5	0	1	9	93
Brown-headed Cowbird	6	8	0	1	5	0	1	1	1	1	24
Black-throated Green Warbler	216	6	8	42	1	17	8	14	7	51	370
Lark Sparrow	4	7	0	1	0	0	0	4	0	1	17
White-winged Dove	40	86	9	26	7	7	17	13	6	12	223
Blue-headed Vireo	0	2	0	2	1	0	0	0	0	0	5
Northern Mockingbird	9	11	2	1	4	0	2	0	1	4	34
Eastern Meadowlark	3	8	2	2	4	1	0	0	0	2	22
Yellow-bellied Flycatcher	2	2	1	0	0	0	1	0	0	1	7
Ruby-crowned Kinglet	28	37	6	9	5	3	6	6	2	14	116
Virginia Rail	1	4	1	0	0	0	0	0	0	2	8
Cliff Swallow	17	1	3	12	0	0	10	1	0	2	46
Savannah Sparrow	20	32	4	7	4	3	7	8	4	13	102
Orange-crowned Warbler	13	15	3	4	6	3	2	5	3	6	60
Dickcissel	13	21	6	7	2	2	4	4	6	8	73
Common Yellowthroat	165	69	6	36	34	13	20	25	12	82	462
Clay-colored Sparrow	4	15	6	4	8	1	4	2	1	6	51
Canada Warbler	6	2	2	1	2	0	0	0	1	4	18
Purple Gallinule	2	0	1	0	1	0	3	0	0	0	7
Barn Swallow	39	8	7	37	4	2	10	6	2	21	136
Least Flycatcher	9	12	7	4	12	0	12	0	2	6	64
Vesper Sparrow	2	2	1	0	0	1	0	1	0	2	9
Yellow-breasted Chat	18	65	7	11	5	1	14	6	9	37	173
Belted Kingfisher	6	3	1	3	0	0	3	1	1	4	22
White-throated Sparrow	1	12	0	0	1	2	0	3	0	6	25

Table 9.3.

Comparative longitudinal distributions of fall trans-Gulf migrants

Numbers shown indicate numbers of individuals undertaking stopovers on each platform during fall 1999. Species are listed in order from most westerly distribution at top to most easterly distribution at bottom. Species with <5 stopovers are not included.

Species	PN975	MI622	HI561	GB189	VE265	SM147	GC18	EW826	SP89	VK786	Total
Bank Swallow	6	1	0	4	1	2	4	0	0	3	21
White-crowned Sparrow	1	4	0	0	0	1	0	2	0	2	10
Cattle Egret	41	14	19	21	13	2	35	45	4	6	200
Warbling Vireo	1	1	0	1	1	0	1	0	0	1	6
Peregrine Falcon	52	37	12	22	16	5	62	29	26	19	280
Eastern Phoebe	3	13	1	3	3	2	3	3	2	8	41
Field Sparrow	0	2	0	3	1	0	0	0	1	1	8
Baltimore Oriole	6	8	1	0	0	1	4	4	1	7	32
Acadian Flycatcher	2	3	5	2	2	2	2	0	0	5	23
Mourning Dove	109	133	28	45	27	35	84	83	28	131	703
Orchard Oriole	6	8	2	3	1	0	0	2	3	10	35
Brown Thrasher	9	6	3	3	4	4	4	2	5	9	49
Blue-gray Gnatcatcher	0	4	1	3	1	0	1	1	1	3	15
Myrtle Warbler	16	22	11	9	16	15	14	13	7	25	148
Green Heron	6	2	3	5	8	7	6	8	3	2	50
Eastern Wood-Pewee	5	10	2	2	1	2	3	2	0	13	40
Summer Tanager	0	3	2	3	3	1	2	2	1	2	19
Rose-breasted Grosbeak	2	1	1	2	1	0	2	1	0	3	13
Winter Wren	1	1	0	1	3	0	1	1	1	1	10
Great Crested Flycatcher	4	7	0	3	9	0	10	2	2	7	44
Prairie Warbler	3	2	1	3	2	2	4	3	1	4	25
Golden-crowned Kinglet	0	1	1	1	2	1	0	0	0	2	8
Purple Martin	4	0	4	6	0	1	2	0	0	8	25
Eastern Kingbird	3	4	1	2	6	3	2	0	5	6	32
Merlin	3	2	0	2	0	0	7	3	1	3	21
Song Sparrow	2	6	0	1	3	0	3	2	0	8	15
unid. *Empidonax* flycatcher	0	7	1	1	3	2	3	1	3	6	27
Red-eyed Vireo	1	8	2	3	6	2	1	2	0	12	37
Yellow-throated Warbler	6	0	2	3	0	3	2	2	1	8	27
Blue-winged Teal	1	0	0	0	0	1	3	0	0	1	6
Marsh Wren	9	28	7	11	12	5	16	13	4	51	156
Gray Catbird	5	8	1	9	3	0	7	10	2	19	64
Blue Grosbeak	1	4	0	3	0	0	3	0	0	8	19
Pine Warbler	1	0	0	2	2	1	0	5	0	2	13
Black-throated Blue Warbler	3	0	0	4	0	2	2	2	0	7	20
American Kestrel	5	9	1	5	2	1	6	2	4	25	60
Ovenbird	32	12	4	12	8	3	5	18	7	84	185
Louisiana Waterthrush	0	0	0	1	0	2	0	1	0	1	5
Yellow-billed Cuckoo	1	1	0	2	3	2	0	1	1	6	17
Cape May Warbler	1	0	0	1	0	0	0	0	1	2	5
Western Palm Warbler	3	2	4	5	8	7	8	8	3	19	67
Blue-winged Warbler	1	0	0	1	1	0	2	0	0	3	8
White-eyed Vireo	1	3	3	0	1	2	12	11	0	9	42
Northern Parula	13	1	10	32	8	23	21	23	3	65	199
Swainson's Thrush	0	3	1	1	2	1	3	7	1	7	26
Northern Waterthrush	4	2	2	4	2	3	7	7	2	18	51
Swainson's Warbler	1	0	0	1	0	0	1	2	0	3	8
Swamp Sparrow	1	5	0	1	5	0	6	3	6	14	41
Red-winged Blackbird	0	2	0	0	0	0	0	0	0	4	6
Yellow Warbler	25	14	3	5	3	8	10	51	6	98	223

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Numbers shown indicate numbers of individuals undertaking stopovers on each platform during fall 1999. Species are listed in order from most westerly distribution at top to most easterly distribution at bottom. Species with <5 stopovers are not included.

Species	PN975	MI622	HI561	GB189	VE265	SM147	GC18	EW826	SP89	VK786	Total
Scarlet Tanager	1	2	0	1	1	0	2	1	2	8	18
Black-and-white Warbler	11	6	3	6	6	5	3	12	5	55	112
Kentucky Warbler	2	0	0	0	6	1	2	6	3	11	31
Northern Rough-winged Swallow	0	0	1	1	0	0	0	0	0	3	5
American Robin	0	0	0	1	0	1	1	0	1	2	6
Hooded Warbler	2	3	4	13	5	11	8	17	3	54	120
Tennessee Warbler	4	7	2	13	1	20	8	15	1	77	148
Worm-eating Warbler	1	0	1	1	3	2	2	1	1	13	25
Yellow-throated Vireo	1	0	0	1	0	0	0	0	0	5	7
Bobolink	0	0	0	0	0	0	1	2	1	1	5
Eurasian Collared-Dove	0	0	0	0	0	1	1	2	2	2	8
Prothonotary Warbler	1	0	0	3	9	8	44	47	12	72	196
American Redstart	16	13	13	16	8	19	10	27	32	250	404
Magnolia Warbler	7	3	9	29	24	43	25	58	28	356	582
Bay-breasted Warbler	1	0	0	2	2	3	1	11	3	37	60
Blackburnian Warbler	1	0	1	3	1	3	1	2	5	34	51
Chestnut-sided Warbler	0	1	0	4	1	3	1	3	3	45	61
Cerulean Warbler	0	0	0	1	0	0	0	1	1	13	16

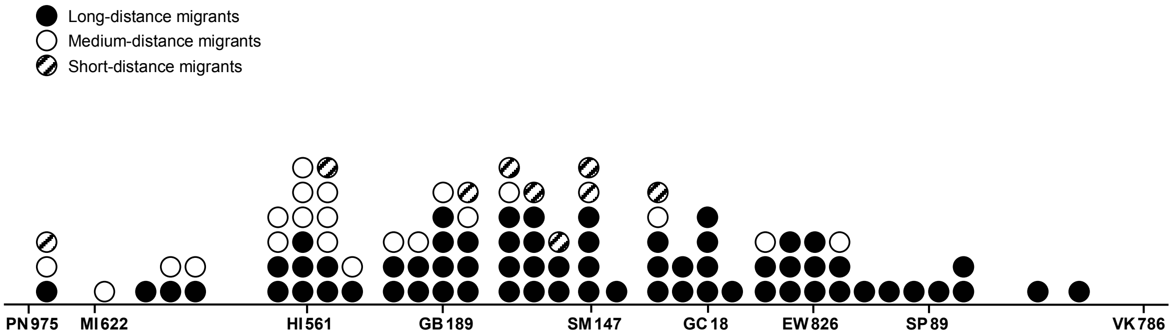


Figure 9.15. Frequency distribution of mean species-specific longitudinal positions in fall 1999. Each symbol indicates the mean position calculated from the entire sample of stopovers (i.e., all weather types) for one of the species listed in Table 9.3. Longitude is indicated by reference to the relative positions of selected study platforms.

9.7 AGE-RELATED VARIATION IN MIGRATION ROUTES

For a number of species of warblers we were able to determine the age of many individuals based on plumage, and to analyze geographic patterns of age ratio. Geographic variation in age ratio provides important insights concerning migration strategies because a high percentage of young (along with a comparatively low absolute density of individual migrants) characterizes the periphery of a species' migration route (Ralph 1981).

Adult males generally have the most distinctive plumage, and in many species it is difficult to determine the age of females or to distinguish adult females from young males. These problems mean that while virtually all adult males can be identified and counted, many adult females are excluded from samples of individuals of determined age; as a result, the proportion of adults in visually identified samples will be biased low. To address this problem, we estimated the proportion of adults in a given sample as $(2 \cdot X)/N$, where N is the sample size and X is the proportion of adult males in the sample.

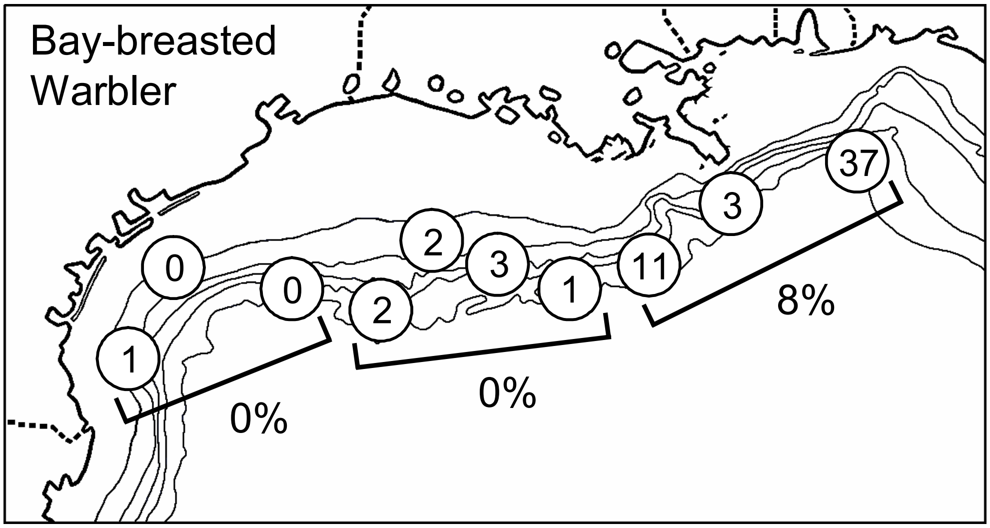
Geographic patterns of abundance and age ratio for 16 species of warblers are presented in Figures 9.16-9.23.

Bay-breasted Warblers were relatively more common toward the east and had a higher proportion of adults in the eastern region, consistent with an easterly trans-Gulf route (Figure 9.16). However, the proportion of adults even in the eastern portion of our study area was very low (8%), implying that the main route of this species is considerably to the east of our study area, and perhaps even along the Florida peninsula. Prairie Warblers showed a pattern similar to Bay-breasted Warblers, except that they were very scarce even in the eastern region (Figure 9.16).

Chestnut-sided Warblers, Blackburnian Warblers, Black-and-white Warblers, Kentucky Warblers, and Prothonotary Warblers were more common toward the east, with peak abundance at VK786, and all showed an obvious gradient in age ratio across the Gulf, with the largest proportion of adults in the eastern region (Figures 9.17-9.20). These patterns are consistent with a primarily eastern trans-Gulf route that includes VK786 along its western periphery.

Like the previous group, Northern Parulas, American Redstarts, and Yellow Warblers exhibited peaks in both abundance and proportion of adults at the eastern end of our study area (Figures 9.18-9.19, 9.21). However, these species were also moderately common in the central and western regions of the Gulf, with moderately high proportions of adults (≥ 18%) in the western region. These patterns are consistent with a primarily eastern trans-Gulf route that is nonetheless broader and less geographically concentrated than in the previous group.

Mourning Warblers and Wilson's Warblers had peak abundance in the western region and showed an obvious gradient in age ratio across the Gulf, with the largest proportion of adults in the western region (Figure 9.23). These patterns indicate a primarily western trans-Gulf route – or perhaps even a primarily circum-Gulf route – for these species, with PN975 and MI622 along the eastern periphery.



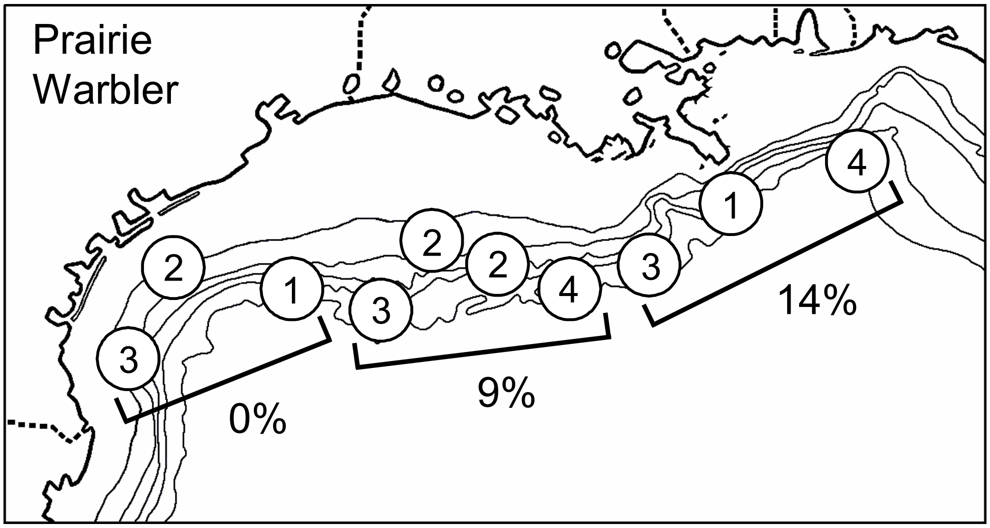
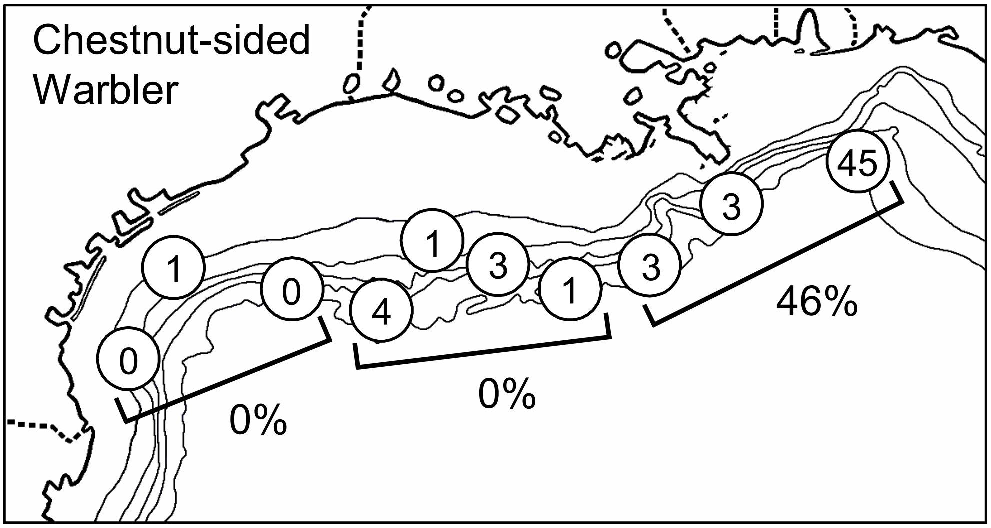


Figure 9.16. Patterns of abundance and age ratios of Bay-breasted Warblers and Prairie Warblers across the Gulf during fall 1999. The numbers in circles indicate the total numbers of individuals of the species recorded on each platform over the course of the season. The numbers shown below indicate the percentages of adults in the samples of individuals identifiable to age in the western (PN975, MI622, HI561), central (GB189, VR265, SM147, GC18), and eastern (EW826, SP89, VK786) portions of the study region.



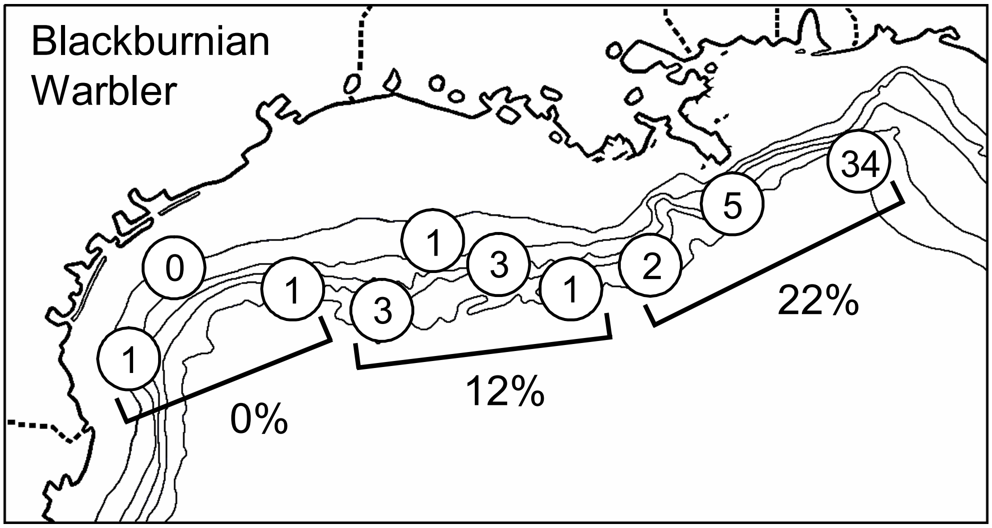


Figure 9.17. Patterns of abundance and age ratios of Chestnut-sided Warblers and Blackburnian Warblers across the Gulf during fall 1999. The numbers in circles indicate the total numbers of individuals of the species recorded on each platform over the course of the season. The numbers shown below indicate the percentages of adults in the samples of individuals identifiable to age in the western (PN975, MI622, HI561), central (GB189, VR265, SM147, GC18), and eastern (EW826, SP89, VK786) portions of the study region.

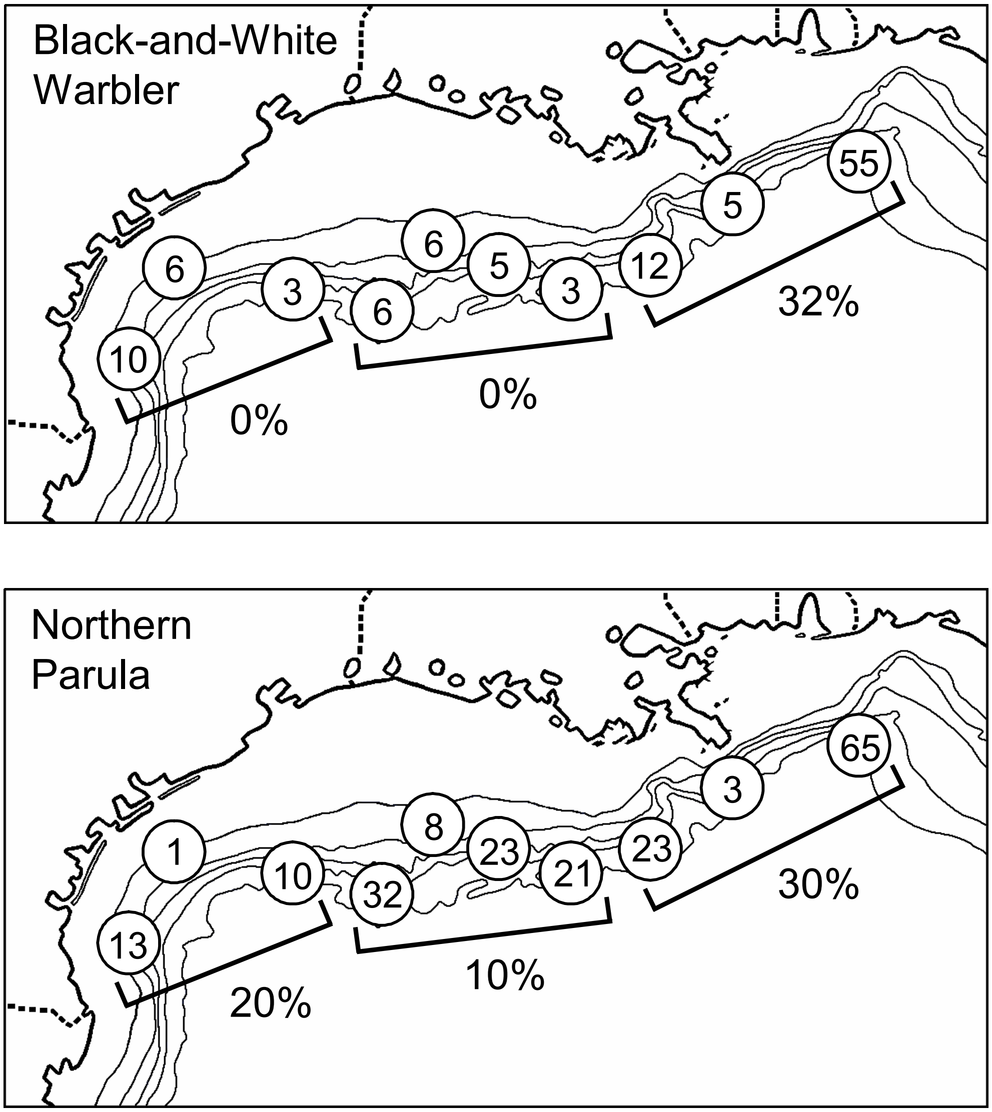


Figure 9.18. Patterns of abundance and age ratios of Black-and-white Warblers and Northern Parulas across the Gulf during fall 1999. The numbers in circles indicate the total numbers of individuals of the species recorded on each platform over the course of the season. The numbers shown below indicate the percentages of adults in the samples of individuals identifiable to age in the western (PN975, MI622, HI561), central (GB189, VR265, SM147, GC18), and eastern (EW826, SP89, VK786) portions of the study region.

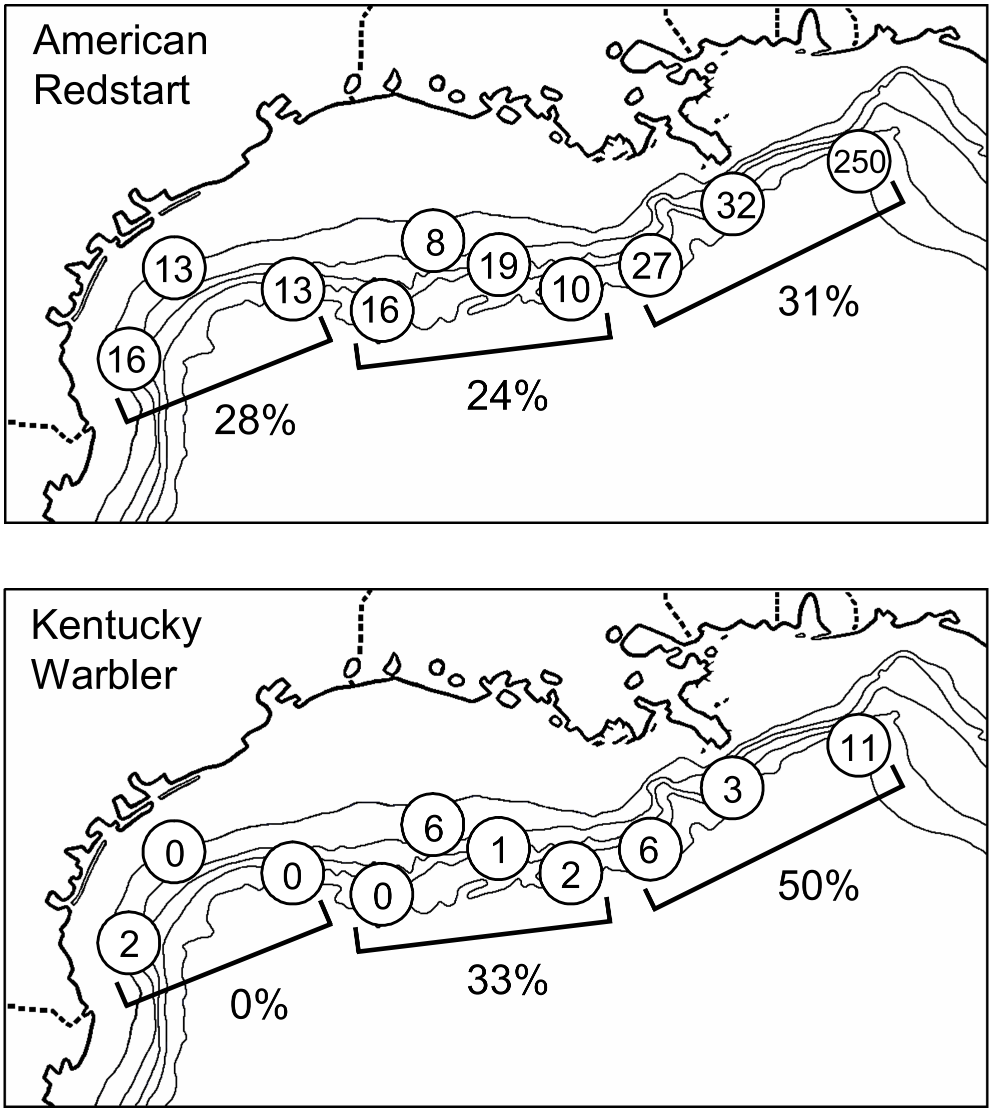
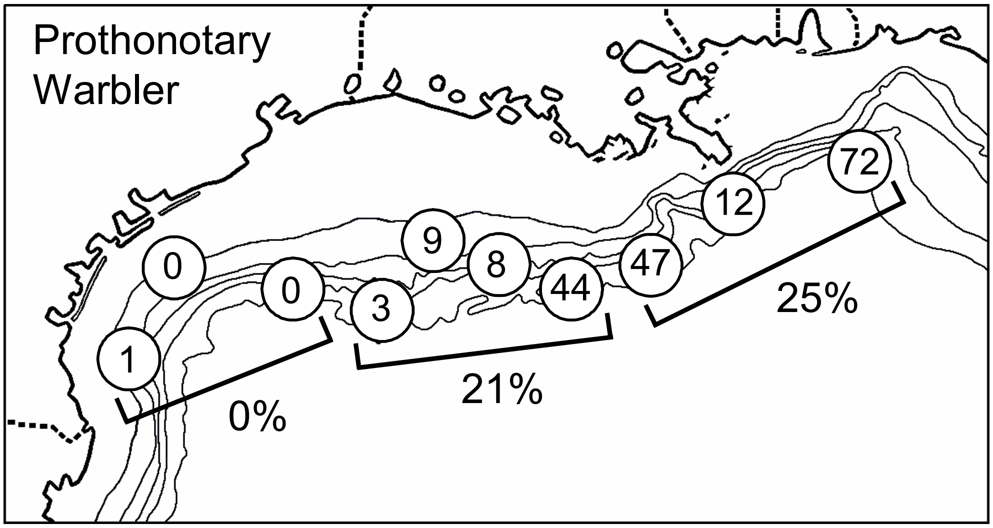


Figure 9.19. Patterns of abundance and age ratios of American Redstarts and Kentucky Warblers across the Gulf during fall 1999. The numbers in circles indicate the total numbers of individuals of the species recorded on each platform over the course of the season. The numbers shown below indicate the percentages of adults in the samples of individuals identifiable to age in the western (PN975, MI622, HI561), central (GB189, VR265, SM147, GC18), and eastern (EW826, SP89, VK786) portions of the study region.



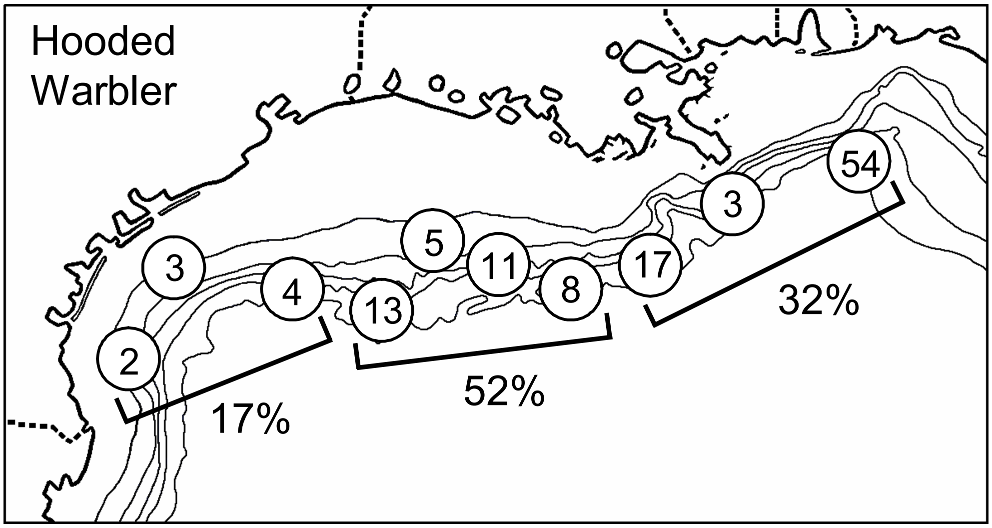


Figure 9.20. Patterns of abundance and age ratios of Prothonotary Warblers and Hooded Warblers across the Gulf during fall 1999. The numbers in circles indicate the total numbers of individuals of the species recorded on each platform over the course of the season. The numbers shown below indicate the percentages of adults in the samples of individuals identifiable to age in the western (PN975, MI622, HI561), central (GB189, VR265, SM147, GC18), and eastern (EW826, SP89, VK786) portions of the study region.

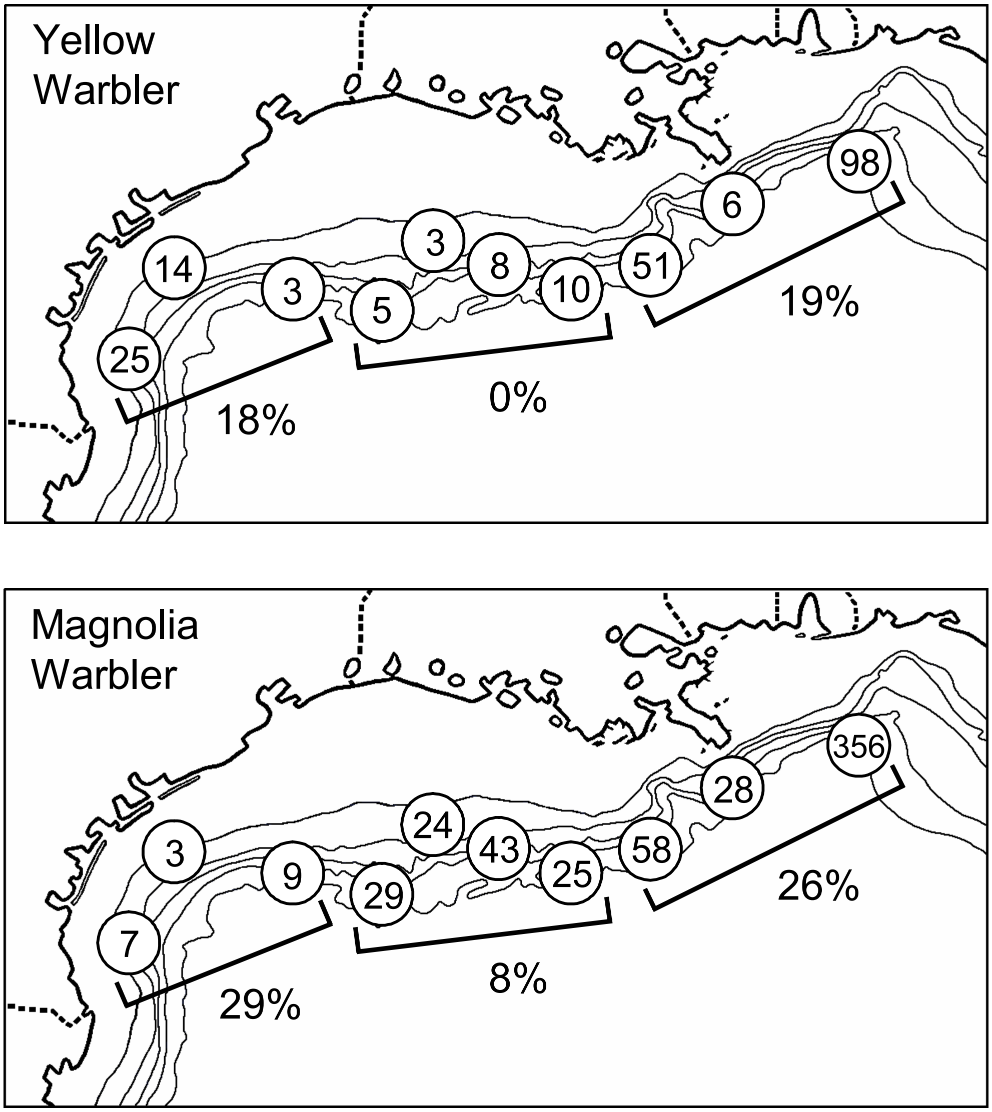


Figure 9.21. Patterns of abundance and age ratios of Yellow Warblers and Magnolia Warblers across the Gulf during fall 1999. The numbers in circles indicate the total numbers of individuals of the species recorded on each platform over the course of the season. The numbers shown below indicate the percentages of adults in the samples of individuals identifiable to age in the western (PN975, MI622, HI561), central (GB189, VR265, SM147, GC18), and eastern (EW826, SP89, VK786) portions of the study region.

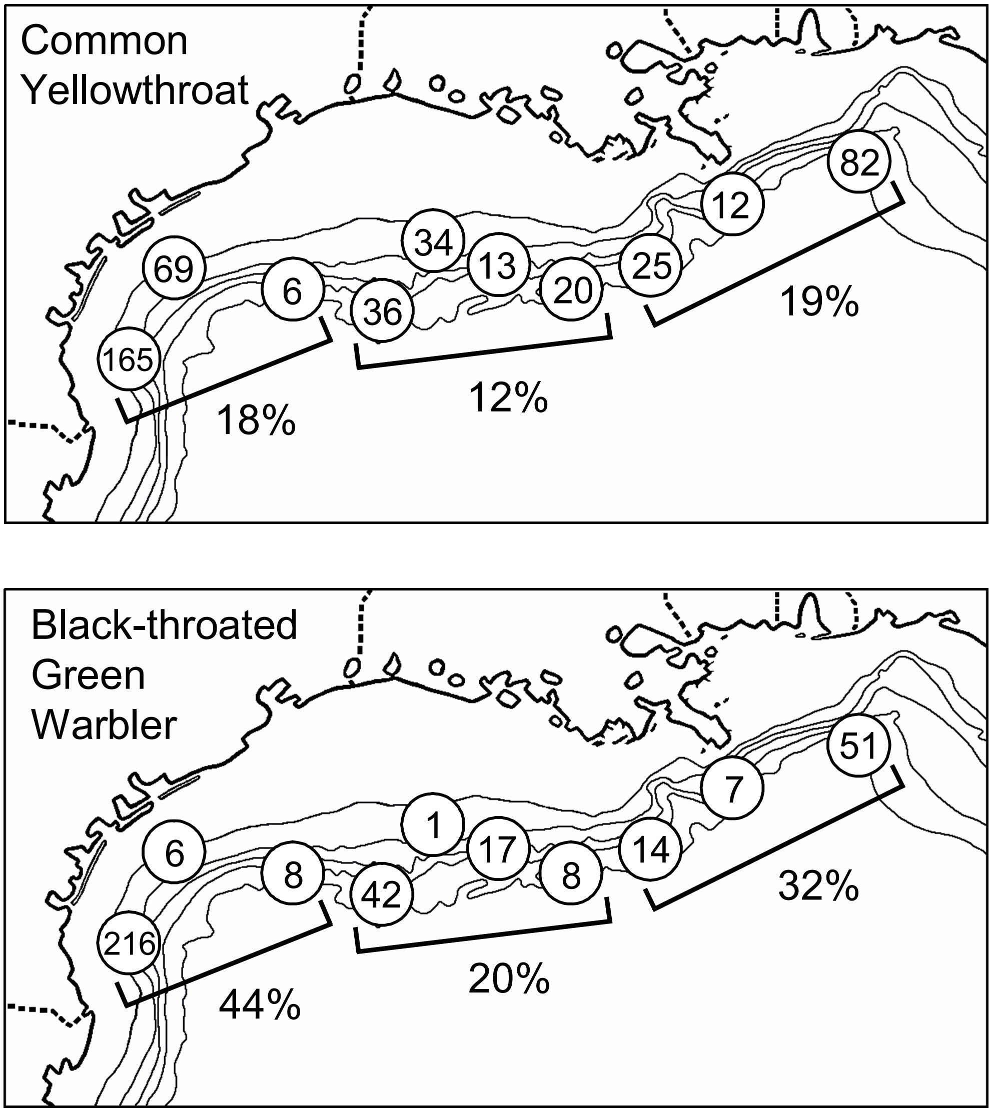


Figure 9.22. Patterns of abundance and age ratios of Common Yellowthroats and Black-throated Green Warblers across the Gulf during fall 1999. The numbers in circles indicate the total numbers of individuals of the species recorded on each platform over the course of the season. The numbers shown below indicate the percentages of adults in the samples of individuals identifiable to age in the western (PN975, MI622, HI561), central (GB189, VR265, SM147, GC18), and eastern (EW826, SP89, VK786) portions of the study region.

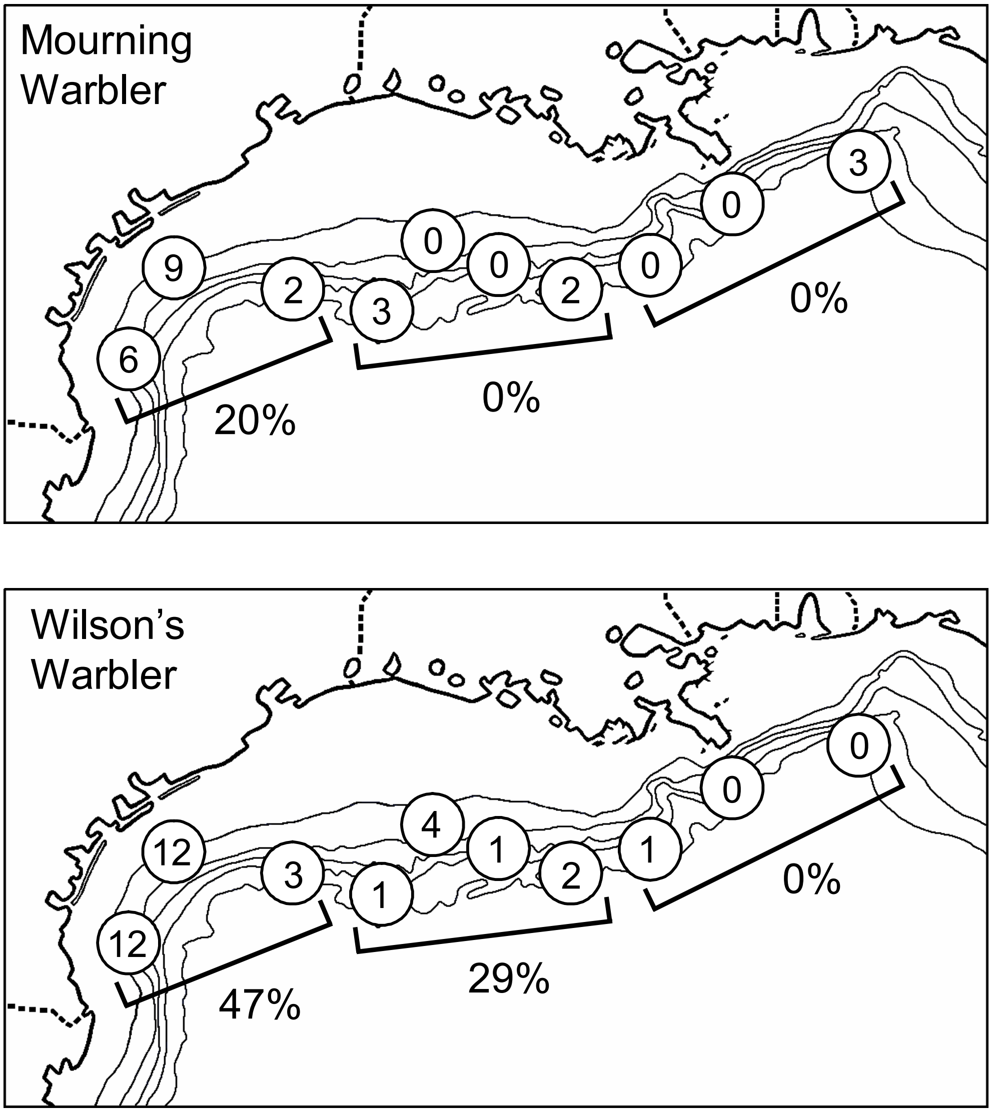


Figure 9.23. Patterns of abundance and age ratios of Mourning Warblers and Wilson's Warblers across the Gulf during fall 1999. The numbers in circles indicate the total numbers of individuals of the species recorded on each platform over the course of the season. The numbers shown below indicate the percentages of adults in the samples of individuals identifiable to age in the western (PN975, MI622, HI561), central (GB189, VR265, SM147, GC18), and eastern (EW826, SP89, VK786) portions of the study region.

The remaining species showed more complex patterns. Hooded Warblers and Magnolia Warblers had peak abundance at VK786 but had the highest proportion of adults in the central or western region (Figures 9.20, 9.21). Common Yellowthroats and Black-throated Green Warblers had peak abundance in the far west at PN975 but a secondary peak in the far east at VK786, with high proportions of adults in both the western and eastern regions (Figure 9.22).

9.8 SEASONAL TIMING

As was the case in the spring (Chapter 8.3.1), the volume of trans-Gulf migration detected on platforms varied dramatically from day to day during the fall (Figure 9.24).

In 1999, migration peaks seemed to be approximately Gaussian and symmetric around the peak of approximately October 1. The broad seasonal pattern was more difficult to evaluate in 1998 because of the series of irregular coverage gaps resulting from hurricane evacuations.

Early in the fall, most migration peaks occurred on **ECH**, **GH**, and **TLOW** days (Figure 9.24). Starting around the last week in September, migration peaks occurred mostly on **MCH** and **ELOW** days.

Contrary to popular expectation, peaks in platform-observed migration were not usually associated with precipitation (Figure 9.24). Lack of association with precipitation during the fall makes sense because of the proximity of our platforms to points of migratory takeoff: rain over our platforms usually meant that rain was also occurring along the northern Gulf Coast, precluding takeoff by southbound trans-Gulf migrants.

9.9 INTERSPECIFIC VARIATION IN MIGRATION SCHEDULES

Data on species-specific fall migration schedules are tabulated in Table 9.4 and summarized graphically in Figure 9.25. Neotropical migrants peaked from late August through mid-October, with maximum diversity in early October. Medium-distance migrants peaked in late October, and short-distance migrants peaked in early November. Herons peaked from mid-September through mid-October. Waterfowl peaked in late October and early November, except the two teal species, which peaked in late September and early October. Shorebirds had widely varying migration schedules, with different species peaking from late August through the end of October, but with maximum diversity in early September.

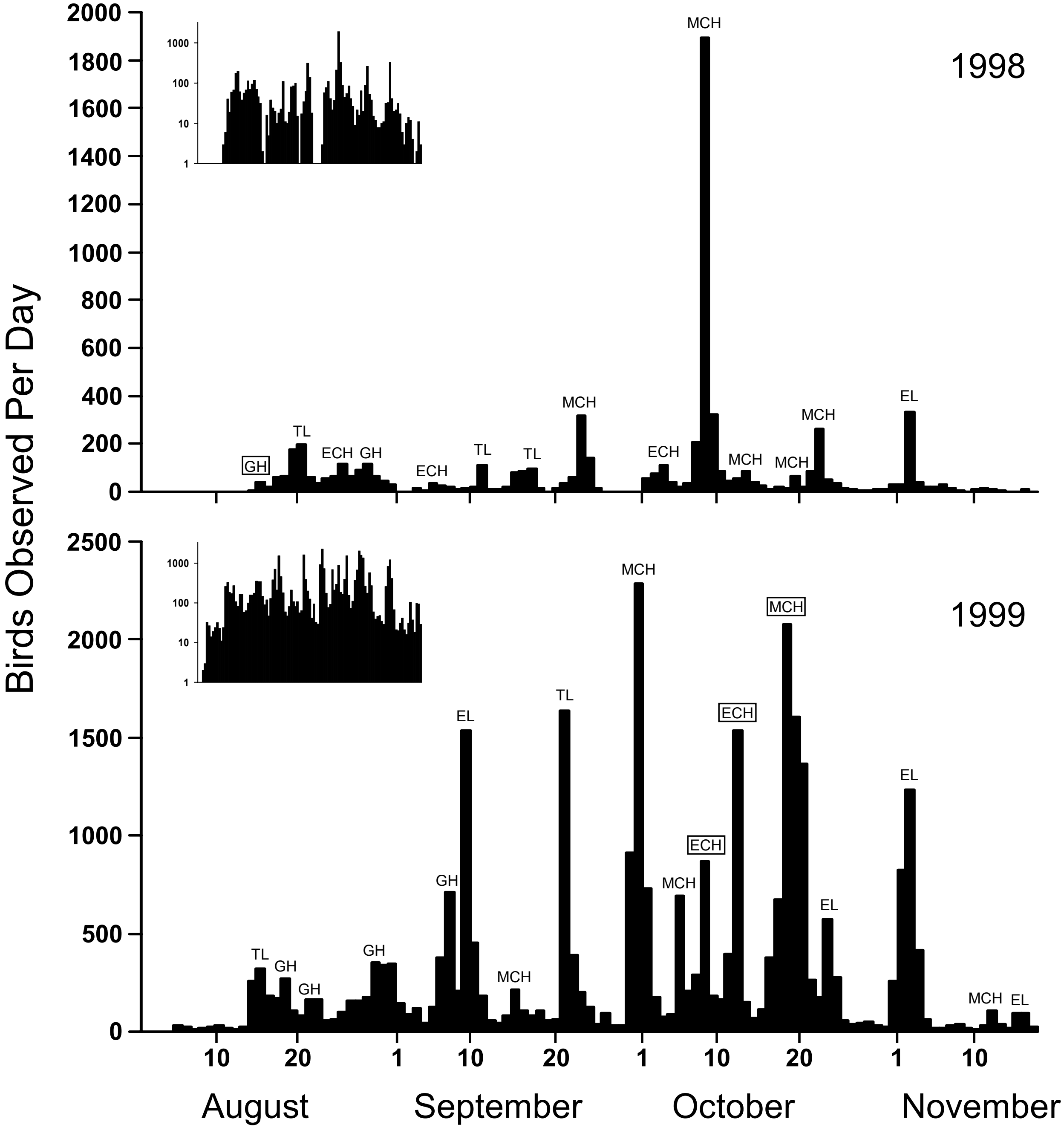


Figure 9.24. Phenology of platform-observed fall migration in 1998 and 1999. The inset figures show the same data (x+1)-transformed on a logarithmic scale for perspective. Synoptic weather types are indicated above intraseasonal migration peaks, and inside a box on days with rain. Note that several considerable coverage gaps occurred in 1998 due to a series of hurricane evacuations (Table 2.3).

Table 9.4.

Species-specific timing of fall trans-Gulf migration in 1999

Species are listed in order from earliest to latest migrants (based on mean date). Sample sizes indicate total numbers of individuals of each species recorded over the entire season, including both stopovers and flyby migrants. 95% confidence intervals are calculated only for sample sizes ≥ 5.

Species	First Date	95% CI Lower Bound	Mean Date	95% CI Upper Bound	Last Date	N
Ringed Kingfisher	---	---	5-Aug	---	---	1
Purple Martin	5-Aug	17-Aug	20-Aug	24-Aug	2-Oct	70
Cerulean Warbler	15-Aug	12-Aug	21-Aug	30-Aug	20-Oct	18
Prothonotary Warbler	5-Aug	18-Aug	21-Aug	23-Aug	10-Nov	209
Least Sandpiper	16-Aug	26-Jul	21-Aug	16-Sep	9-Oct	6
Yellow Warbler	4-Aug	20-Aug	23-Aug	26-Aug	20-Oct	189
Louisiana Waterthrush	17-Aug	14-Aug	28-Aug	11-Sep	10-Sep	5
Kentucky Warbler	14-Aug	24-Aug	29-Aug	3-Sep	5-Oct	35
Orchard Oriole	5-Aug	24-Aug	29-Aug	3-Sep	16-Oct	44
Hooded Warbler	5-Aug	24-Aug	30-Aug	5-Sep	20-Oct	130
Worm-eating Warbler	15-Aug	19-Aug	30-Aug	10-Sep	19-Oct	29
American Golden Plover	---	---	1-Sep	---	---	1
Canada Warbler	22-Aug	29-Aug	1-Sep	4-Sep	8-Sep	18
MacGillivray's Warbler	25-Aug	---	2-Sep	---	7-Sep	3
Tropical/Couch's Kingbird	19-Aug	---	2-Sep	---	17-Sep	2
Solitary Sandpiper	16-Aug	27-Aug	3-Sep	9-Sep	30-Sep	18
Pectoral Sandpiper	9-Aug	---	4-Sep	---	25-Sep	3
Cliff Swallow	8-Aug	1-Sep	4-Sep	8-Sep	31-Oct	67
Willet	3-Sep	---	5-Sep	---	7-Sep	2
Spotted Sandpiper	18-Aug	25-Aug	6-Sep	17-Sep	21-Sep	8
Bank Swallow	7-Aug	3-Sep	6-Sep	10-Sep	10-Oct	54
Prairie Warbler	6-Aug	29-Aug	7-Sep	15-Sep	3-Nov	28
Eastern Kingbird	13-Aug	4-Sep	7-Sep	10-Sep	24-Sep	51
Acadian Flycatcher	5-Aug	1-Sep	8-Sep	15-Sep	12-Oct	24
Baird's Sandpiper	---	---	9-Sep	---	---	1
Black-chinned Hummingbird	---	---	9-Sep	---	---	1
Bell's Vireo	30-Aug	---	9-Sep	---	19-Sep	2
Yellow-bellied Flycatcher	9-Aug	20-Aug	9-Sep	28-Sep	16-Oct	7
Least Flycatcher	5-Aug	6-Sep	9-Sep	13-Sep	5-Oct	59
Great Crested Flycatcher	15-Aug	7-Sep	10-Sep	13-Sep	9-Oct	55
Mourning Warbler	19-Aug	4-Sep	10-Sep	16-Sep	18-Oct	26
unid. *Empidonax* flycatcher	5-Aug	5-Sep	11-Sep	17-Sep	20-Oct	44
Loggerhead Kingbird	---	---	12-Sep	---	---	1
Western Sandpiper	---	---	12-Sep	---	---	1
Yellow-breasted Chat	16-Aug	10-Sep	12-Sep	14-Sep	21-Oct	182
Western Kingbird	11-Sep	---	12-Sep	---	14-Sep	2
Upland Sandpiper	14-Aug	3-Sep	13-Sep	22-Sep	18-Oct	33
Eurasian Collared-Dove	16-Aug	29-Aug	13-Sep	27-Sep	9-Oct	8

Table 9.4.

Species-specific timing of fall trans-Gulf migration in 1999

Species are listed in order from earliest to latest migrants (based on mean date). Sample sizes indicate total numbers of individuals of each species recorded over the entire season, including both stopovers and flyby migrants. 95% confidence intervals are calculated only for sample sizes ≥ 5.

Species	First Date	95% CI Lower Bound	Mean Date	95% CI Upper Bound	Last Date	N
Tricolored Heron	18-Aug	29-Aug	13-Sep	29-Sep	17-Oct	12
Rock Dove	---	---	14-Sep	---	---	1
Baltimore Oriole	27-Aug	11-Sep	14-Sep	18-Sep	7-Oct	33
Green Heron	14-Aug	10-Sep	15-Sep	21-Sep	4-Nov	98
Chuck-Will's-Widow	16-Aug	11-Sep	16-Sep	20-Sep	3-Nov	65
Red-winged Blackbird	15-Aug	9-Aug	16-Sep	23-Oct	15-Nov	9
Ruby-throated Hummingbird	14-Aug	14-Sep	16-Sep	17-Sep	1-Nov	239
Lesser Yellowlegs	9-Aug	---	16-Sep	---	31-Oct	4
Traill's Flycatcher	4-Aug	10-Sep	16-Sep	23-Sep	11-Oct	29
Little Blue Heron	9-Aug	9-Sep	17-Sep	24-Sep	20-Oct	70
Northern Waterthrush	15-Aug	12-Sep	17-Sep	22-Sep	20-Oct	54
Swainson's Warbler	16-Aug	28-Aug	17-Sep	7-Oct	18-Oct	9
Barn Swallow	6-Aug	15-Sep	18-Sep	22-Sep	10-Nov	403
Rufous Hummingbird	---	---	19-Sep	---	---	1
Yellow-headed Blackbird	10-Sep	10-Sep	19-Sep	27-Sep	30-Sep	6
Red-eyed Vireo	15-Aug	12-Sep	19-Sep	26-Sep	24-Oct	43
unid. Dowitcher	28-Aug	---	19-Sep	---	12-Nov	4
Groove-billed Ani	8-Sep	---	20-Sep	---	30-Sep	3
White Ibis	20-Aug	8-Aug	20-Sep	1-Nov	1-Nov	18
Loggerhead Shrike	14-Aug	26-Aug	22-Sep	19-Oct	1-Nov	7
Western Wood-Pewee	23-Sep	---	23-Sep	---	24-Sep	2
Blue-winged Warbler	7-Sep	11-Sep	23-Sep	5-Oct	12-Oct	8
Belted Kingfisher	6-Aug	14-Sep	23-Sep	3-Oct	19-Oct	30
Northern Parula	14-Aug	20-Sep	25-Sep	29-Sep	24-Oct	188
Blue-winged Teal	25-Aug	15-Sep	25-Sep	5-Oct	11-Nov	106
Northern Rough-winged Swallow	14-Aug	6-Sep	25-Sep	14-Oct	9-Nov	14
Cattle Egret	9-Aug	19-Sep	25-Sep	2-Oct	17-Nov	366
Least Bittern	5-Aug	15-Sep	25-Sep	6-Oct	18-Oct	21
Ruddy Turnstone	4-Sep	17-Aug	26-Sep	5-Nov	6-Nov	6
Snowy Egret	15-Aug	9-Sep	26-Sep	13-Oct	20-Oct	43
Lark Sparrow	28-Aug	19-Sep	26-Sep	3-Oct	18-Oct	18
Black-and-white Warbler	5-Aug	22-Sep	26-Sep	30-Sep	22-Oct	112
Gray-cheeked Thrush	22-Aug	---	27-Sep	---	16-Oct	3
Inca Dove	24-Sep	---	27-Sep	---	4-Oct	3
unid *Plegadis* ibis	29-Aug	6-Feb	27-Sep	17-May	1-Nov	5
Common Nighthawk	1-Sep	21-Sep	27-Sep	4-Oct	18-Oct	19
Yellow-billed Cuckoo	5-Aug	20-Sep	28-Sep	5-Oct	21-Oct	33

Table 9.4.

Species-specific timing of fall trans-Gulf migration in 1999

Species are listed in order from earliest to latest migrants (based on mean date). Sample sizes indicate total numbers of individuals of each species recorded over the entire season, including both stopovers and flyby migrants. 95% confidence intervals are calculated only for sample sizes ≥ 5.

Species	First Date	95% CI Lower Bound	Mean Date	95% CI Upper Bound	Last Date	N
Purple Gallinule	15-Aug	21-Sep	28-Sep	5-Oct	17-Oct	27
Blue-gray Gnatcatcher	10-Sep	19-Sep	28-Sep	8-Oct	6-Nov	14
Cave Swallow	29-Sep	---	29-Sep	---	29-Sep	2
Wilson's Warbler	30-Aug	23-Sep	29-Sep	5-Oct	8-Nov	37
Blackburnian Warbler	31-Aug	23-Sep	29-Sep	5-Oct	20-Oct	47
Merlin	14-Sep	26-Sep	29-Sep	1-Oct	2-Nov	56
Eurasian Starling	---	---	30-Sep	---	---	1
Painted Bunting	21-Sep	---	1-Oct	---	18-Oct	4
Sanderling	30-Aug	12-Sep	1-Oct	20-Oct	19-Oct	8
Vermilion Flycatcher	22-Sep	---	1-Oct	---	11-Oct	2
Green-winged Teal	9-Sep	3-May	1-Oct	1-Mar	8-Nov	5
Burrowing Owl	---	---	2-Oct	---	---	1
Yellow-throated Vireo	26-Aug	20-Sep	2-Oct	13-Oct	19-Oct	9
Whip-Poor-Will	15-Sep	---	2-Oct	---	18-Oct	4
Osprey	23-Aug	24-Sep	2-Oct	10-Oct	2-Nov	26
Ovenbird	13-Aug	29-Sep	2-Oct	5-Oct	3-Nov	181
Yellow-throated Warbler	16-Aug	24-Sep	2-Oct	10-Oct	2-Nov	27
Red-breasted Nuthatch	14-Sep	---	2-Oct	---	21-Oct	2
Yellow-crowned Night-Heron	11-Aug	8-Sep	2-Oct	26-Oct	20-Oct	23
Great Egret	6-Aug	23-Sep	3-Oct	13-Oct	7-Nov	67
Black-throated Blue Warbler	12-Sep	29-Sep	4-Oct	8-Oct	20-Oct	22
Semipalmated Plover	19-Aug	---	4-Oct	---	8-Oct	2
Philadelphia Vireo	22-Sep	---	4-Oct	---	15-Oct	3
Eastern Wood-Pewee	25-Aug	29-Sep	4-Oct	9-Oct	27-Oct	42
Bobolink	7-Sep	10-Sep	4-Oct	28-Oct	27-Oct	5
Golden-winged Warbler	---	---	5-Oct	---	---	1
Chestnut-sided Warbler	31-Aug	1-Oct	5-Oct	9-Oct	21-Oct	47
Peregrine Falcon	3-Sep	4-Oct	5-Oct	6-Oct	12-Nov	372
American Redstart	5-Aug	3-Oct	5-Oct	7-Oct	20-Oct	277
Clay-colored Sparrow	29-Aug	1-Oct	5-Oct	10-Oct	1-Nov	51
Long-billed Dowitcher	25-Aug	---	6-Oct	---	17-Oct	2
Summer Tanager	7-Aug	28-Sep	6-Oct	14-Oct	4-Nov	21
Black-crowned Night-Heron	15-Aug	14-Sep	6-Oct	28-Oct	19-Oct	10
Cooper's Hawk	---	---	7-Oct	---	---	1
Dickcissel	14-Aug	1-Oct	7-Oct	12-Oct	9-Nov	96
Scarlet Tanager	21-Sep	2-Oct	7-Oct	11-Oct	20-Oct	20
Black Swift	---	---	8-Oct	---	---	1
Brown Thrasher	17-Sep	5-Oct	8-Oct	11-Oct	3-Nov	50

Table 9.4.

Species-specific timing of fall trans-Gulf migration in 1999

Species are listed in order from earliest to latest migrants (based on mean date). Sample sizes indicate total numbers of individuals of each species recorded over the entire season, including both stopovers and flyby migrants. 95% confidence intervals are calculated only for sample sizes ≥ 5.

Species	First Date	95% CI Lower Bound	Mean Date	95% CI Upper Bound	Last Date	N
Red-headed Woodpecker	15-Sep	---	8-Oct	---	24-Oct	4
Swainson's Thrush	17-Aug	2-Oct	8-Oct	14-Oct	20-Oct	33
unid. *Catharus* thrush	1-Oct	1-Oct	8-Oct	16-Oct	20-Oct	22
Cuban Pewee	---	---	9-Oct	---	---	1
Nashville Warbler	29-Aug	3-Oct	9-Oct	15-Oct	5-Nov	42
Blue Grosbeak	9-Sep	3-Oct	9-Oct	15-Oct	11-Nov	24
Red-necked Phalarope	---	---	10-Oct	---	---	1
House Wren	16-Sep	8-Oct	10-Oct	12-Oct	3-Nov	197
Warbling Vireo	24-Sep	28-Sep	10-Oct	21-Oct	20-Oct	6
Flammulated Owl	10-Oct	---	10-Oct	---	11-Oct	2
Cassin's Sparrow	21-Sep	---	10-Oct	---	31-Oct	3
Black-billed Cuckoo	22-Sep	25-Sep	10-Oct	26-Oct	21-Oct	5
Townsend's Warbler	---	---	11-Oct	---	---	1
Veery	7-Oct	5-Oct	11-Oct	16-Oct	19-Oct	5
Cape May Warbler	25-Sep	21-Sep	11-Oct	30-Oct	3-Nov	5
Wood Thrush	24-Sep	4-Oct	11-Oct	18-Oct	23-Oct	9
Clapper Rail	23-Sep	30-Sep	11-Oct	22-Oct	18-Oct	6
Great Blue Heron	26-Aug	7-Oct	11-Oct	15-Oct	16-Nov	143
Magnolia Warbler	11-Sep	11-Oct	11-Oct	12-Oct	3-Nov	439
Common Grackle	18-Sep	---	12-Oct	---	3-Nov	4
Common Yellowthroat	3-Sep	10-Oct	12-Oct	13-Oct	16-Nov	366
Chimney Swift	8-Oct	8-Oct	12-Oct	17-Oct	19-Oct	13
White-eyed Vireo	23-Sep	11-Oct	13-Oct	14-Oct	19-Oct	57
Bay-breasted Warbler	17-Sep	11-Oct	13-Oct	14-Oct	20-Oct	62
Tennessee Warbler	6-Sep	11-Oct	13-Oct	14-Oct	4-Nov	135
American Kestrel	15-Sep	9-Oct	13-Oct	16-Oct	15-Nov	78
Greater Yellowlegs	11-Sep	---	13-Oct	---	20-Oct	2
Western Palm Warbler	23-Sep	11-Oct	13-Oct	15-Oct	3-Nov	68
Sharp-shinned Hawk	---	---	14-Oct	---	---	1
Audubon's Warbler	10-Oct	---	14-Oct	---	21-Oct	3
Downy Woodpecker	11-Oct	---	14-Oct	---	18-Oct	2
Sora	1-Sep	10-Oct	14-Oct	18-Oct	10-Nov	63
Marsh Wren	15-Sep	12-Oct	14-Oct	16-Oct	3-Nov	161
Pied-billed Grebe	12-Sep	11-Oct	14-Oct	18-Oct	1-Nov	30
Rose-breasted Grosbeak	30-Aug	10-Oct	14-Oct	19-Oct	21-Oct	28
Green-tailed Towhee	24-Sep	---	15-Oct	---	31-Oct	3
Virginia Rail	30-Sep	4-Oct	16-Oct	28-Oct	16-Nov	8
Northern Mockingbird	14-Aug	8-Oct	16-Oct	25-Oct	8-Nov	35
Mourning Dove	22-Aug	15-Oct	17-Oct	18-Oct	16-Nov	603

Table 9.4.

Species-specific timing of fall trans-Gulf migration in 1999

Species are listed in order from earliest to latest migrants (based on mean date). Sample sizes indicate total numbers of individuals of each species recorded over the entire season, including both stopovers and flyby migrants. 95% confidence intervals are calculated only for sample sizes ≥ 5.

Species	First Date	95% CI Lower Bound	Mean Date	95% CI Upper Bound	Last Date	N
Lesser Nighthawk	7-Sep	24-Sep	17-Oct	8-Nov	11-Nov	6
Gray Catbird	8-Sep	14-Oct	17-Oct	19-Oct	16-Nov	75
Yellow-shafted Flicker	30-Sep	7-Oct	17-Oct	26-Oct	5-Nov	9
Scissor-tailed Flycatcher	21-Sep	15-Oct	17-Oct	19-Oct	1-Nov	66
Common Ground-Dove	30-Sep	14-Oct	17-Oct	21-Oct	13-Nov	29
Blackpoll Warbler	12-Oct	---	17-Oct	---	27-Oct	4
Blue-headed Vireo	23-Sep	29-Sep	17-Oct	5-Nov	2-Nov	5
Black-throated Green Warbler	2-Sep	16-Oct	17-Oct	19-Oct	3-Nov	181
Indigo Bunting	26-Sep	16-Oct	17-Oct	19-Oct	12-Nov	152
Black-bellied Whistling Duck	---	---	18-Oct	---	---	1
Black-necked Stilt	---	---	18-Oct	---	---	1
Broad-winged Hawk	---	---	18-Oct	---	---	1
Couch's Kingbird	---	---	18-Oct	---	---	1
Short-eared Owl	---	---	18-Oct	---	---	1
American Bittern	9-Oct	---	18-Oct	---	27-Oct	4
Ruby-crowned Kinglet	10-Sep	15-Oct	18-Oct	21-Oct	17-Nov	128
American Coot	18-Oct	17-Oct	18-Oct	19-Oct	22-Oct	11
Reddish Egret	---	---	19-Oct	---	---	1
Yellow Rail	---	---	19-Oct	---	---	1
Long-billed Thrasher	1-Oct	---	19-Oct	---	14-Nov	3
Common Snipe	23-Sep	8-Oct	19-Oct	31-Oct	13-Nov	11
Burrowing Owl	18-Oct	17-Oct	20-Oct	22-Oct	23-Oct	6
White-breasted Nuthatch	---	---	21-Oct	---	---	1
Yellow-bellied Sapsucker	18-Oct	---	21-Oct	---	24-Oct	2
King Rail	11-Oct	---	21-Oct	---	1-Nov	2
American Wigeon	29-Sep	12-Sep	21-Oct	29-Nov	15-Nov	7
Brown-headed Cowbird	13-Aug	12-Oct	21-Oct	30-Oct	16-Nov	31
Northern Harrier	4-Oct	10-Oct	21-Oct	2-Nov	12-Nov	7
Great-tailed Grackle	---	---	22-Oct	---	---	1
Spotted Towhee	---	---	22-Oct	---	---	
Bronzed Cowbird	11-Oct	---	22-Oct	---	2-Nov	2
Chipping Sparrow	30-Aug	16-Oct	22-Oct	28-Oct	16-Nov	38
Sage Thrasher	---	---	23-Oct	---	---	1
Lincoln's Sparrow	20-Sep	21-Oct	23-Oct	25-Oct	17-Nov	135
Boat-tailed Grackle	---	---	24-Oct	---	---	1
Sedge Wren	10-Oct	20-Oct	24-Oct	27-Oct	3-Nov	17
White-winged Dove	14-Sep	22-Oct	24-Oct	25-Oct	16-Nov	197

Table 9.4.

Species-specific timing of fall trans-Gulf migration in 1999

Species are listed in order from earliest to latest migrants (based on mean date). Sample sizes indicate total numbers of individuals of each species recorded over the entire season, including both stopovers and flyby migrants. 95% confidence intervals are calculated only for sample sizes ≥ 5.

Species	First Date	95% CI Lower Bound	Mean Date	95% CI Upper Bound	Last Date	N
Barn Owl	18-Oct	14-Oct	24-Oct	3-Nov	3-Nov	5
Eastern Meadowlark	10-Oct	21-Oct	25-Oct	28-Oct	14-Nov	21
Northern Shoveler	7-Sep	1-Oct	25-Oct	19-Nov	1-Nov	7
Eastern Phoebe	1-Oct	23-Oct	25-Oct	28-Oct	16-Nov	41
Surf Scoter	---	---	26-Oct	---	---	1
Hermit Thrush	17-Oct	20-Oct	26-Oct	31-Oct	3-Nov	7
Winter Wren	10-Oct	21-Oct	26-Oct	31-Oct	3-Nov	11
Orange-crowned Warbler	5-Oct	23-Oct	26-Oct	29-Oct	16-Nov	57
Common Moorhen	17-Oct	---	27-Oct	---	1-Nov	3
Slate-colored Junco	15-Oct	---	27-Oct	---	7-Nov	4
Western Meadowlark	17-Oct	24-Oct	27-Oct	30-Oct	14-Nov	30
Killdeer	17-Oct	16-Oct	28-Oct	8-Nov	15-Nov	8
Golden-crowned Kinglet	21-Oct	23-Oct	28-Oct	2-Nov	3-Nov	8
Swamp Sparrow	5-Oct	25-Oct	28-Oct	1-Nov	16-Nov	41
Grasshopper Sparrow	30-Sep	26-Oct	28-Oct	31-Oct	16-Nov	77
Northern Pintail	23-Oct	19-Oct	29-Oct	7-Nov	16-Nov	15
Pyrrhuloxia	22-Oct	25-Oct	29-Oct	1-Nov	2-Nov	10
Brewer's Blackbird	23-Oct	---	29-Oct	---	2-Nov	4
unid. Meadowlark	7-Oct	27-Oct	30-Oct	1-Nov	4-Nov	37
Vesper Sparrow	14-Oct	25-Oct	30-Oct	4-Nov	12-Nov	12
White-crowned Sparrow	20-Oct	26-Oct	30-Oct	4-Nov	12-Nov	11
Savannah Sparrow	16-Sep	28-Oct	30-Oct	1-Nov	17-Nov	109
American Avocet	---	---	31-Oct	---	---	1
Say's Phoebe	---	---	31-Oct	---	---	1
Sprague's Pipit	---	---	31-Oct	---	---	1
Mallard	23-Oct	---	31-Oct	---	16-Nov	2
American Goldfinch	---	---	1-Nov	---	---	1
Pine Siskin	---	---	1-Nov	---	---	1
Pink-sided Junco	---	---	1-Nov	---	---	1
Gray-headed Junco	1-Nov	---	1-Nov		1-Nov	2
Greater White-fronted Goose	1-Nov	30-Oct	1-Nov	2-Nov	2-Nov	9
Gadwall	31-Oct	31-Oct	1-Nov	2-Nov	2-Nov	6
Eastern Towhee	23-Oct	---	1-Nov	---	11-Nov	2
Ring-necked Duck	---	---	2-Nov	---	---	1
Ross's Goose	---	---	2-Nov	---	---	1
Redhead	2-Nov	---	2-Nov	---	2-Nov	2
Myrtle Warbler	12-Oct	31-Oct	2-Nov	3-Nov	17-Nov	157
Lesser Scaup	23-Oct	24-Oct	2-Nov	11-Nov	15-Nov	19

Table 9.4.

Species-specific timing of fall trans-Gulf migration in 1999

Species are listed in order from earliest to latest migrants (based on mean date). Sample sizes indicate total numbers of individuals of each species recorded over the entire season, including both stopovers and flyby migrants. 95% confidence intervals are calculated only for sample sizes ≥ 5.

Species	First Date	95% CI Lower Bound	Mean Date	95% CI Upper Bound	Last Date	N
White-throated Sparrow	11-Oct	30-Oct	2-Nov	6-Nov	16-Nov	28
Field Sparrow	24-Oct	27-Oct	2-Nov	9-Nov	16-Nov	8
Henslow's Sparrow	---	---	3-Nov	---	---	1
Short-eared/Long-eared Owl	3-Nov	---	3-Nov	---	3-Nov	2
Long-eared Owl	24-Oct	---	3-Nov	---	16-Nov	4
Song Sparrow	21-Oct	30-Oct	3-Nov	7-Nov	17-Nov	25
American Pipit	21-Oct	25-Oct	3-Nov	12-Nov	16-Nov	8
Pine Warbler	20-Oct	28-Oct	3-Nov	10-Nov	17-Nov	13
LeConte's Sparrow	2-Nov		4-Nov		8-Nov	4
Snow Goose	22-Oct	27-Oct	5-Nov	14-Nov	16-Nov	19
Tree Swallow	2-Nov	2-Nov	6-Nov	9-Nov	15-Nov	12
Chestnut-collared Longspur	1-Nov	---	6-Nov	---	12-Nov	2
Hooded Merganser	---	---	8-Nov	---	---	1
Nelson's Sharp-tailed Sparrow	2-Nov	---	9-Nov	---	16-Nov	2
American Robin	3-Nov	8-Nov	13-Nov	18-Nov	17-Nov	7
Ash-throated Flycatcher	---	---	15-Nov	---	---	1
Lesser Goldfinch	---	---	15-Nov	---	---	1
Red-breasted Merganser	---	---	17-Nov	---	---	1

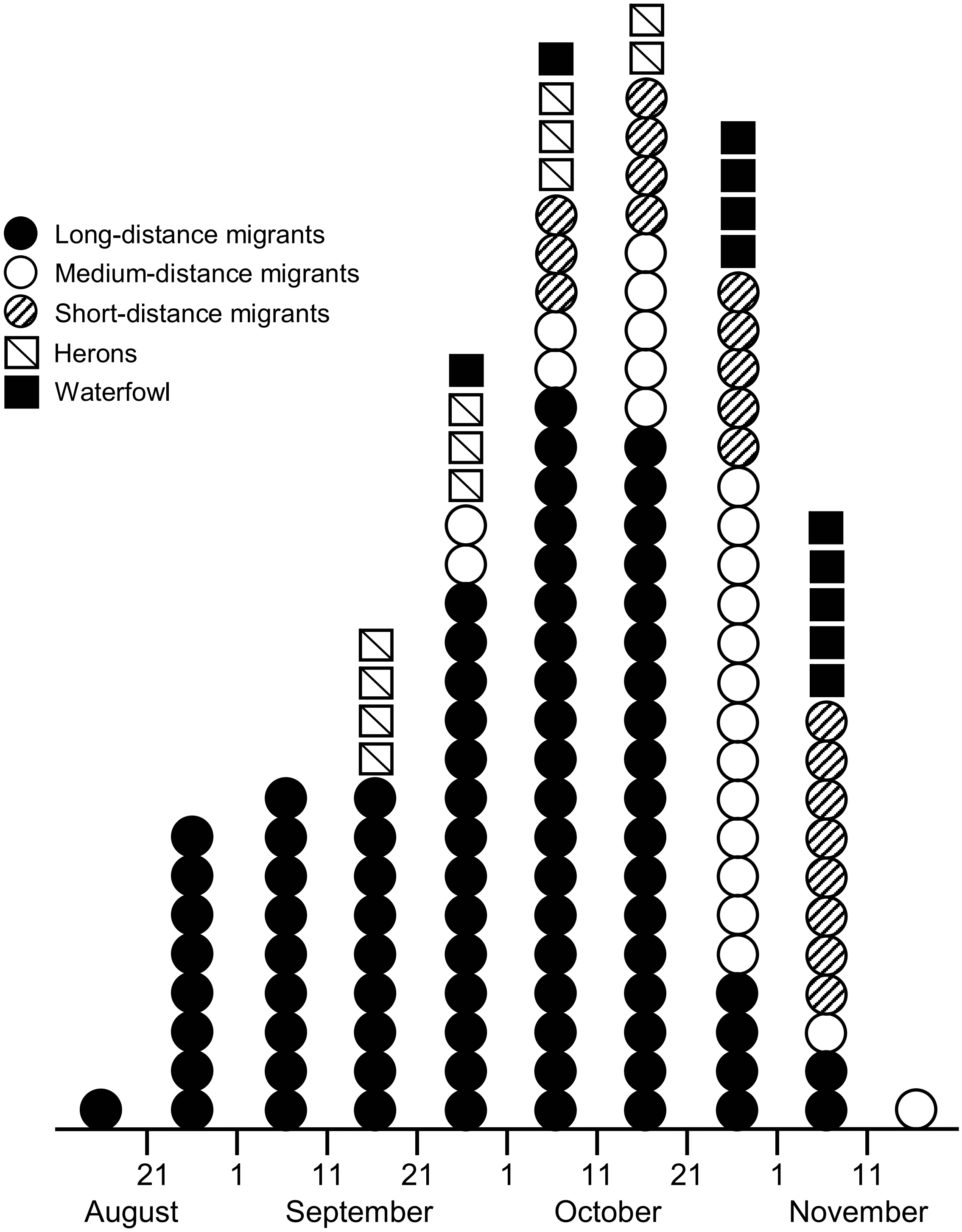


Figure 9.25. Frequency distribution of species-specific peak fall arrival times in 1999. Each symbol indicates the mean date of occurrence for one of the species listed in Table 9.4. "Long-distance migrants" includes aerial insectivores and diurnal raptors. Species represented by single observations are not included.

Chapter 10

Fall Trans-Gulf Migration and Platform Use by Peregrine Falcons

Robert W. Russell

10.1 INTRODUCTION

Peregrine Falcons (*Falco peregrinus*) proved to be among the most obvious and interesting beneficiaries of the platform archipelago. Populations of this apex predator had declined precipitously and approached extinction in parts of its range by the mid-1960's as a result of exposure to the organochlorine pesticide DDT and its breakdown product DDE, which accumulated in fatty tissues and induced reproductive failure by interfering with normal calcium deposition during eggshell formation (reviewed by Kiff 1988). The American and Arctic subspecies (*F. p. anatum* and *F. p. tundrius*) were listed as Endangered in 1970 under the Endangered Species Conservation Act of 1969 (which preceded the Endangered Species Act of 1973), and DDT was banned in the United States starting in 1973. After reaching a nadir of as few as 324 nesting pairs by 1975 (Fyfe et al. 1976), the continental population subsequently rebounded by over two orders of magnitude to perhaps 59,000 individuals in the mid-1980s (Cade et al. 1988). The Arctic subspecies was officially downgraded from Endangered to Threatened in 1984, and was delisted altogether in 1994; removal of the American subspecies from the endangered species list followed in 1999 (U.S. Fish and Wildlife Service 1999).

This chapter documents the migration ecology of Peregrine Falcons and their use of Gulf platforms during the fall 1999 field season, when we achieved our most extensive geographical and seasonal coverage. All patterns were similar or identical in other years.

10.2 SEASONAL TIMING

The seasonal timing of Peregrine trans-Gulf migration was highly compressed into the period from late September to mid-October (Figure 10.1). 60% of all recorded individuals were initially detected in the 2-week period from September 29-October 12.

10.3 POPULATION STRUCTURE

Among 284 individuals that could be identified to age and sex, 61% were male (♂:♀= 1.6:1) and 60% were juveniles (HY:AHY = 1.5:1). There were significant seasonal and geographical differences among the age-sex classes in patterns of occurrence. A two-way ANOVA on Julian day of arrival (Figure 10.1) indicated that adults arrived earlier than juveniles ($F_{1,280} = 15.3$, $P < 0.001$) and that females arrived earlier than males ($F_{1,280} = 4.62$, $P = 0.032$), with no interaction between age and sex ($F_{1,280} = 0.14$, $P = 0.71$). However, the absolute differences in seasonal timing were minor: there was only a week's difference between peak arrival of the earliest (AHY ♀ = October 2) and latest (HY ♂ = October 9) age-sex classes. Interestingly, there was a significant longitudinal gradient in sex ratio, with a female bias toward the east and a male bias toward the west (Figure 10.2). Overall sex ratio did not differ between the age classes in the population we sampled ($G = 2.1$, $df = 1$, $P = 0.15$).

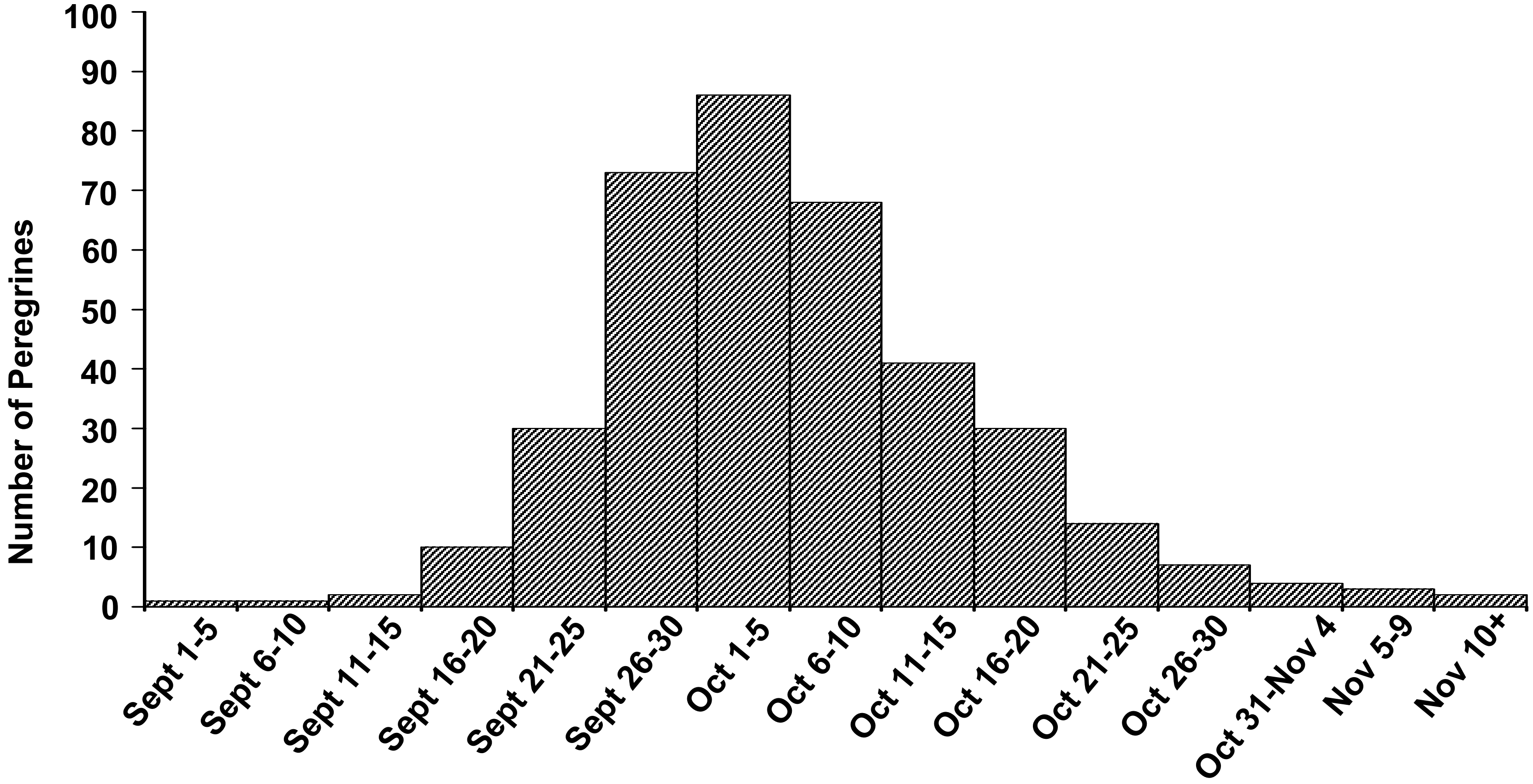


Figure 10.1. Frequency distribution of the dates of initial detection of all 372 Peregrine Falcons recorded during the fall 1999 season. The sample includes both platform stopovers and flybys.

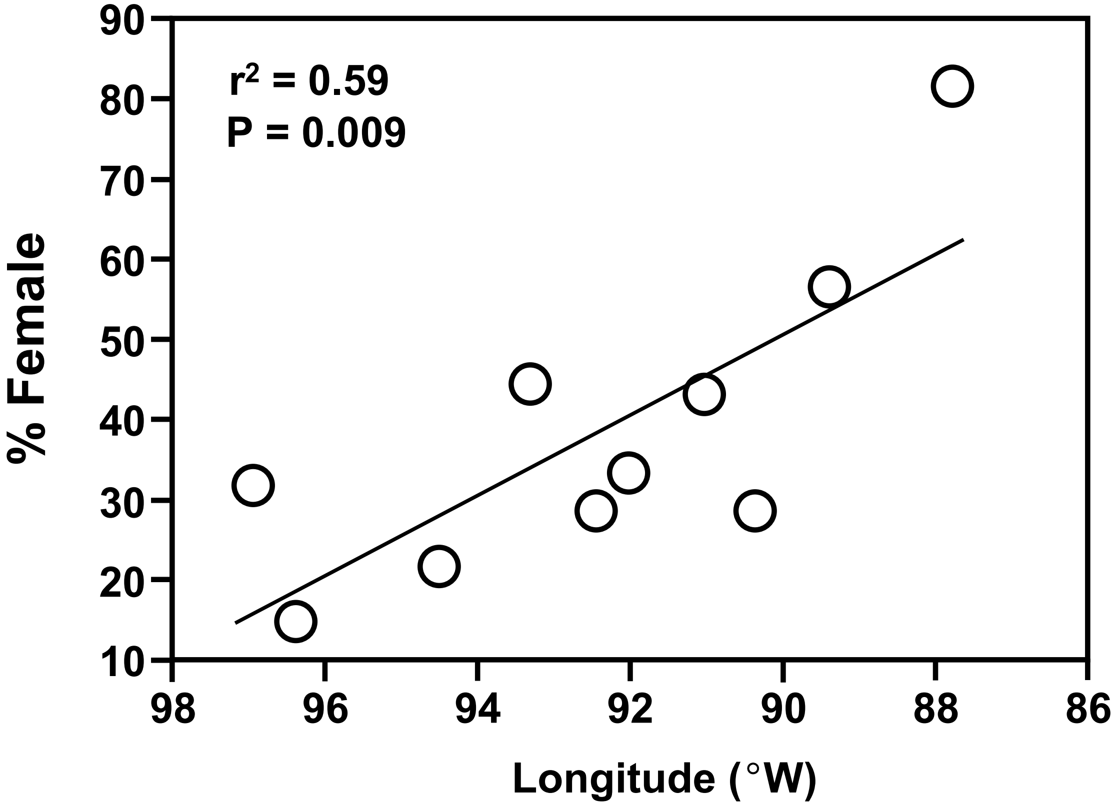


Figure 10.2. Longitudinal trend in sex ratios of Peregrine Falcons in fall 1999.

10.4 POPULATION SIZE

We documented 273 Peregrines using our 10 study platforms in fall 1999. There was substantial variation among platforms (range = 5-63 birds per platform; Figure 10.3), with falcons tending to favor larger platforms with taller towers.

Based on our direct observations and interviews with platform workers, fishermen, and supply boat personnel from all parts of the Gulf, it is certain that virtually every "major" platform complex in the Gulf (i.e., excluding complexes consisting of caissons with fewer than six completions and three pieces of production equipment) hosts Peregrines during peak migration periods. Our platforms constituted a representative sample of the major platform space (i.e., we selected a range of platform types and sizes for the study). According to the latest MMS database (Minerals Management Service 2004), there were 2434 major platform complexes in the northern Gulf of Mexico as of October 1, 1999. A simple extrapolation of our results to the total platform space yields a population estimate of more than 66,000 Peregrines using platforms during the entire fall migration.

While most individuals remained on or in the immediate vicinity of one platform complex during their stopovers, we sometimes noted birds patrolling nearby platforms. Thus, our straightforward estimate of 27.3 Peregrines per platform per season is probably too liberal for extrapolation because of replication among platforms, though we have no direct data bearing on the degree of multiple platform use.

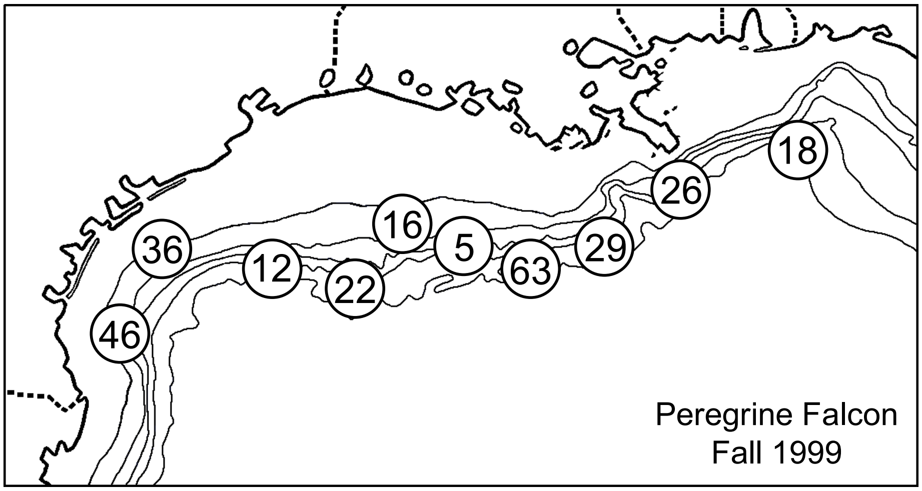


Figure 10.3. Numbers of Peregrines undertaking stopovers on each of the 10 study platforms in fall 1999.

An extreme lower bound for a population estimate can be obtained by assessing the number of unique individuals that could be accounted for during a short period. During the peak 3-day period in fall 1999 (September 29-October 1), we recorded 45 unique individuals using our 10 platforms. Extrapolation yields an instantaneous point estimate of about 11,000 Peregrines on platforms throughout the Gulf at that time. This figure is very conservative because it only considers birds in the Gulf at the peak of the migration (cf. Figure 10.1), and also because Peregrines also frequently used minor caissons that were excluded from the calculations.

Our observations and extrapolations thus suggest that the number of Peregrines using Gulf platforms during fall 1999 fell somewhere in the range from 11,000-66,000. We were unable to find any very recent estimates of continental Peregrine populations. However, based on an analysis of migration statistics from banding and retrapping, Cade et al. (1988) estimated that in the mid-1980s, the migratory population consisted of 26,000 breeding adults, 13,000 nonbreeders, and 20,000 young of the year — i.e., a total population size of 59,000. This estimated population size is larger than the number of migrants that could potentially use platforms because it includes a component from western North America that probably does not routinely cross the Gulf of Mexico, and it does not account for an estimated 15-20% mortality of juveniles before reaching trapping points south of Canada (Cade et al. 1988).

It is also noteworthy that juveniles comprised 60% of the population of Peregrines on Gulf platforms, compared to a maximum of ~34% in the hypothetical total migratory population (Cade et al. 1988). This discrepancy indicates that proportionally more adults may use routes that avoid trans-Gulf crossings, or that adults are less likely than juveniles to use platforms. The former explanation is supported by radiotelemetry work suggesting that Peregrines traveling offshore along the Atlantic seaboard in the fall are predominantly adult males (Cochran 1985).

Despite the considerable uncertainty involved in both our estimates and the estimates of Cade et al. (1988), it is clear that a substantial portion of the North American population of Peregrine Falcons — and perhaps a majority of the juveniles — now uses Gulf platforms during fall migration.

10.5 PLATFORM USE

Peregrines typically arrived on platforms in the afternoon and stayed up to several days, hunting primarily at night when most migrant landbirds were aloft. Peregrines took avian prey of a wide variety (at least 69 species; Table 10.1) and of all sizes, but relied almost entirely on migrants rather than local marine birds (which comprised only 1% of all prey items) and clearly favored larger species. In addition to the avian prey listed in Table 10.1, Peregrines also frequently captured and consumed migrating green darners (*Anax junius*).

Of the 389 avian prey items in our total sample, 92 were known to have been taken by individual Peregrines identifiable to sex. Based on this sample, avian prey items taken by male Peregrines had a median body mass of 48 g compared to a median body mass of 112 g for prey taken by females (Figure 10.4); this difference was statistically significant (Mann-Whitney U = 1374, P = 0.006). Also, all Peregrines observed preying on migrant dragonflies were males.

Table 10.1.

Avian prey species taken by Peregrine Falcons using offshore platforms during fall migration

Total sample consisted of 389 prey items from 1998-2000.

Prey Species	N	Proportion of Prey Items
Sora	41	0.105
unid. passerine	34	0.087
Gray Catbird	23	0.059
Lincoln's Sparrow	23	0.059
Yellow-billed Cuckoo	23	0.059
Mourning Dove	22	0.057
White-winged Dove	17	0.044
Scissor-tailed Flycatcher	15	0.039
Purple Gallinule	12	0.031
Upland Sandpiper	11	0.028
Common Snipe	9	0.023
Common Yellowthroat	9	0.023
unid. warbler	9	0.023
Pied-billed Grebe	8	0.021
Wood Thrush	8	0.021
House Wren	7	0.018
Magnolia Warbler	6	0.015
unid. sparrow	6	0.015
Blue-winged Teal	5	0.013
Belted Kingfisher	4	0.010
Rose-breasted Grosbeak	4	0.010
Yellow-breasted Chat	4	0.010
unid. shorebird	4	0.010
Chuck-Will's-Widow	3	0.008
Black-billed Cuckoo	3	0.008
unid. dove	3	0.008
Indigo Bunting	3	0.008
Nashville Warbler	3	0.008

Table 10.1.

Avian prey species taken by Peregrine Falcons using offshore platforms during fall migration

Total sample consisted of 389 prey items from 1998-2000.

		Proportion of
Ovenbird	3	0.008
Yellow-bellied Sapsucker	3	0.008
American Kestrel	3	0.008
Baird's Sandpiper	2	0.005
Brown Thrasher	2	0.005
Cattle Egret	2	0.005
Eastern Kingbird	2	0.005
Eastern Wood-Pewee	2	0.005
Greater Yellowlegs	2	0.005
Long-billed Dowitcher	2	0.005
Least Bittern	2	0.005
Northern Mockingbird	2	0.005
Ruby-crowned Kinglet	2	0.005
Summer Tanager	2	0.005
unid. meadowlark	2	0.005
Western Meadowlark	2	0.005
White-eyed Vireo	2	0.005
Wilson's Warbler	2	0.005
American Redstart	1	0.003
Black Tern	1	0.003
Black-throated Blue Warbler	1	0.003
Clay-colored Sparrow	1	0.003
Chimney Swift	1	0.003
Common Ground-Dove	1	0.003
Flammulated Owl	1	0.003
Grasshopper Sparrow	1	0.003
Hooded Warbler	1	0.003
Inca Dove	1	0.003
Least Sandpiper	1	0.003
Lesser Yellowlegs	1	0.003
Myrtle Warbler	1	0.003
Northern Waterthrush	1	0.003
Northern Rough-winged Swallow	1	0.003
Prairie Warbler	1	0.003
Red-shafted Flicker	1	0.003
Sanderling	1	0.003
Sandwich Tern	1	0.003
Short-billed Dowitcher	1	0.003
unid. storm-petrel	1	0.003
Stilt Sandpiper	1	0.003
Swainson's Thrush	1	0.003
Tree Swallow	1	0.003
Sooty/Bridled Tern	1	0.003

Table 10.1.

Avian prey species taken by Peregrine Falcons using offshore platforms during fall migration

Total sample consisted of 389 prey items from 1998-2000.

		Proportion of
unid. flycatcher	1	0.003
Veery	1	0.003
Western Tanager	1	0.003
Yellow-shafted Flicker	1	0.003
Least Grebe	1	0.003
Yellow-throated Vireo	1	0.003

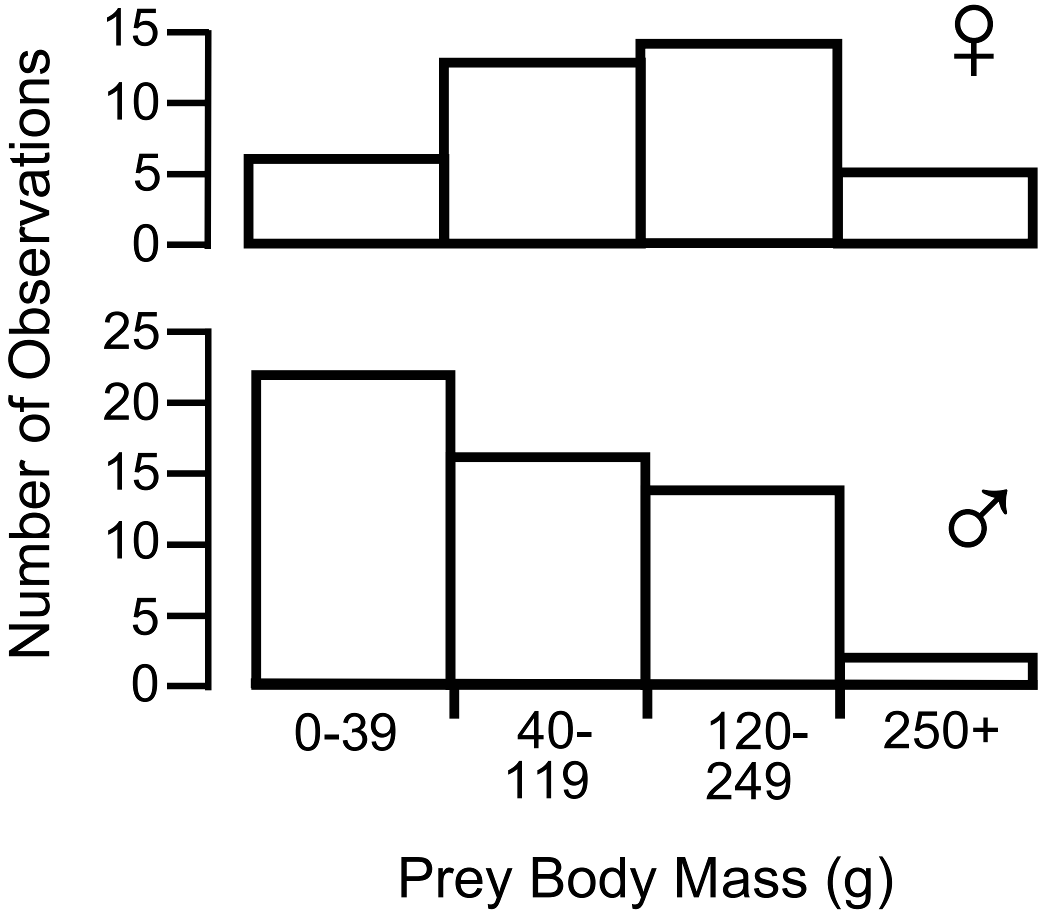


Figure 10.4. Comparison of body masses of prey taken during the fall by male and female Peregrine Falcons. Data from three seasons (1998-2000) are combined.

10.6 FLIGHT STRATEGIES

Among 44 individuals observed in high-altitude, direct migratory flight, vanishing bearings were significantly oriented toward the southwest (Figure 10.5; $\bar{x} = 218°$, 95% CI = 203°-232°, r = 0.70, Rayleigh P << 0.001), suggesting that many or most of the birds we saw were destined for the western shore of the Gulf of Mexico (as opposed to Cuba or the Yucatan Peninsula). Most Peregrines arrived on platforms or were observed flying by platforms after early morning. This pattern differed dramatically from the daily pattern of arrival of most trans-Gulf migrant passerines (Figure 10.6), indicating that Peregrines usually departed the northern Gulf coast during hours of daylight.

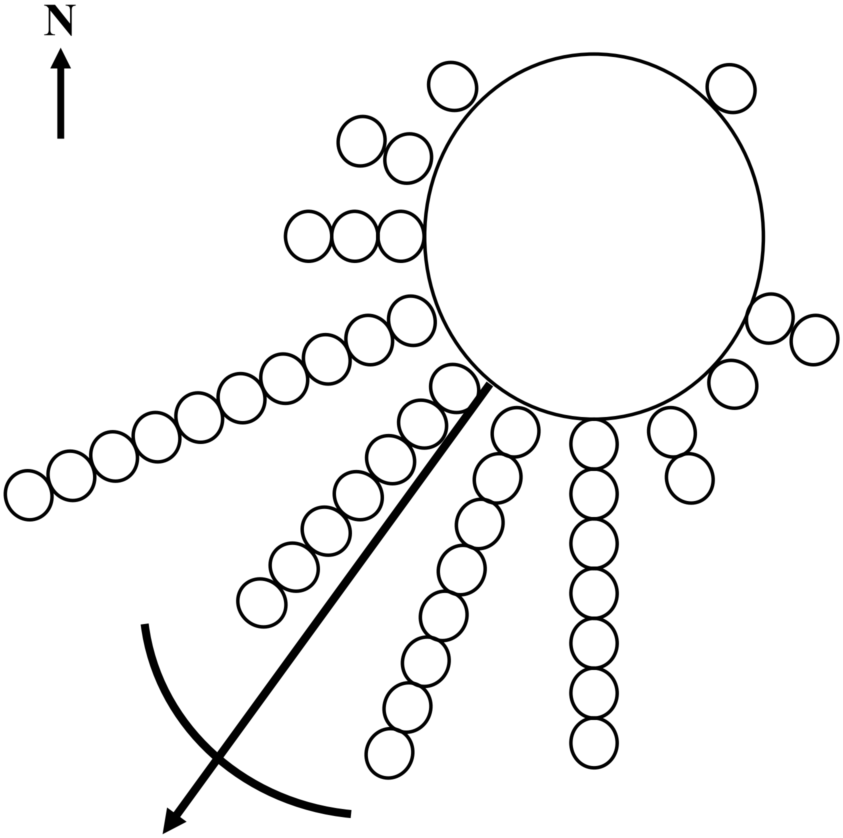


Figure 10.5. Vanishing bearings of Peregrine Falcons in fall 1999. The long arrow indicates the mean angle of the sample, and the arc shows the 95% confidence interval around the mean.

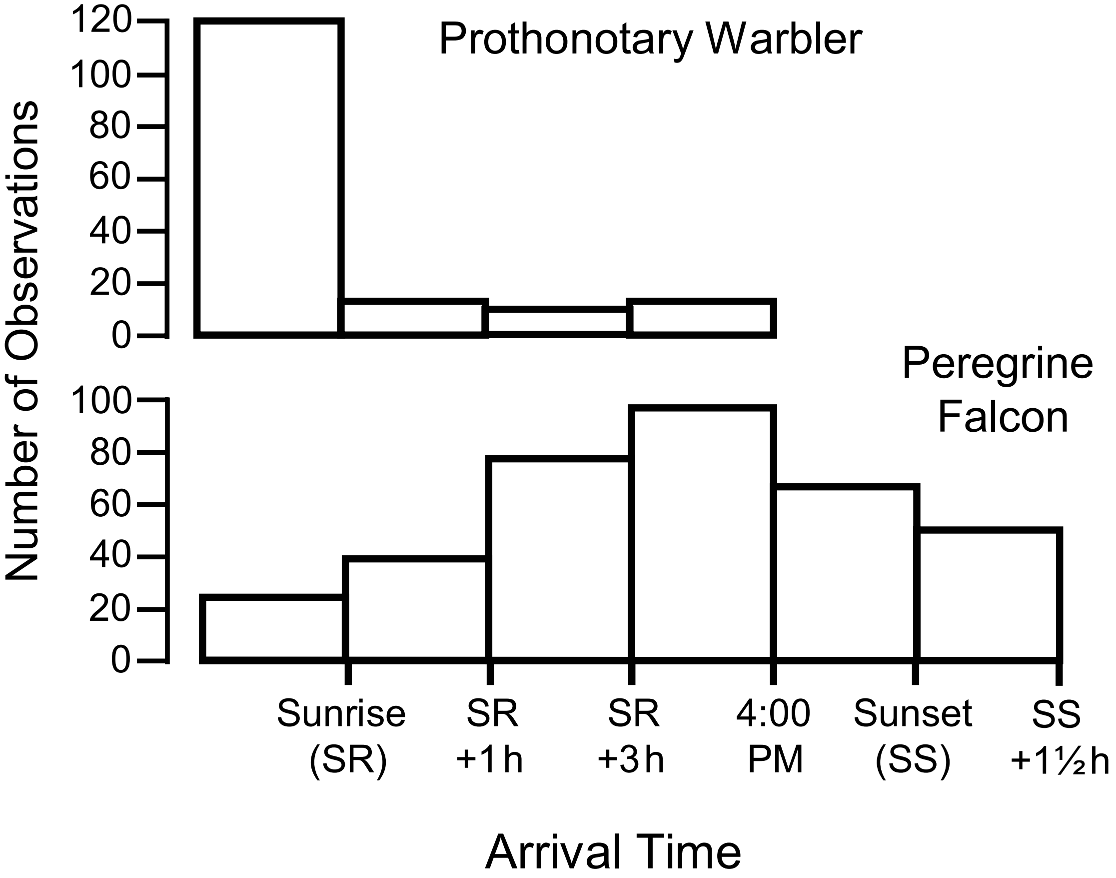


Figure 10.6. Comparison of arrival times of Peregrines and a representative trans-Gulf migrant passerine in fall 1999.

10.7 POSSIBLE SELECTIVE INFLUENCE OF PLATFORMS

This study showed that large numbers of Peregrine Falcons — including perhaps the majority of North American juveniles — now undertake stopovers on Gulf platforms for resting and hunting during fall migration. Peak migration occurred during a well-defined period from late September through mid-October. Because of their high success preying on nocturnal migrant landbirds, it seems that Peregrines are now "anticipating" ephemeral periods of high resource availability on platforms. It is possible that this adaptive behavior may be a precursor to more dramatic and perhaps evolutionary changes, and that Peregrines are being influenced by the installation of an artificial archipelago of oil and gas production platforms in the Gulf in a fashion similar to how Eleonora's Falcons (*Falco eleonorae*) have evolved a strategy of breeding on Mediterranean islands during the fall, when abundant trans-Mediterranean migrant landbird prey are available for provisioning young. Wondering why there is no ecological counterpart of Eleonora's Falcon in the Gulf of Mexico region, Walter (1979) concluded that a similar niche does not exist because of the lack of islands. With the explosion of the North American Peregrine population in the last three decades and the concurrent completion of the world's largest artificial archipelago in the Gulf of Mexico, Walter's conclusion may need to be revised in coming decades.

Chapter 11

Synoptic Weather and Vagrancy

Robert W. Russell

One of the interesting results of this study was the discovery of a large number of "vagrants" offshore. Vagrants are individuals that occur well outside of their species' typical geographic range.

Over the course of the study, 29 species were recorded as spring vagrants (Table 11.1). Among the 231 total individuals involved, all were independent occurrences with the exception of three flocks of Bobolinks involving 2, 7, and 29 individuals. In general, spring Caribbean vagrants tended to be more common in the eastern part of the study area, whereas western vagrants tended to be more common toward the west. In spring 1998 (Figure 11.1), 74% of Caribbean vagrants occurred from the South Marsh Island platform eastward, whereas 86% of western vagrants were recorded west of South Marsh Island ($G = 25.5$, $df = 1$, $P < 0.0001$). The pattern was similar in spring 1999 (Figure 11.2), except a higher percentage of western vagrants occurred in the eastern part of the study area (44%, compared to 71% of Caribbean vagrants), and the difference was not significant ($G = 2.1$, $df = 1$, $P = 0.15$). In spring 2000 (Figure 11.3), 55% of Caribbean vagrants occurred from the South Marsh Island platform eastward, whereas 92% of western vagrants were recorded west of South Marsh Island ($G = 23.8$, $df = 1$, $P < 0.0001$). Most spring vagrants were males (Table 11.1).

Geographic patterns of vagrancy were similar in the fall, when 42 species were recorded as vagrants (Table 11.2). As in spring, Caribbean vagrants tended to be more common in the eastern part of the study area, whereas western vagrants tended to be more common toward the west. In fall 1998 (Figure 11.4), 76% of Caribbean vagrants occurred from the South Marsh Island platform eastward, whereas 83% of western vagrants were recorded west of South Marsh Island ($G = 7.5$, $df = 1$, $P = 0.006$). The pattern was similar in fall 1999 (Figure 11.5): 61% of Caribbean vagrants occurred from the South Marsh Island platform eastward, whereas 89% of western vagrants were recorded west of South Marsh Island ($G = 47.0$, $df = 1$, $P << 0.0001$).

Adequate samples of vanishing bearings were available for a comparison of the orientation of western vagrants and Caribbean vagrants in spring and fall (Figure 11.6). During the fall, vanishing bearings of both western and Caribbean vagrants were random. In the spring, both western and Caribbean vagrants were significantly oriented toward the NNW. There was no significant difference between vanishing bearings of western and Caribbean vagrants in the spring (Watson-Williams test: $F_{1,30} = 0.16$, $P = 0.69$).

Table 11.1.

Spring vagrants recorded in 1998-2000

Species are listed in descending order of abundance. Numbers of each sex are shown for species routinely identifiable to sex in the field. Confidence intervals are shown for species with N > 5.

Species	N	♂	♀	Mean Date	95% CI (range)
Bobolink	69	27	13	Apr 27	Apr 24-30 (Apr 18-May 21)
Lesser Nighthawk	45	34	4	Apr 8	Apr 4-13 (Mar 15-May 20)
Western Palm Warbler	30	-----	-----	Apr 20	Apr 14-26 (Mar 18-May 12)
Western Kingbird	13	-----	-----	May 4	Apr 28-May 10 (Apr 20-May 23)
Prairie Warbler	13	9	2	Apr 16	Apr 9-23 (Apr 2-May 5)
Cape May Warbler	10	10	0	Apr 28	Apr 25-May 1 (Apr 21-May 7)
Yellow-headed Blackbird	9	3	6	Apr 24	Apr 13-May 4 (Mar 31-May 11)
Black-throated Blue Warbler	6	5	1	May 10	Apr 28-May 21 (Apr 29-May 28)
Ash-throated Flycatcher	4	-----	-----	Apr 14	----- (Apr 3-21)
Gray Kingbird	3	-----	-----	May 8	----- (Apr 30-May 22)
Brown-crested Flycatcher	3	-----	-----	May 12	----- (May 9-19)
Burrowing Owl	2	-----	-----	Mar 23	----- (Mar 10-Apr 5)
Tropical Kingbird	2	-----	-----	May 10	----- (May 6-14)
Couch's Kingbird	2	-----	-----	May 13	----- (May 6-21)
Tropical/Couch's Kingbird	2	-----	-----	Apr 30	----- (Apr 21-May 9)
Black-whiskered Vireo	2	-----	-----	May 4	----- (May 4-5)
Western Tanager	2	1	1	Apr 18	----- (na)
Audubon's Warbler	2	1	1	Apr 21	----- (Apr 17-25)
Cassin's Sparrow	2	-----	-----	Apr 10	----- (Mar 30-Apr 21)
Band-tailed Pigeon	1	-----	-----	Apr 26	
Cave Swallow	1	-----	-----	May 11	
Violet-green Swallow	1	1	0	Mar 26	
Townsend's Warbler	1	1	0	Apr 8	
Hermit Warbler	1	1	0	Apr 15	
Black-throated Gray Warbler	1	1	0	May 6	
Connecticut Warbler	1	1	0	Apr 30	
Bronzed Cowbird	1	1	0	Mar 31	
Lazuli Bunting	1	1	0	Apr 3	
Varied Bunting	1	1	0	Apr 12	

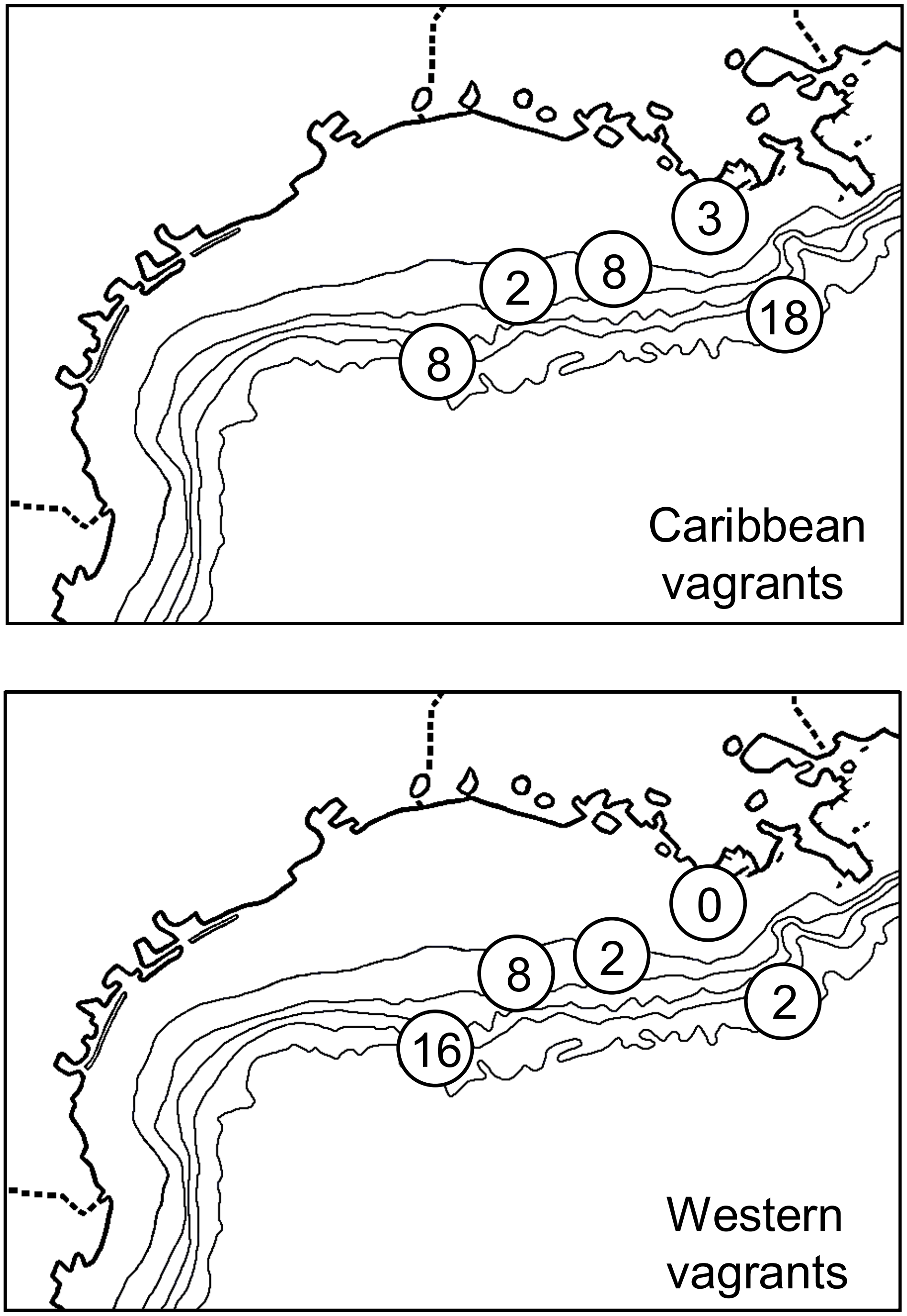


Figure 11.1. Comparative distribution of occurrences of Caribbean vagrants and western vagrants in spring 1998.

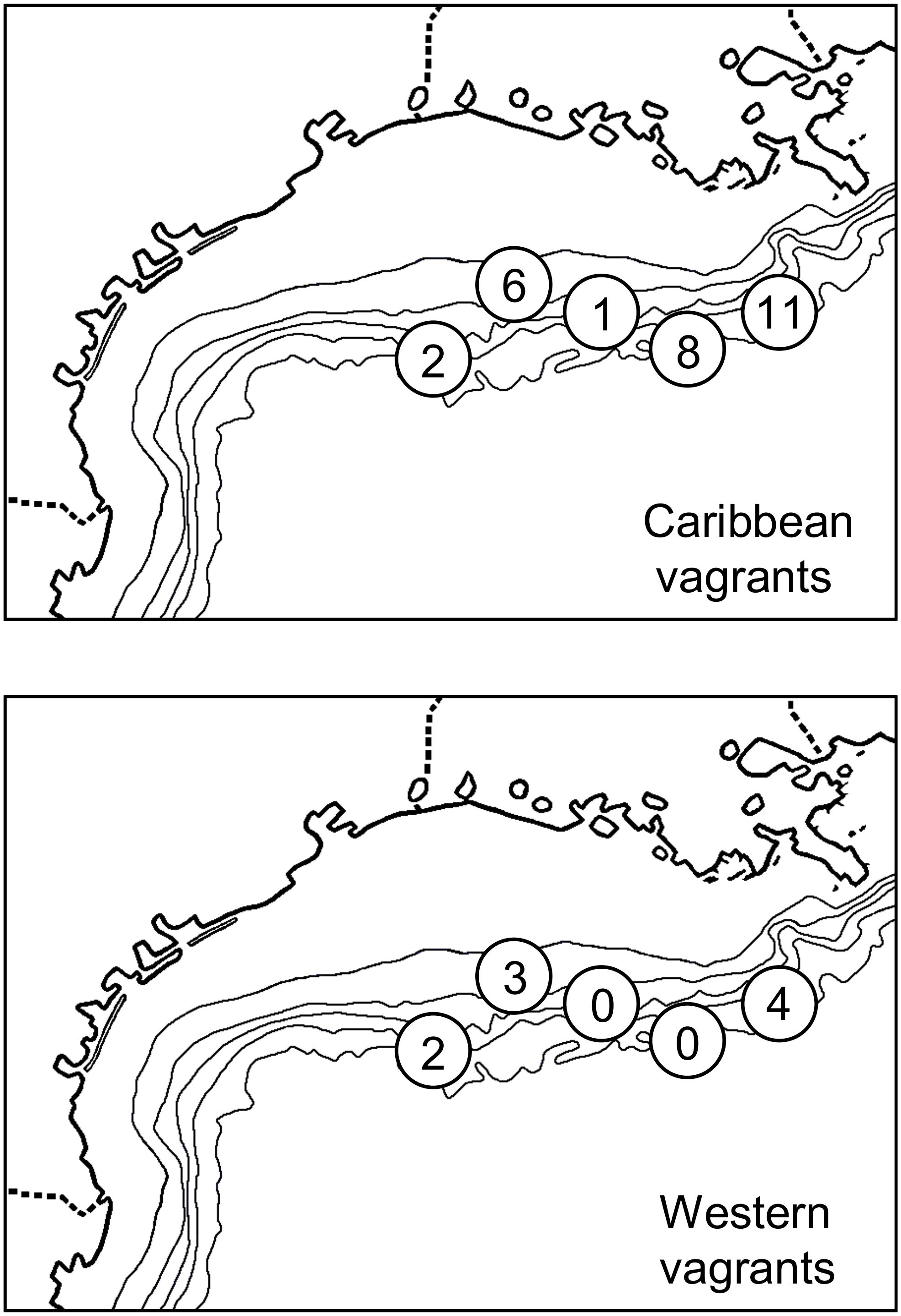
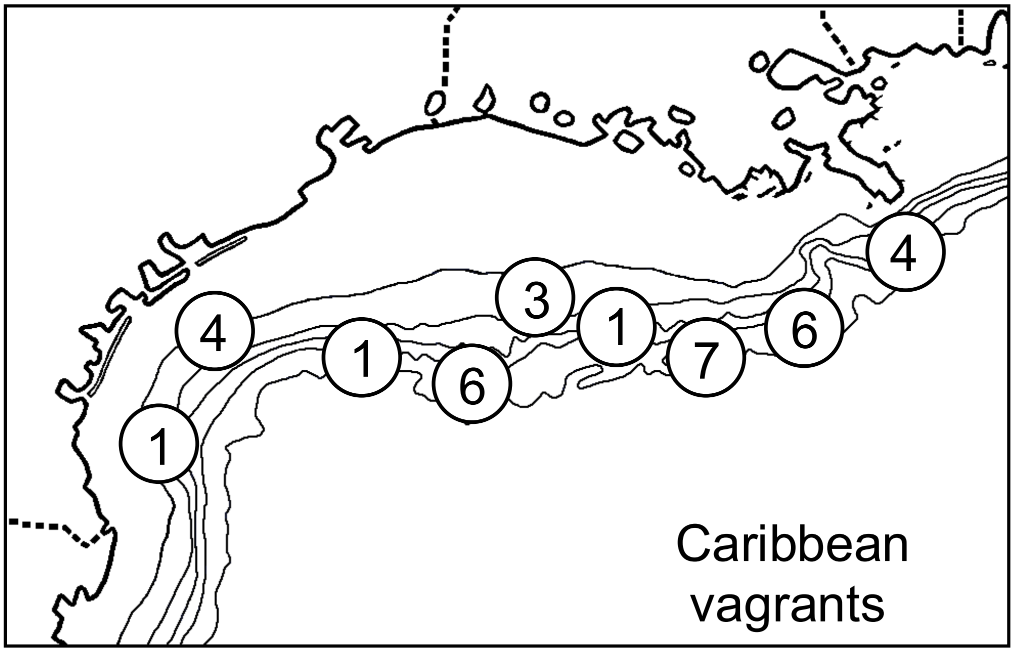


Figure 11.2. Comparative distribution of occurrences of Caribbean vagrants and western vagrants in spring 1999.



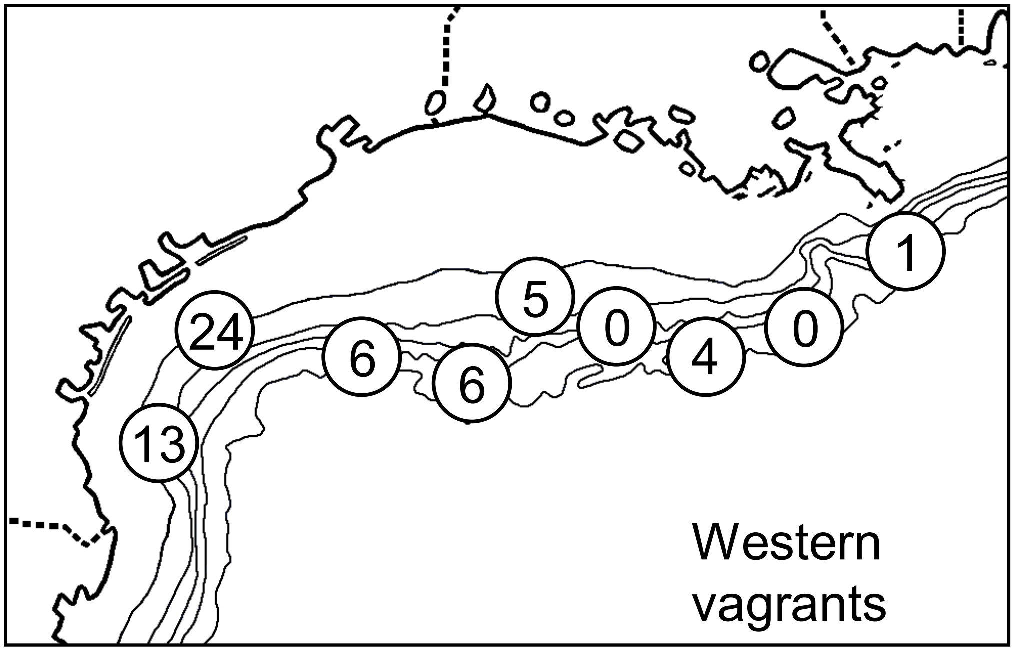


Figure 11.3. Comparative distribution of occurrences of Caribbean vagrants and western vagrants in spring 2000.

Table 11.2.

Fall vagrants recorded in 1998 and 1999

Species are listed in descending order of abundance. Confidence intervals are shown for species with N > 5.

Species	N	Mean Date	95% CI (range)
Prairie Warbler	41	Sept 4	Aug 28-Sept 11 (Aug 6-Nov 3)
Black-throated Blue Warbler	31	Oct 1	Sept 26-Oct 6 (Sept 11-Oct 24)
Lesser Nighthawk	10	Oct 24	Oct 10-Nov 7 (Sept 7-Nov 15)
Pyrrhuloxia	10	Oct 29	Oct 25-Nov 1 (Oct 22-Nov 2)
Bobolink	7	Sept 28	Sept 11-Oct 16 (Sept 7-Oct 27)
Yellow-headed Blackbird	7	Sept 21	Sept 12-Oct 1 (Sept 10-Oct 8)
Burrowing Owl	6	Oct 20	Oct 17-22 (Oct 18-23)
Cape May Warbler	6	Oct 5	Sept 14-Oct 26 (Sept 7-Nov 3)
Cave Swallow	5	Sept 28	----- (Sept 23-Oct 3)
Blackpoll Warbler	4	Oct 17	----- (Oct 12-27)
Groove-billed Ani	3	Sept 20	----- (Sept 8-30)
Western Kingbird	3	Sept 25	----- (Sept 11-Oct 21)
Gray Kingbird	3	Sept 22	----- (Aug 27-Oct 16)
Long-billed Thrasher	3	Oct 19	----- (Oct 1-Nov 14)
Audubon's Warbler	3	Oct 14	----- (Oct 10-21)
MacGillivray's Warbler	3	Sept 2	----- (Aug 25-Sept 7)
Green-tailed Towhee	3	Oct 15	----- (Sept 24-Oct 31)
Cassin's Sparrow	3	Oct 10	----- (Sept 21-Oct 31)
Flammulated Owl	2	Oct 10	----- (Oct 10-11)
Vermilion Flycatcher	2	Oct 1	----- (Sept 22-Oct 11)
Tropical/Couch's Kingbird	2	Sept 2	----- (Aug 19-Sept 17)
Western Wood-Pewee	2	Sept 23	----- (Sept 23-24)
Bell's Vireo	2	Sept 9	----- (Aug 30-Sept 19)
Bronzed Cowbird	2	Oct 22	----- (Oct 11-Nov 2)
Bullock's Oriole	2	Sept 28	----- (Sept 24-Oct 2)
Gray-headed Junco	2	Nov 1	----- (na)
Chestnut-collared Longspur	2	Nov 6	----- (Nov 1-12)
Ringed Kingfisher	1	Aug 5	
Rufous Hummingbird	1	Sept 19	
Black-chinned Hummingbird	1	Sept 9	
Black Swift	1	Oct 8	
Couch's Kingbird	1	Oct 18	
Loggerhead Kingbird	1	Sept 12	

Table 11.2.

Fall vagrants recorded in 1998 and 1999

Species are listed in descending order of abundance. Confidence intervals are shown for species with N > 5.

Species	N	Mean Date	95% CI (range)
Ash-throated Flycatcher	1	Nov 15	
Say's Phoebe	1	Oct 31	
Cuban Pewee	1	Oct 9	
Sage Thrasher	1	Oct 23	
Sprague's Pipit	1	Oct 31	
Townsend's Warbler	1	Oct 11	
Western Tanager	1	Nov 10	
Spotted Towhee	1	Oct 22	
Lesser Goldfinch	1	Nov 15	
Pink-sided Junco	1	Nov 1	

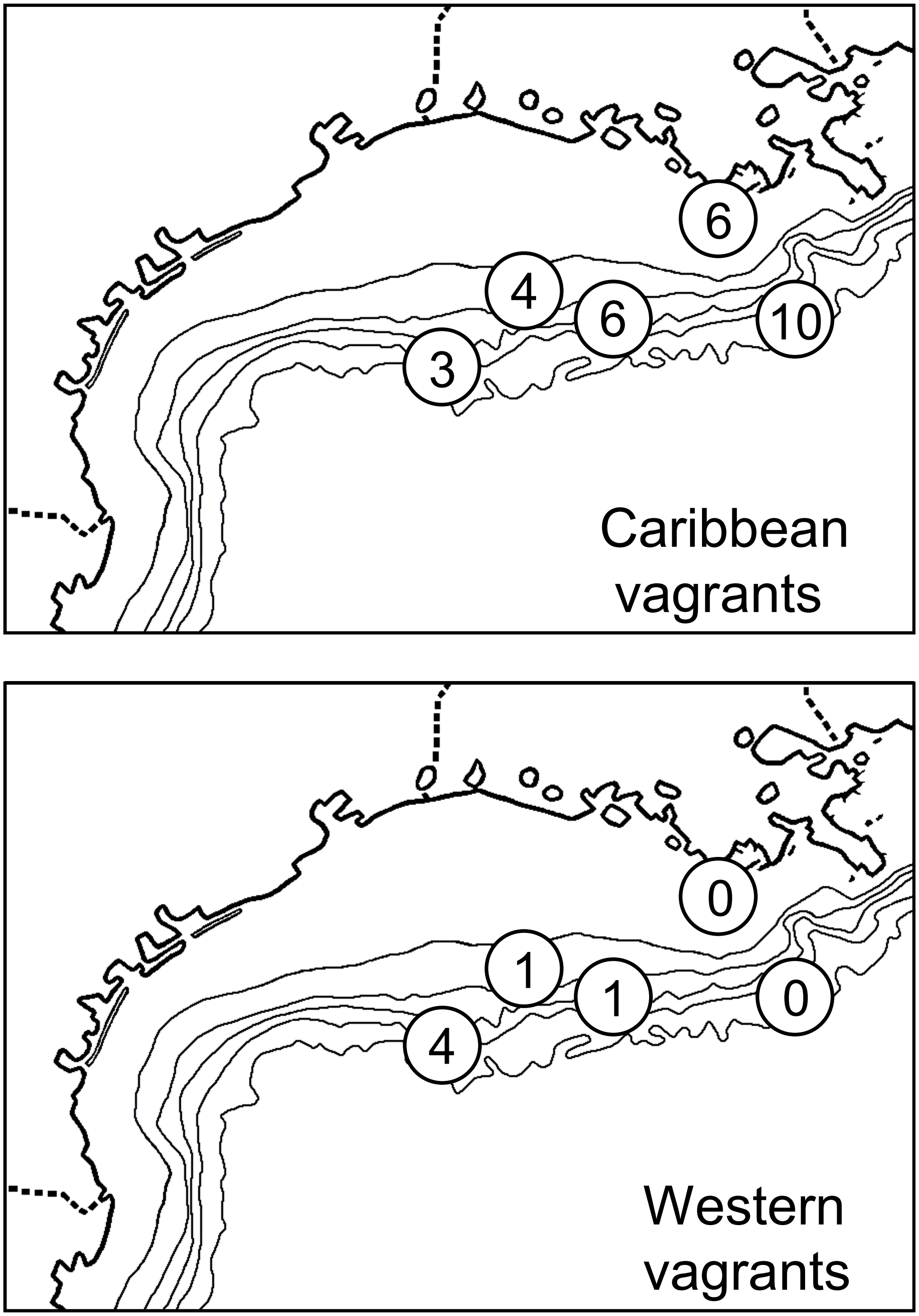
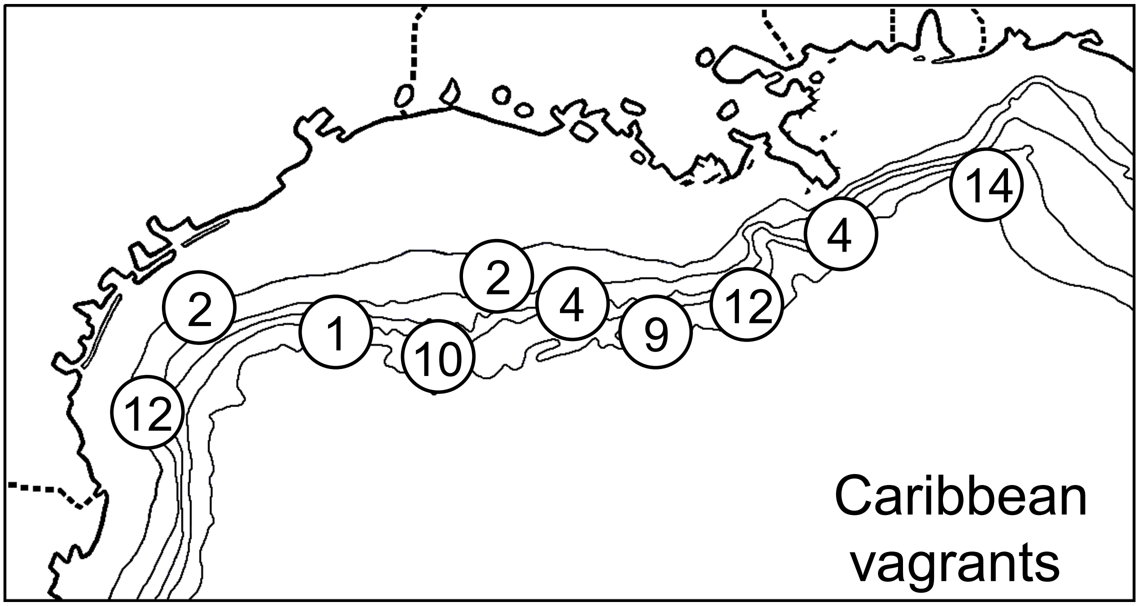


Figure 11.4. Comparative distribution of occurrences of Caribbean vagrants and western vagrants in fall 1998.



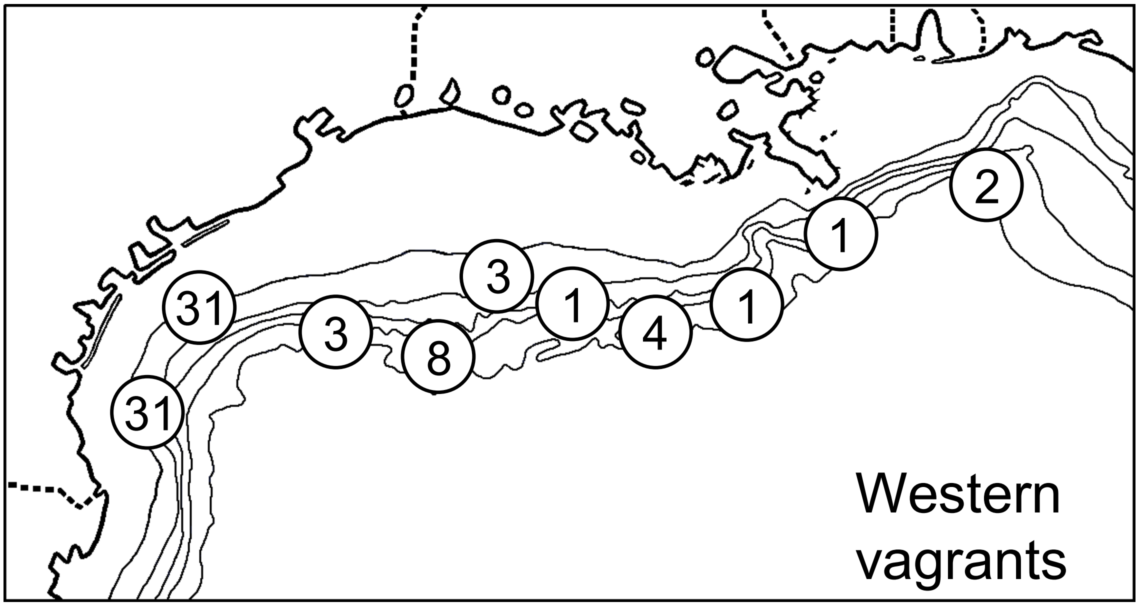


Figure 11.5. Comparative distribution of occurrences of Caribbean vagrants and western vagrants in fall 1999.

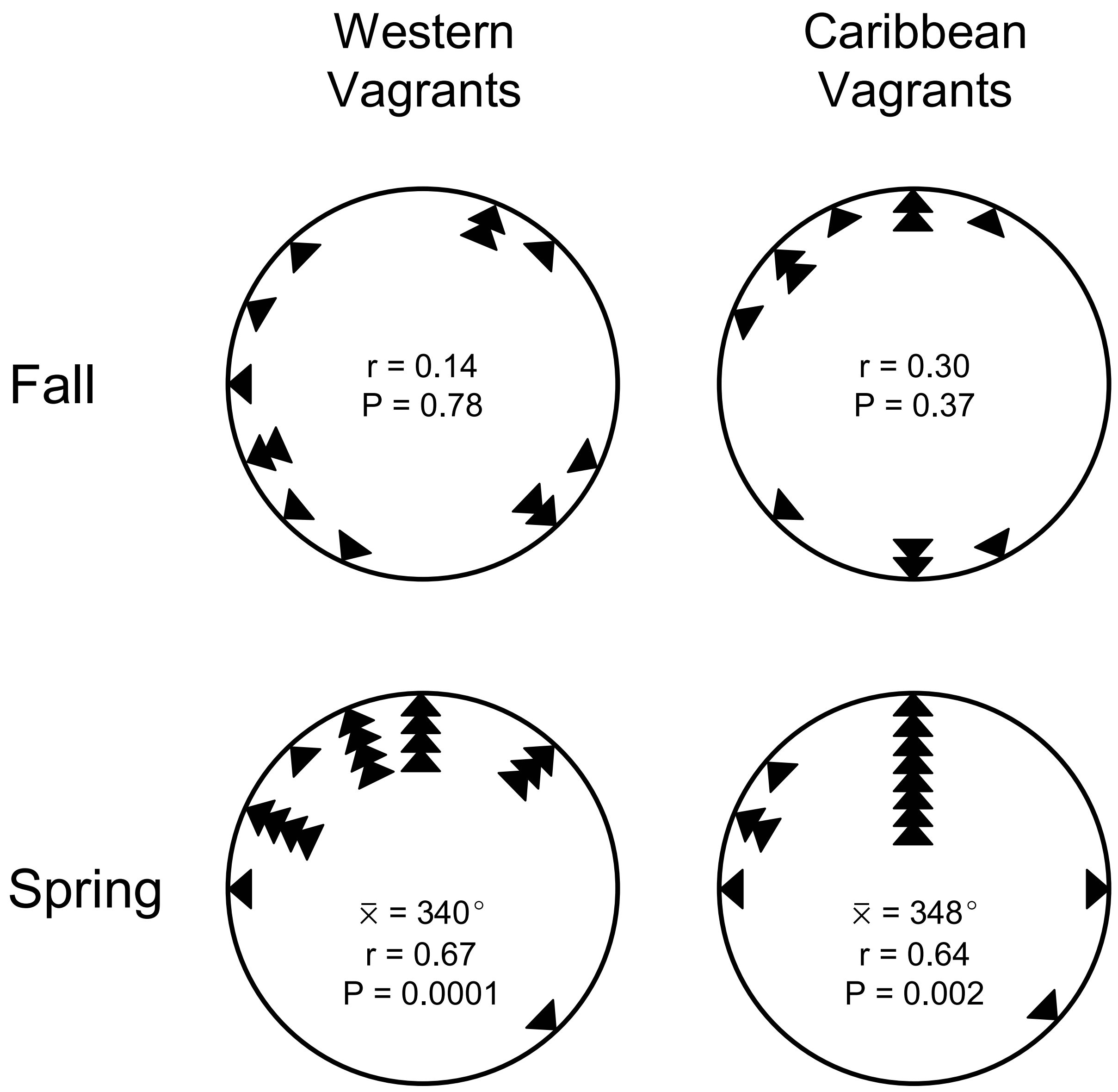


Figure 11.6. Comparison of vanishing bearings of Western vagrants and Caribbean vagrants in spring and fall.

PART 3

SUPPLEMENTAL STUDIES

Chapter 12

“Winter” and “Summer” Migrations

Robert W. Russell

12.1 INTRODUCTION

Our first year’s data suggested that migratory movements probably continue well outside of the nominal seasonal limits of March-May in the spring and August-November in the fall. Although these “extraseasonal” flights are probably quantitatively small, they are potentially very informative because they involve individuals operating in the tail ends of their species’ frequency distributions for seasonal timing. In some cases, these individuals may be of unusually high or low genetic quality (e.g., very early spring migrants and very late spring migrants, respectively), and information on their occurrence and behavior may shed light on the environmental factors limiting trans-Gulf migration. Alternatively, extraseasonal migrants may possess aberrant spatiotemporal programs for migration, which might also be evident in unusual patterns of orientation or platform use. In addition, because of the strong genetic basis for migration timing (Berthold 1990, 1991; Berthold and Helbig 1992; Møller 2001; Pulido et al. 2001), changes in the occurrence of extraseasonal migration could be reflective of evolutionary changes in response to altered selective regimes associated with important environmental shifts such as global warming. A baseline understanding of the occurrence and ecology of extraseasonal migrants is therefore a prerequisite for developing any long-term strategies for monitoring trans-Gulf migration.

To determine whether offshore migration continues during “winter” and “summer” months, we staffed one platform (GC18) on the following dates: November 18-December 16, 1999; January 6-February 29, 2000; and June 1-August 1, 2000. Field methods during these periods were identical to those used during regular field seasons (Chapter 3). In the winter, we used the fall survey schedule (Table 3.2) during November-December, and the spring schedule (Table 3.1) during January-February. In the summer, we used the spring survey schedule (Table 3.1) through July 7 and the fall schedule (Table 3.2) thereafter. These extended seasonal observations provided us with a nearly complete year-round perspective from a single platform, with coverage gaps (due to staffing limitations) only on December 17-January 5, March 1-6, and August 2-3.

12.2 RESULTS AND DISCUSSION

Complete listings of all migrants detected at GC18 during winter 1999-2000 and summer 2000 are presented in Tables 12.1 and 12.2.

Table 12.1 indicates that southbound trans-Gulf migration of neotropical migrant landbirds continued at least until November 25, and perhaps until December 6. In addition, overshooting by shorter-distance migrants continued at least until December 7.

Table 12.1.

“Winter” observations at GC18: November 18-December 16, 1999, and January 6-February 29, 2000

Synoptic weather type (Chapter 5) is listed in parentheses following each date of initial observation. Number of individuals, age and sex (when known), species, and behavior are listed after date and weather type. Inclusive times of occurrence and supplementary behavioral notes are given in parentheses following primary data. Times indicated by an asterisk are exact arrival or departure times. The condition of all individuals was “vigorous” unless otherwise noted. Abbreviation: unid = unidentified.

Date	Sightings
Nov 20 (**ND**)	1 HY ♂ American Robin on platform (06:15-Dec 1 20:00; foraged on rice and crackers provided by workers, drank)
Nov 24 (**GF**/**MCH**)	1 Great Egret flew past to SE (09:54*; in flock with 4 Great Blue Herons)
Nov 24 (**GF**/**MCH**)	4 Great Blue Herons flew past to SE (09:54*; in flock with 1 Great Egret)
Nov 25 (**GF**/**MCH**)	1 Tree Swallow flew past to S (11:35*)
Nov 25 (**GF**/**MCH**)	2 Tree Swallows flew past to S (11:39*)
Nov 25 (**GF**/**MCH**)	2 Tree Swallows flew past to S (11:40*)
Nov 25 (**GF**/**MCH**)	1 Tree Swallow flew past to SW (11:50*)
Nov 25 (**GF**/**MCH**)	4 Tree Swallows flew past to S (11:57*; single individuals)
Nov 26 (**ELOW**)	1 White-winged Dove approached platform (08:10*)
Nov 26 (**ELOW**)	1 American Pipit approached platform (08:15*)
Nov 27 (**GH**)	1 Mourning Dove flew past to N (08:15*)
Nov 28 (**GH**)	1 HY ♂ Peregrine Falcon on platform (17:18*-17:40; probably roosted overnight)
Nov 29 (**MCH**)	1 HY Myrtle Warbler on platform (08:25)
Nov 30 (**MCH**)	1 unid dove flew past (08:19*; landed on distant freighter)
Dec 1 (**ECH**)	1 White-winged Dove on platform (09:50-Dec 2 07:45)
Dec 6 (**GF/ELOW**)	1 unid passerine flew past to S (08:14*)
Dec 7 (**MCH**)	1 HY Snow Goose swimming around platform (09:02)
Dec 7 (**MCH**)	1 Myrtle Warbler on platform (departed to W 10:08*)
Dec 11 (**GF/MCH**)	3 AHY Great Blue Herons flew past to ENE (08:00*)
Jan 6 (**ECH**)	1 Snowy Egret approached platform from E (10:25*; departed to NW)
Jan 27 (**MCH**)	1 Sora on platform (PC3-PC5; tired)
Jan 28 (**GF**)	1 Common Snipe on platform (arrived at 15:57*)
Jan 29 (**GF**)	1 ASY ♂ Purple Martin approached platform (06:53*; soaring, drifted to SE until lost from sight)
Jan 31 (**GF**)	1 ♀ Mallard approached platform from SW (07:01*; departed to SSW)
Jan 31 (**GF**)	1 ASY ♂ Purple Martin approached platform from SSW (07:47*; cruised in lee of platform until 08:00)
Feb 1 (**GF**)	1 ASY ♂ Purple Martin flew past to N (16:29*)
Feb 1 (**GF**)	1 ASY ♂ Purple Martin approached platform (16:36*; cruised in lee of platform until 16:48)
Feb 5 (**MCH**)	2 ASY ♂ Purple Martins flew past (17:45*)
Feb 9 (**GH**)	1 Sora on platform (15:00)
Feb 19 (**GF**)	4 Great Egrets flew past to N (10:09*)
Feb 19 (**GF**)	1 ♂ Northern Parula on platform (12:37-12:45)
Feb 19 (**GF**)	1 Cattle Egret flew past to NNW (15:59*)
Feb 19 (**GF**)	3 Purple Martins on platform (2 ASY ♂, 1 ♀/SY ♂; 18:10-19:20)
Feb 28 (**MCH**)	1 White-winged Dove approached platform (09:45*)

Table 12.2.

“Summer” observations at GC18: June 1-August 1, 2000

Synoptic weather type (Chapter 5) is listed in parentheses following each date of initial observation. Number of individuals, age and sex (when known), species, and behavior are listed after date and weather type. Inclusive times of occurrence and supplementary behavioral notes are given in parentheses following primary data. Times indicated by an asterisk are exact arrival or departure times. The condition of all individuals was “vigorous” unless otherwise noted. Abbreviation: unid = unidentified.

Date	Sightings
Jun 1 (**ECH**)	1 Cattle Egret flew past to N (FC1*)
Jun 1 (**ECH**)	5 Cattle Egrets flew past to N (PC2*)
Jun 1 (**ECH**)	1 Barn Swallow on platform (18:30)
Jun 2 (**ECH**)	1 ♀ Common Yellowthroat on platform (PC4; foraged)
Jun 3 (**GH**)	1 Cattle Egret approached platform (FC1*)
Jun 5 (**BH**)	1 American Redstart approached platform (FC1*)
Jun 5 (**BH**)	1 ♂ Blackpoll Warbler on platform (PC4)
Jun 6 (**GF**)	1 Couch’s Kingbird on platform (PC1-PC5; foraged successfully)
Jun 6 (**GF**)	1 Osprey flew past platform to N (12:00*)
Jun 6 (**GF**)	1 ♂ Blackpoll Warbler on platform (13:10-PC3)
Jun 6 (**GF**)	1 ♀ Blackpoll Warbler on platform (PC3)
Jun 6 (**GF**)	1 unid ♀/HY martin on platform (18:00-20:00; foraged)
Jun 7 (**GF**)	1 Barn Swallow on platform (FC1)
Jun 7 (**GF**)	6 Cattle Egrets approached platform from S (FC1*)
Jun 8 (**ECH**)	1 Northern Waterthrush (PC0-06:30*; tired)
Jun 9 (**ECH**)	1 Cattle Egret approached platform (PC1*)
Jun 15 (**BH**)	1 Cattle Egret approached platform (12:58*; departed to ENE)
Jun 18 (**BH**)	1 Cattle Egret approached platform from N (10:44*; departed to ESE)
Jun 22 (**GH**)	1 ASY ♂ Indigo Bunting on platform (PC5)
Jun 25 (**GH**)	1 Cattle Egret on platform (PC4)
Jun 26 (**GH**)	1 Cattle egret approached platform (11:04*; departed to E)
Jun 27 (**GH**)	1 ASY ♀ Myrtle Warbler on platform (14:48*- Jul 1 PC5; arrived from SE)
Jul 4 (**ECH**)	1 AHY White-winged Dove on platform (FC2-PC5)
Jul 7 (**GH**)	1 AHY Cattle Egret approached platform from W (09:08*)
Jul 10 (**GH**)	1 Snowy Egret approached platform from W (12:08*; departed to E)
Jul 11 (**GH**)	1 ♀/HY Prothonotary Warbler on platform (PC1)
Jul 11 (**GH**)	1 Willet flew past to WNW (08:23*)
Jul 13 (**GH**)	1 AHY Yellow-throated Warbler on platform (PC1-FC1)
Jul 13 (**GH**)	1 HY Barn Swallow on platform (PC6-Jul 14 00:20; tired)
Jul 15 (**GH**)	1 unid white egret flew past to SE (07:56*)
Jul 22 (GH)	1 Louisiana Waterthrush on platform (PC1)
Jul 22 (**GH**)	1 unid warbler approached platform (07:24*; departed to S)

Table 12.2.

“Summer” observations at GC18: June 1-August 1, 2000

Synoptic weather type (Chapter 5) is listed in parentheses following each date of initial observation. Number of individuals, age and sex (when known), species, and behavior are listed after date and weather type. Inclusive times of occurrence and supplementary behavioral notes are given in parentheses following primary data. Times indicated by an asterisk are exact arrival or departure times. The condition of all individuals was “vigorous” unless otherwise noted. Abbreviation: unid = unidentified.

Date	Sightings
Jul 23 (**GH**)	1 ♀/HY Yellow Warbler on platform (PC1)
Jul 23 (**GH**)	1 Barn Swallow approached platform (07:56*; departed to S)
Jul 23 (**GH**)	1 ♀/HY Purple Martin cruised platform (14:11*; foraged)
Jul 24 (**GF/MCH**)	2 ♀/HY Purple Martins cruised platform (14:45*-14:50; foraged)
Jul 24 (**GF/MCH**)	1 ♀/HY Purple Martin cruised platform (20:13*; foraged)
Jul 25 (**GF/MCH**)	1 ♀/HY Prothonotary Warbler on platform (PC1)
Jul 26 (**ND**)	1 AHY ♂ Prothonotary Warbler on platform (PC3-09:08; tired)
Jul 26 (**ND**)	1 ♀/HY Black-and-white Warbler on platform (PC4; foraged)
Jul 27 (**GH**)	1 HY Cliff Swallow on platform (17:23*-Jul 28 FC1; foraged)
Jul 28 (**ECH**)	1 unid warbler approached platform (07:12*; departed to W)
Jul 28 (**ECH**)	1 HY Barn Swallow cruised platform (07:17*-FC1; foraged)
Jul 28 (**ECH**)	1 Cattle Egret approached platform (09:54*; departed to NE)
Jul 29 (**GH**)	1 ♀/HY Yellow Warbler on platform (PC1)
Jul 29 (**GH**)	1 ♀/HY Prothonotary Warbler on platform (PC1-06:27*; departed to S)
Jul 29 (**GH**)	1 ♀/HY American Redstart on platform (PC1-PC2)
Jul 29 (**GH**)	1 HY Barn Swallow cruised platform (11:30*; foraged)
Jul 30 (**GH**)	1 ♀/HY Black-and-white Warbler on platform (PC1)
Aug 1 (**GH**)	1 HY Snowy Egret flew past to SW (09:59*)

Heron movements oriented to the ENE and NW on December 11 and January 6 are difficult to characterize, and could represent overshooting, nonmigratory wandering, or extremely early northbound “spring” migration.

Weather circumstances strongly suggested that the Sora and Common Snipe on January 27-28 were southbound “fall” migrants, yet these dates are so extreme that some behavioral phenomenon other than “normal” migration must be involved. Recent work has demonstrated that many aspects of migratory behavior are governed by endogenous “programs” that are under direct genetic control (reviewed by Berthold 1990, 1991). During the normal fall migration period, migration is generally obligate and determined by these endogenous programs. However, other evidence from both field and laboratory studies (reviewed by Terrill 1990a,b) indicates that migration can be extended facultatively well beyond the normal fall migratory period in response to exogenous factors such as changes in food availability in wintering areas. Haila et al. (1986) recognized such delayed fall migration and defined it as “an attempt to stay in the north through the winter combined with the ability to start migration as late as mid-winter if conditions become unbearable.” The most detailed studies of this phenomenon have shown that Yellow-rumped Warblers (*Dendroica coronata*) extend their fall migration into the winter months in response to varying food availability in wintering areas, which in turn depends on weather conditions (Terrill and Ohmart 1984). Extensive facultative nocturnal movements during midwinter have also been documented unambiguously (via tower kills) for American Tree Sparrows in the Midwest (Niles et al. 1969) and Myrtle Warblers along Gulf Coast (Terrill and Crawford 1988). We suggest that the January Sora and Common Snipe represent additional instances of facultatively extended fall migration. Interestingly, long-term data from the Tall Timbers Research Station on the Florida Panhandle (Crawford 1981) indicate that nocturnal tower kills of Soras and Common Snipes occur regularly from late December through January, supporting our contention.

Unambiguous northbound "spring" migration began on January 29 with the arrival of the first Purple Martin, and small numbers of martins continued through February. A Mallard that approached the platform on January 31 could have been either southbound or northbound. A Sora recorded on February 9 was probably a northbound migrant (on the basis of weather circumstances). Unambiguous northbound "spring" migration by species other than Purple Martins began on February 19 with the arrival of a Northern Parula and two species of herons.

Table 12.2 indicates that northbound "spring" trans-Gulf migration by neotropical migrants continued at least to June 8. Unambiguous southbound "fall" trans-Gulf migration by neotropical migrants began on July 11 with the arrival of a Prothonotary Warbler. Observations made during the interim period between unambiguous northbound and southbound migration (June 9-July 10) were difficult to characterize, and were dominated by a largely eastward movement by Cattle Egrets. The Indigo Bunting and Myrtle Warbler on the platform on June 22 and 27 were so far removed from their species' normal migration schedules that they probably involved injury, disease, or mutation of the spatiotemporal program. The only other species recorded during the midsummer period were a White-winged Dove and a Snowy Egret (which, curiously, was flying eastward like the Cattle Egrets).

Several observations suggested that southbound "fall" migration began even earlier than indicated in Table 12.2 (i.e., technically during the spring field season). On April 23, 2000, during PC3, a female Purple Martin was observed flying due S past PN975. The synoptic weather on April 23 was classified as **ECH**, and local winds at PN975 were from the SSE at Beaufort force 2. On May 9, 2000, at 19:21, a juvenile Purple Martin was found on GB189. The synoptic weather on May 9 was classified as **BH**, and local winds at GB189 were from the SE at Beaufort force 4. On May 20, 2000, at 10:34, 30 unidentified small shorebirds (probably Least Sandpipers) were observed flying due S past HI561 at flight altitude 0. The synoptic weather on May 20 was classified as **BH**, and local winds at HI561 were from the SW at Beaufort force 2.

Chapter 13

Insect Dispersal Over the Gulf of Mexico

Robert W. Russell and Sidney A. Gauthreaux, Jr.

13.1 INTRODUCTION

(by Robert W. Russell)

The first two field seasons revealed an unexpected abundance and diversity of terrestrial insects offshore. During both spring and fall, a blanket of terrestrial arthropods — the "aerial plankton" — was often transported passively over the Gulf by offshore winds. The aerial plankton appeared to represent a significant food resource for birds that stopped to rest on platforms. Many of the migrant birds on the platforms were able to forage successfully, and in fact, energy intake rates of birds on platforms sometimes seemed to be higher than generally observed in "natural" habitats onshore (see Chapter 15.2.5). Because of the possible importance of insects as a food resource for fuel-depleted migrant birds on platforms, we expanded the focus of the field program starting in spring 1999 to include insect monitoring using both visual surveys and quantitative sampling methods.

13.2 METHODS

(by Robert W. Russell)

13.2.1 Visual Surveys

During each Platform Census, we visually assessed the abundance of insects that could potentially serve as prey for foraging birds. At the conclusion of each Platform Census, we made two estimates of insect numbers encountered on and about the platform. First, we estimated the abundance of "aerial plankton," which was operationally defined as all small flying insects excluding butterflies, dragonflies, and moths (i.e., flies, lacewings, beetles, planthoppers, aphids, true bugs, damselflies, etc.). Second, we estimated the number of what we called "bird-food" moths (i.e., all moths excluding black witches [*Ascalapha odorata*] and sphinx moths [Family Sphingidae]). The aerial plankton and bird-food moth categories were distinguished because our initial observations suggested that small moths were overwhelmingly the most important resource for foraging birds. "Macro-insects" (dragonflies, butterflies, sphingid moths, Black Witches, and sphinx moths) were excluded because they are generally too large and robust to be taken alive by birds; however, these species were interesting in their own right because many of them appeared to be migratory, and we identified and counted them individually for a separate study.

Abundance estimates reflected the approximate number of individuals detectable by the observer along the standard census route using a logarithmic abundance scale (Table 13.1).

Table 13.1.

Logarithmic abundance scale for visual surveys of insects.

Abundance Code	Observed Abundance Range
0	0
1	1
2	2-10
3	11-100
4	101-1000
5	1001-10,000
6	>10,000

13.2.2 Ultraviolet Light Trapping

During fall 1999 and spring 2000, we sampled insect abundance and biodiversity quantitatively using Universal Light Traps (#2851L, BioQuip Products, Inc.) equipped with 22-watt Circline black light tubes with full 360-degree visibility. To the extent possible, permanent sites for the traps were chosen in poorly lit, well sheltered areas that were easily accessible and away from areas of heavy use by platform workers. However, availability of a devoted power outlet was usually the primary determinant of trap location. Traps remained in the same locations throughout the study, except at PN975 where heavy construction required a location change beginning on April 27, 2000.

The traps were deployed on all nights except when severe weather rendered the security of the trap doubtful or when power outlets were unavailable or production or drilling operations otherwise rendered trap deployment infeasible (Table 13.2). Incomplete samples resulting from nighttime power outages or wind blowovers were discarded. Light traps were turned on a half hour after sunset, and samples were retrieved from the traps the following morning at sunrise or as soon as possible thereafter. A paper towel or coffee filter was often used to filter the contents when large numbers of very small species were present. Trap contents (including any filters, when used) were transferred into Ziploc bags and then stored in a freezer for later enumeration and identification in the laboratory.

Table 13.2.

Dates of light trap deployment on the platforms

Dates in parentheses are those when samples were not obtained for one of the reasons described in the text.

Platform	Fall 1999	Spring 2000
VK786	Aug 19-Nov 17 (Sept 2)	Platform not available
SP89	Aug 6-Nov 16	Mar 8-May 30 (Mar 19, May 8-9)
GC18	Aug 15-Nov 17	Mar 8-May 31 (Mar 15,16,19)
VR265	Aug 6-Nov 17 (Aug 22, Sept 17,24,26-29, Oct 6, Nov 13)	Mar 9-May 28 (Mar 19,30-31, Apr 4-7)
HI561	Platform not available	Mar 12-May 30 (Mar 16,19, Apr 20, May 4,18)
MI622	Aug 10-Nov 16 (Oct 14,19)	Mar 9-May 29 (Mar 11,14,15,19,20, Apr 4)
PN975	Aug 7-Nov 15 (Sept 16-24, Oct 18-20)	Mar 9-May 31 (Mar 15,18, Apr 1-6, May 17)

In addition, a light trap was deployed at GC18 from November 18-December 16, 1999, January 6-February 29, 2000, and June 1-August 1, 2000, as part of the seasonally extended program there (Chapter 12).

13.2.3 Taxonomic Identification and Sorting of Insect Specimens

The frozen samples were thawed, enumerated, measured, and identified to the lowest taxon possible under magnification in the laboratory. Body length was measured from the frons to the tip of the abdomen. Antennae, terminal abdominal appendages, and wings extending beyond these points were not included in length measurements. Identifications were made by comparison to specimens in the collections of the Louisiana State Arthropod Museum, and by using a variety of published guides and keys (e.g., Oliver and Chapin 1981).

13.2.4 Computation of Insect Biomass

Insect body mass was estimated from measured body length using the taxon-specific regression equations in Sage (1982) and Sample et al. (1993). Equations from Sample et al. (1993) were used for most taxa, since they were generally based on larger samples and yielded higher explained variances than the equations in Sage (1982). The only exception was for the order Orthoptera, which was not included in the study by Sample et al. (1993). The predictive equations for dry mass are summarized in Table 13.3. Dry mass was converted to wet mass assuming an average water content of 2.33 ml H_2O/g dry mass (Bell 1990).

Table 13.3.

Allometric equations used for estimating insect body mass from body length

Abbreviations: DM = dry mass (mg); L = body length (mm).

Taxon	Predictive Equation	Explained Variance
Insecta:	$DM = 0.02657 \bullet L^{2.494}$	($R^2 = 0.88$)
Orthoptera:	$\ln(WM) = 1.043 + 0.2792 \bullet L — 0.002873 \bullet L^2$	($R^2 = 0.89$)
Homoptera:	$DM = 0.05943 \bullet L^{2.225}$	($R^2 = 0.81$)
Cicadellidae:	$DM = 0.02387 \bullet L^{2.561}$	($R^2 = 0.90$)
Hemiptera:	$DM = 0.008362 \bullet L^{3.075}$	($R^2 = 0.93$)
Pentatomidae:	$DM = 0.01504 \bullet L^{3.053}$	($R^2 = 0.95$)
Neuroptera:	$DM = 0.01130 \bullet L^{2.570}$	($R^2 = 0.97$)
Coleoptera:	$DM = 0.03889 \bullet L^{2.492}$	($R^2 = 0.86$)
Carabidae:	$DM = 0.02414 \bullet L^{2.755}$	($R^2 = 0.96$)
Chrysomelidae:	$DM = 0.08830 \bullet L^{2.171}$	($R^2 = 0.86$)
Coccinelidae:	$DM = 0.007248 \bullet L^{3.867}$	($R^2 = 0.96$)
Lepidoptera:	$DM = 0.006500 \bullet L^{3.122}$	($R^2 = 0.93$)
Microlepidoptera:	$DM = 0.007350 \bullet L^{2.918}$	($R^2 = 0.93$)
Arctiidae:	$DM = 0.02340 \bullet L^{2.658}$	($R^2 = 0.96$)
Noctuidae:	$DM = 0.03554 \bullet L^{2.499}$	($R^2 = 0.86$)
Diptera:	$DM = 0.04142 \bullet L^{2.213}$	($R^2 = 0.85$)
Hymenoptera:	$DM = 0.01379 \bullet L^{2.696}$	($R^2 = 0.89$)
Ichneumonidae:	$DM = 0.01578 \bullet L^{2.464}$	($R^2 = 0.90$)

13.3 MAGNITUDE AND TAXONOMIC COMPOSITION OF THE AERIAL PLANKTON

(by Robert W. Russell)

A complete listing of the insects sampled by the light traps is provided in Table 13.4.

Table 13.4.

Taxonomic composition of the aerial plankton sampled by light traps

Numbers shown are totals from all platforms across all dates during spring and fall (Table 13.2).

Order	Family	Species	Fall 1999	Spring 2000
Coleoptera				
	Anthicidae		10	0
	Carabidae			
		Anisodactylus sp.	1	0
		Ledia sp.	1	0
		no common name (*Pterostichus monedulus*)	1	0
		unidentified	56	0
	Chrysomelidae			
		twelve-spotted cucumber beetle (*Diabrotica undecimpunctata*)	1,440	4
		Diabrotica punctella	31	0
		unidentified	4	0
	Cicindelidae			
		three-lined tiger beetle (*Cicindela trifasciata*)	13	0
	Coccinellidae		16	32
	Dytiscidae			
		Luccophilus sp.	5	0
	Dytiscidae		12	0
	Gyrinidae		3	0
	Heterocerida			
		Heterocerus sp.	5	0
	Hydrophilidae			
		Berosus sp.	1	0
		unidentified	18	0
	Nitidulidae		218	0
	Noteridae		1	0
	Oedemeridae		2	0
	Scirtidae		3	0
	Scolytidae		4	0
	Staphylinida		167	9
	unidentified		92	318
Diptera			6,067	1,537
Hemiptera				
	Alydidae			

Table 13.4.

Taxonomic composition of the aerial plankton sampled by light traps

Numbers shown are totals from all platforms across all dates during spring and fall (Table 13.2).

Order	Family	Species	Fall 1999	Spring 2000
		Hyalymenus sp.	8	0
	Coreidae			
		western leaf-footed bug (*Leptoglossus clypealis*)	433	6
		eastern leaf-footed bug (*Leptoglossus phyllopus*)	34	0
		citron bug (*Leptoglossus gonagra*)	2	0
		Leptoglossus zonatus	13	0
		Leptoglossus oppositus	3	0
		Leptoglossus sp.	3	0
	Corixidae		4	0
	Lygaeidae			
		unidentified big-eyed bug (*Geocoris* sp.)	58	0
		Pachygrontha sp.	1	0
		unidentified	245	0
	Miridae			
		Polymerus sp.	30	0
		unidentified	111	0
	Pentatomidae			
		predacious stink bug (*Apateticus cynicus*)	0	2
		green juniper stink bug (*Banasa euchlora*)	84	15
		unidentified stink bug (*Banasa* sp.)	7	0
		Chlorochroa senilis	4	0
		Euschistus crassus	2	0
		brown-colored stink bug (*Euschistus quadrator*)	1	0
		unidentified stink bug (*Euschistus* sp.)	3	1
		Mecidea major	81	0
		southern green stink bug (*Nezara viridula*)	19	0
		rice stink bug (*Oebalus pugnax*)	267	1
		predatory stink bug (Alcaeorrhynchus grandis)	17	0
		spined soldier bug (*Podisus maculiventris*)	36	29
		Thyanta custator	4	1
		Thyanta sp.	53	0
		Trichopepla sp	1	0
		unidentified	4	0
	Rhopalidae			
		red-shouldered bug (*Jadera haematoloma*)	1	0
		Liorhyssus hyalinus	39	0
		scentless plant bug (*Niesthrea louisianica*)	29	0
		unidentified	10	0
	Saldidae		12	0

Table 13.4.

Taxonomic composition of the aerial plankton sampled by light traps

Numbers shown are totals from all platforms across all dates during spring and fall (Table 13.2).

Order	Family	Species	Fall 1999	Spring 2000
	Scutelleridae		25	0
	unidentified		1,405	1,801
Homoptera				
	Aphidae		867	289
	Cicadellidae		342	0
	Cixiidae		519	0
	Delphacidae		122	0
	Psyllidae		95	254
	unidentified		10	0
Hymenoptera				
	Ichneumonidae		5	0
	unidentified		53	241
Lepidoptera				
	Papilionidae			
		pipevine swallowtail (*Battus philenor*)	0	1
	Pieridae			
		orange sulphur (*Colias eurytheme*)	0	3
		southern dogface (*Colias cesonia*)	0	4
		little yellow (*Eurema lisa*)	6	0
		lyside sulphur (*Kricogonia lyside*)	0	4
	Lycaenidae			
		gray hairstreak (*Strymon melinus*)	6	6
	Nymphalidae			
		gulf fritillary (*Agraulis vanillae*)	4	1
		monarch (*Danaus plexippus*)	5	0
		variegated fritillary (*Euptoieta claudia*)	0	7
		common buckeye (*Junonia coenia*)	8	1
		American snout (Libytheana carinenta)	4	5
		phaon crescent (*Phyciodes phaon*)	0	1
		American lady (*Vanessa virginiensis*)	0	1
		red admiral (*Vanessa atalanta*)	3	0
		painted lady (*Vanessa cardui*)	2	0
	Hesperiidae			
		Brazilian skipper (*Calpodes ethlius*)	4	1
		ocola skipper (*Panoquina ocola*)	1	0
		long-tailed skipper (*Urbanus proteus*)	1	0
	Oecophoridae		2	0
	Yponomeutidae			

Table 13.4.

Taxonomic composition of the aerial plankton sampled by light traps

Numbers shown are totals from all platforms across all dates during spring and fall (Table 13.2).

Order	Family	Species	Fall 1999	Spring 2000
		ailanthus webworm moth (*Atteva punctella*)	39	0
	Sesiidae			
		oak stump borer moth (*Paranthrene asilipennis*)	0	1
	Pyralidae			
		no common name (*Samea ecclesialis*)	7	0
	Sphingidae			
		titan sphinx (*Aellopos titan*)	0	1
		pink-spotted hawkmoth (*Agrius cingulatus*)	1	0
		mournful sphinx (*Enyo lugubris*)	10	0
		banded sphinx (*Eumorpha fasciata*)	2	0
		pandorus sphinx (*Eumorpha pandorus*)	1	0
		white-lined sphinx (*Hyles lineata*)	2	1
		tersa sphinx (*Xylophanes tersa*)	1	0
	Arctiidae			
		salt marsh moth (*Estigmene acrea*)	0	1
		joyful holomelina (*Holomelina laeta*)	1	0
		Isabella tiger moth (*Pyrrharctia isabella*)	0	2
	Noctuidae			
		four-spotted bird-dropping moth (*Acontia tetragona*)	0	3
		exposed bird-dropping moth (*Acontia aprica*)	0	19
		unidentified dagger moth (*Acronicta* sp.)	1	0
		black cutworm moth (*Agrotis ipsilon*)	2	1
		subterranean dart (*Agrotis subterranea*)	24	1
		rascal dart (*Agrotis malefida*)	0	2
		velvetbean caterpillar moth (*Anticarsia gemmatalis*)	12	0
		no common name (*Bulia deducta*)	0	2
		forage looper moth (*Caenurgina erechtea*)	7	0
		Florida fern moth (*Callopistria floridensis*)	1	0
		no common name (*Condica mobilis*)	1	0
		no common name (*Condica sutor*)	1	0
		chalcedony midget (*Elaphria chalcedonia*)	15	0
		corn earworm moth (*Heliothis zea*)	173	22
		tobacco budworm moth (*Heliothis virescens*)	1	0
		tobacco budworm moth/subflexus straw (*Heliothis virescens/subflexus*)	1	0
		unidentified wainscot (*Leucania* sp.)	1	0
		no common name (*Melipotis acontioides*)	0	1
		indomitable melipotis (*Melipotis indomita*)	0	5

Table 13.4.

Taxonomic composition of the aerial plankton sampled by light traps

Numbers shown are totals from all platforms across all dates during spring and fall (Table 13.2).

Order	Family	Species	Fall 1999	Spring 2000
		small mocis (*Mocis latipes*)	17	0
		large paectes (*Paectes abrostoloides*)	1	0
		armyworm moth (*Pseudaletia unipuncta*)	11	3
		soybean looper moth (*Pseudoplusia includens*)	46	0
		ragweed flower moth (*Schinia rivulosa*)	1	0
		dolichos armyworm moth (*Spodoptera dolichos*)	10	1
		yellow-striped armyworm (*Spodoptera ornithogalli*)	4	2
		fall armyworm moth (*Spodoptera frugiperda*)	100	3
		beet armyworm moth (*Spodoptera exigua*)	5	0
		no common name (*Spodoptera latifascia*)	3	0
		Spodoptera sp.	8	0
		bicolored sallow (*Sunira bicolorago*)	1	0
		small bird-dropping moth (*Tarachidia erastrioides*)	0	1
		cabbage looper moth (*Trichoplusia ni*)	7	0
		lettered zanclognatha (*Zanclognatha lituralis*)	0	1
		unidentified	143	7
	microlepidoptera		236	1
	unidentified moths		189	246
Neuroptera				
	Chrysopidae (green lacewing)		27	0
	Hemerobiidae (brown lacewing)		1	0
	unidentified		11	1
Odonata				
	Coenagrionidae			
		Rambur's forktail (*Ischnura ramburii*)	4	1
		unidentified damselfly	9	1
	Aeshnidae			
		ringed darner (*Anax amazili*)	0	1
		green darner (*Anax junius*)	203	2
	Libellulidae			
		great pondhawk (*Erythemis vesiculosa*)	7	0
		band-winged dragonlet (*Erythrodiplax umbrata*)	4	0

Table 13.4.

Taxonomic composition of the aerial plankton sampled by light traps

Numbers shown are totals from all platforms across all dates during spring and fall (Table 13.2).

Order	Family	Species	Fall 1999	Spring 2000
		blue dasher (*Pachydiplax longipennis*)	19	4
		wandering glider (*Pantala flavescens*)	131	1
		spot-winged glider (*Pantala hymenaea*)	10	36
		variegated meadowhawk (*Sympetrum corruptum*)	19	1
		black-mantled glider (*Tramea lacerata*)	15	1
		violet-masked glider (*Tramea carolina*)	1	0
		red-mantled glider (*Tramea onusta*)	18	0
		hyacinth glider (*Miathyria marcella*)	1	0
		unidentified dragonfly	1	0
Orthoptera				
	Gryllidae			
		southeastern field cricket (*Gryllus rubens*)	35	0
	Tettigoniidae			
		broad-tipped conehead (*Neoconocephalus triops*)	4	0
	unidentified		12	0
Insecta				
	unidentified		55	40
TOTAL			1,4952	4,991

Altogether, we captured 14,952 insects with an estimated biomass of 1261 g in the fall compared to 4991 insects with an estimated biomass of 116 g in the spring. Although light traps were deployed on six platforms in both seasons, VK786 was used only in fall and HI561 was used only in spring. A comparison between spring and fall based on the five platforms with replicated deployments is shown in Figure 13.1. The abundance of insects sampled on a given platform was significantly greater in the fall than in the spring (paired t = 4.93, P = 0.008; log-transformed data). Similarly, the biomass of insects sampled on a given platform was significantly larger in the fall than in the spring (paired t = 4.14, P = 0.014; log-transformed data).

Some of the variation among platforms in insect abundance and biomass was clearly related to distance from source populations (see Figure 2.1, Table 2.2). In the spring, both abundance and biomass were highest at MI622 (the platform closest to land) and lowest at GC18 (the platform farthest from land). In the fall, abundance and biomass were similarly highest at MI622, although abundance was lowest at PN975 and biomass was lowest at VR265.

The composition of the insect assemblages sampled by light traps also differed between seasons (Figure 13.2). Hemipterans were numerically dominant in the spring, whereas Dipterans were dominant in the fall. Dragonflies were the largest component of the captured insect fauna by mass in both spring and fall.

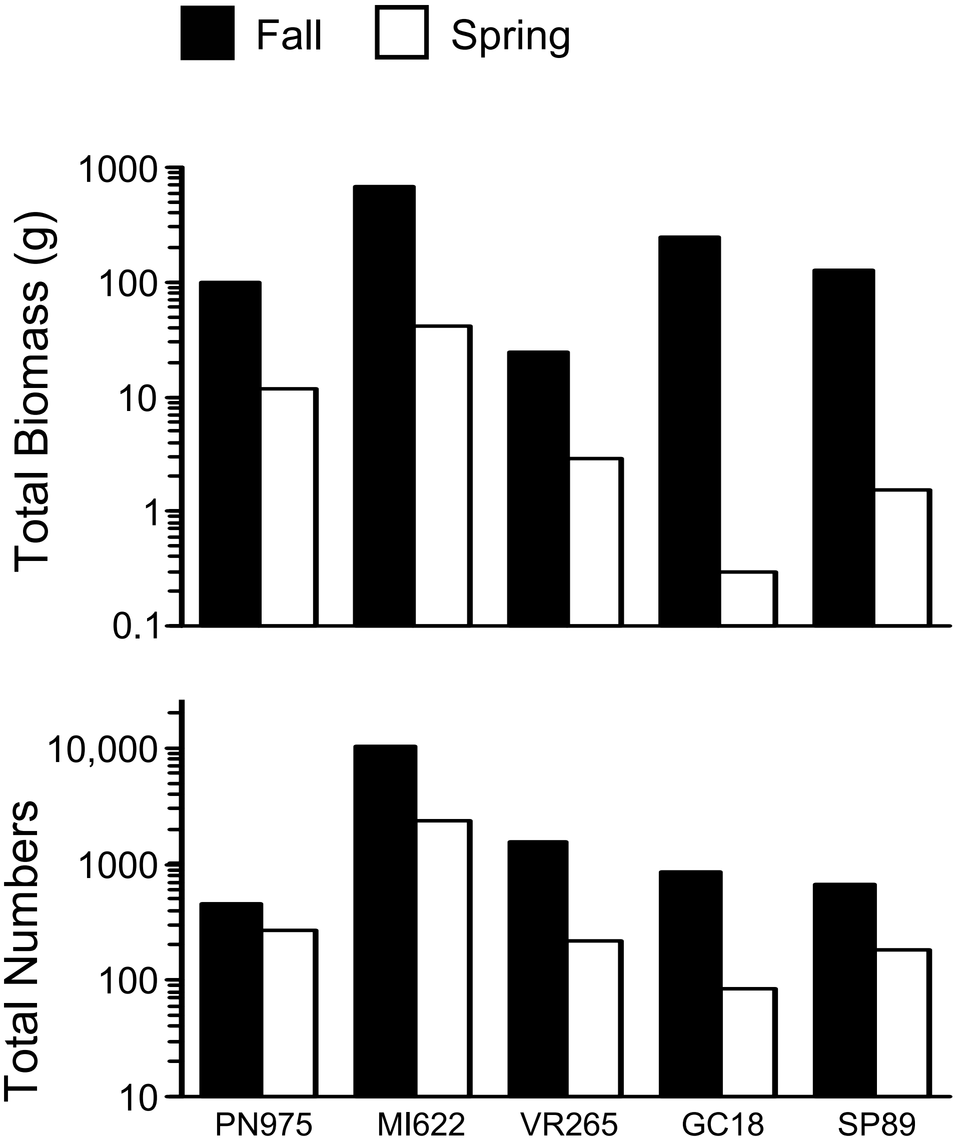


Figure 13.1. Comparison of total abundance and biomass of insects sampled by light traps on offshore platforms during spring and fall.

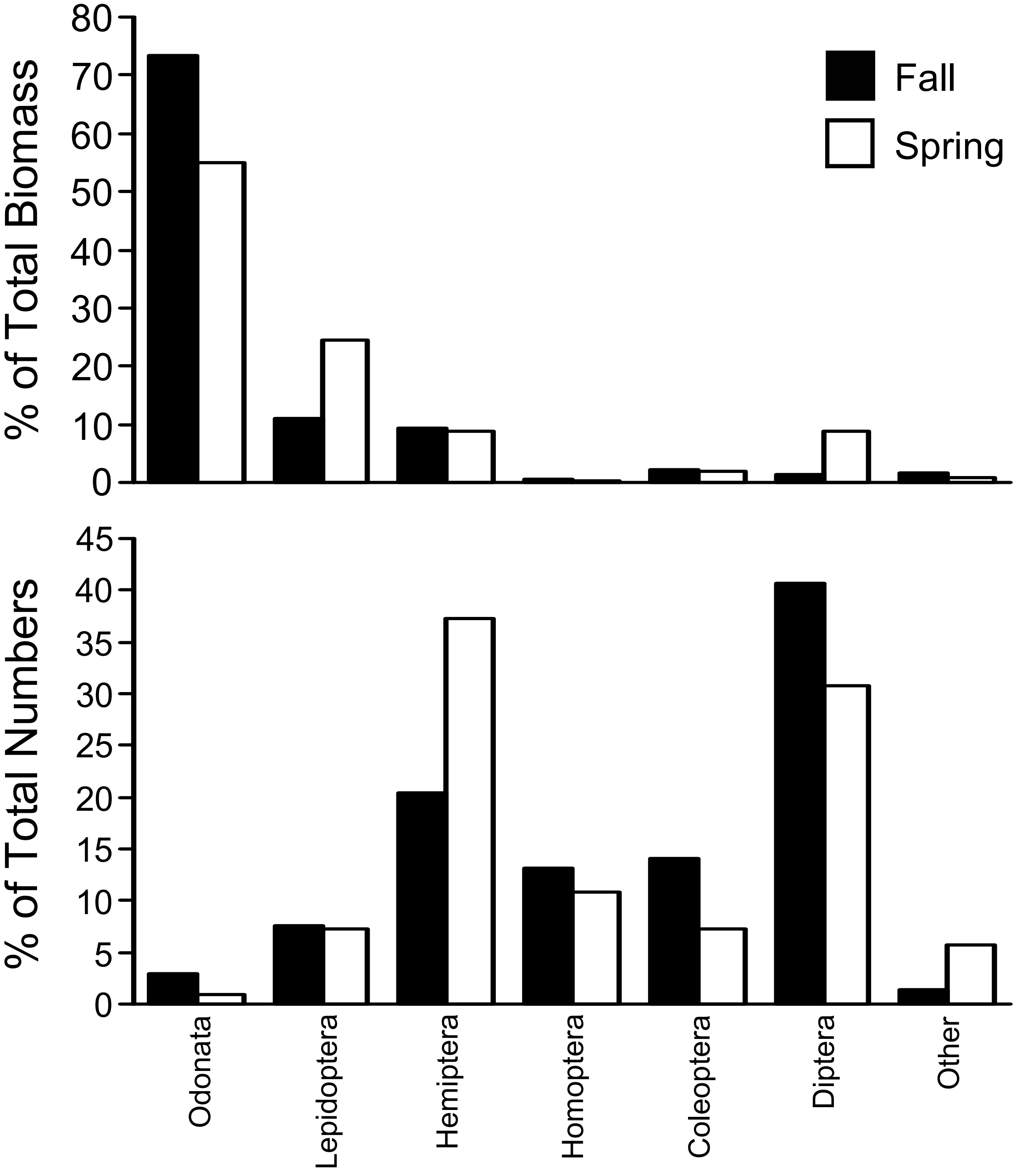


Figure 13.2. Comparison of taxonomic composition of insect assemblages sampled by light traps on offshore platforms during spring and fall. "Other" includes Orthoptera, Hymenoptera, Neuroptera, and unidentified Insecta.

13.4 SEASONAL PATTERNS AND INFLUENCE OF WEATHER

(by Robert W. Russell)

During the fall, insect abundance and biomass peaked from late August through late October, with one very large pulse following in mid-November (Figure 13.3). During the spring, insect movements occurred from late March through late May (Figure 13.4). Spring occurrences were extremely episodic, however: 56% of the total spring biomass was collected during just two events (April 25 and May 13), and 60% of the entire season's numbers was collected on April 25 alone.

Large fall influxes of insects were primarily associated with the **MCH** and **ELOW** synoptic types, but smaller events also occurred on **ECH**, **GH**, and **TLOW** days. Large spring events were strictly associated with **GF** days.

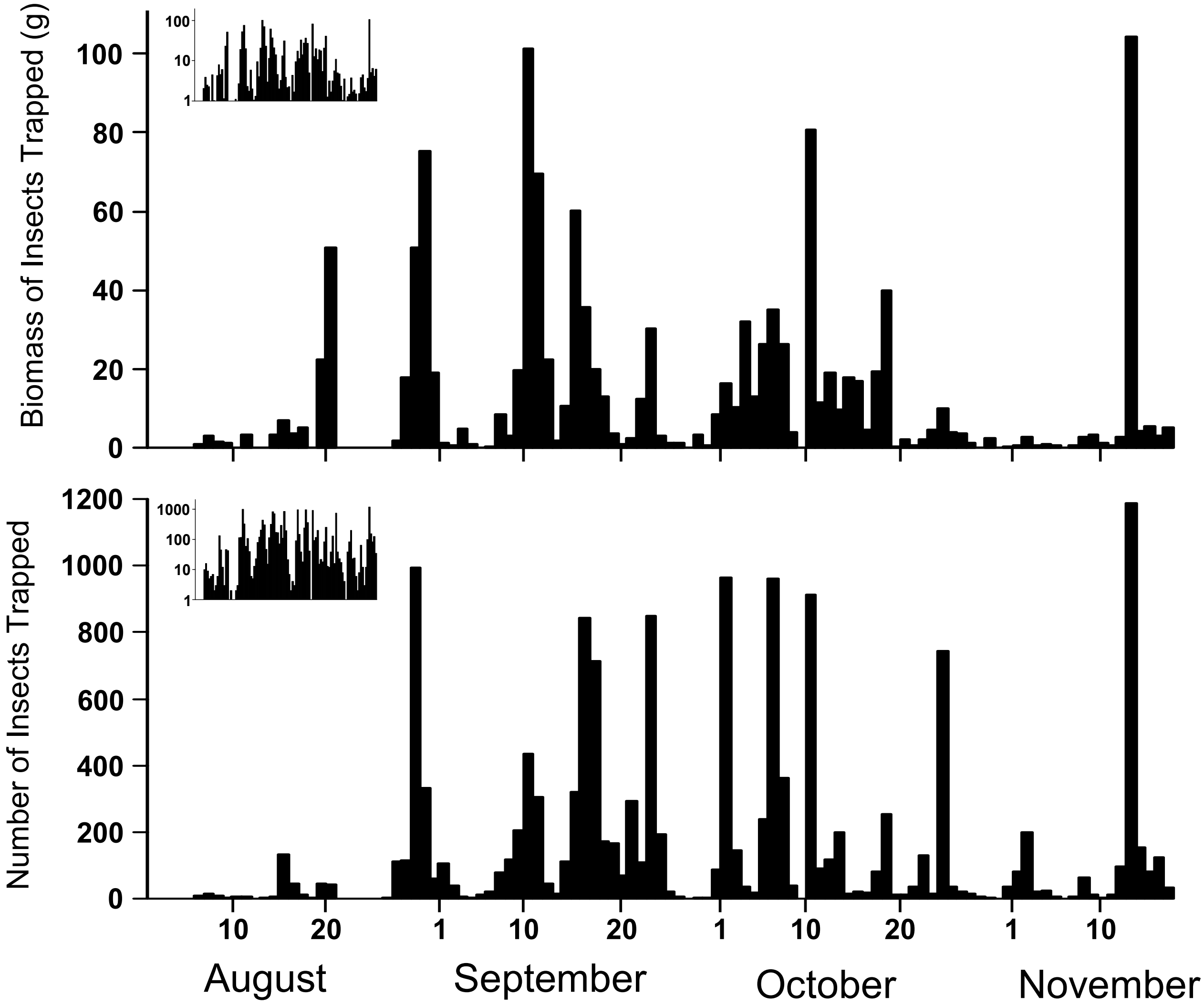


Figure 13.3. Intraseasonal variation in abundance and biomass of insects sampled by light traps on offshore platforms in fall 1999. Data from all platforms (N = 6) are combined for each day. The inset figures show the same data (x+1)-transformed on a logarithmic scale for perspective.

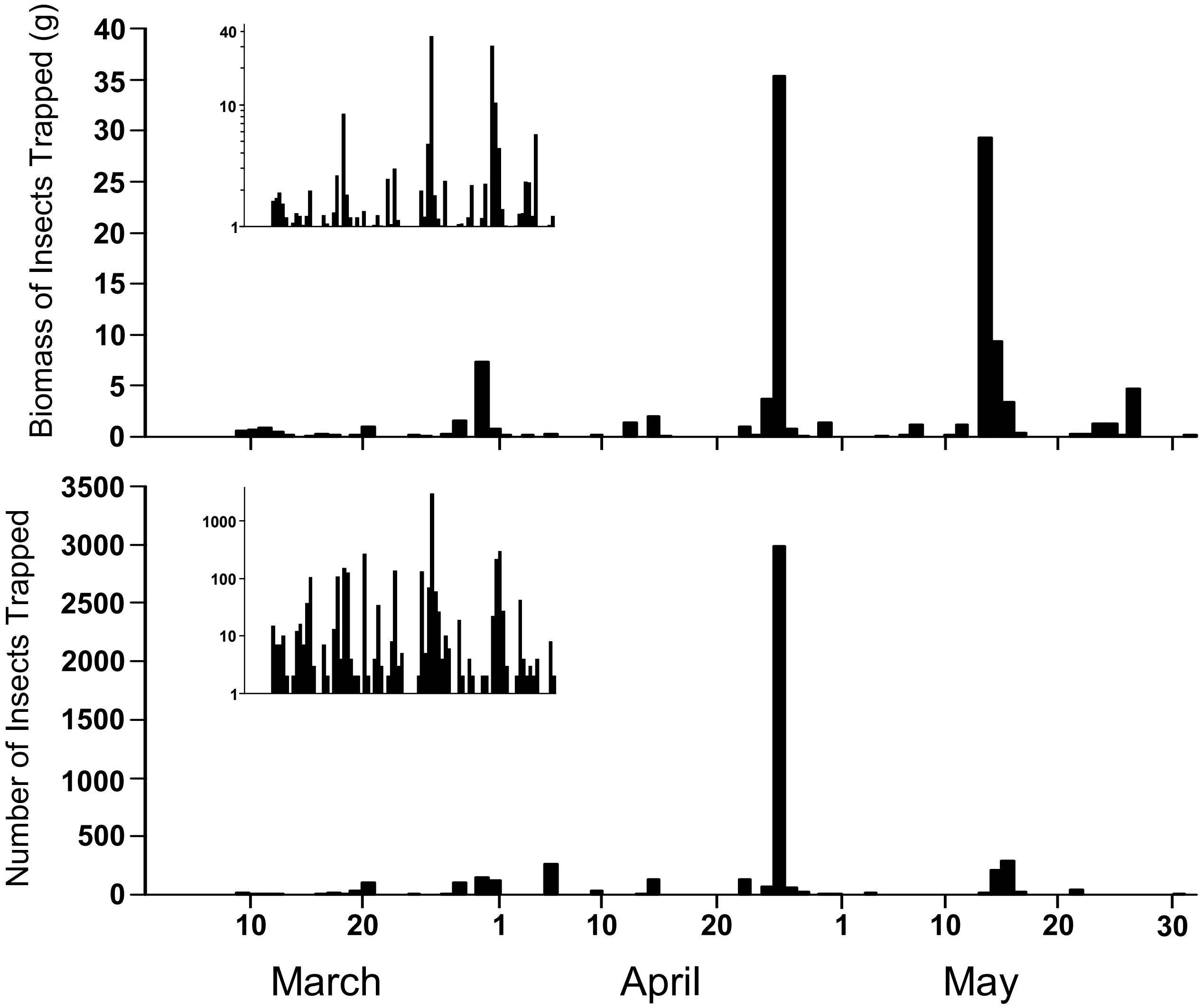


Figure 13.4. Intraseasonal variation in abundance and biomass of insects sampled by light traps on offshore platforms in spring 2000. Data from all platforms (N = 6) are combined for each day. The inset figures show the same data (x+1)-transformed on a logarithmic scale for perspective.

13.5 INSECTS AS A SOURCE OF FALL RADAR ECHOES

(by Robert W. Russell and Sidney A. Gauthreaux, Jr.)

Since we know of no method for decomposing NEXRAD reflectivity data into bird and insect contributions, we decided not to attempt to interpret the fall radar data quantitatively in this study. Many recent advocates of NEXRAD for studying overland bird migration have decided otherwise, assuming implicitly that nocturnal radar echoes over land can be interpreted directly in terms of bird migration. As a result of this and the straightforward availability of high-quality NEXRAD data, avocational "studies" of overland bird migration based on NEXRAD imagery have proliferated on the world wide web. However, the underlying assumption that birds are the primary source of the echoes has not yet been tested critically or discussed thoroughly.

Our offshore insect sampling provided an opportunity to examine the correlation between insect dispersal and nocturnal radar signatures, since SP89 was within the range of the New Orleans (LIX) NEXRAD (see Figures 2.1, 4.1). Figure 13.5 shows that there was a statistically significant correlation between light-trap loads from SP89 and peak nightly reflectivity factors measured at the LIX site across 57 nights in fall 1999.

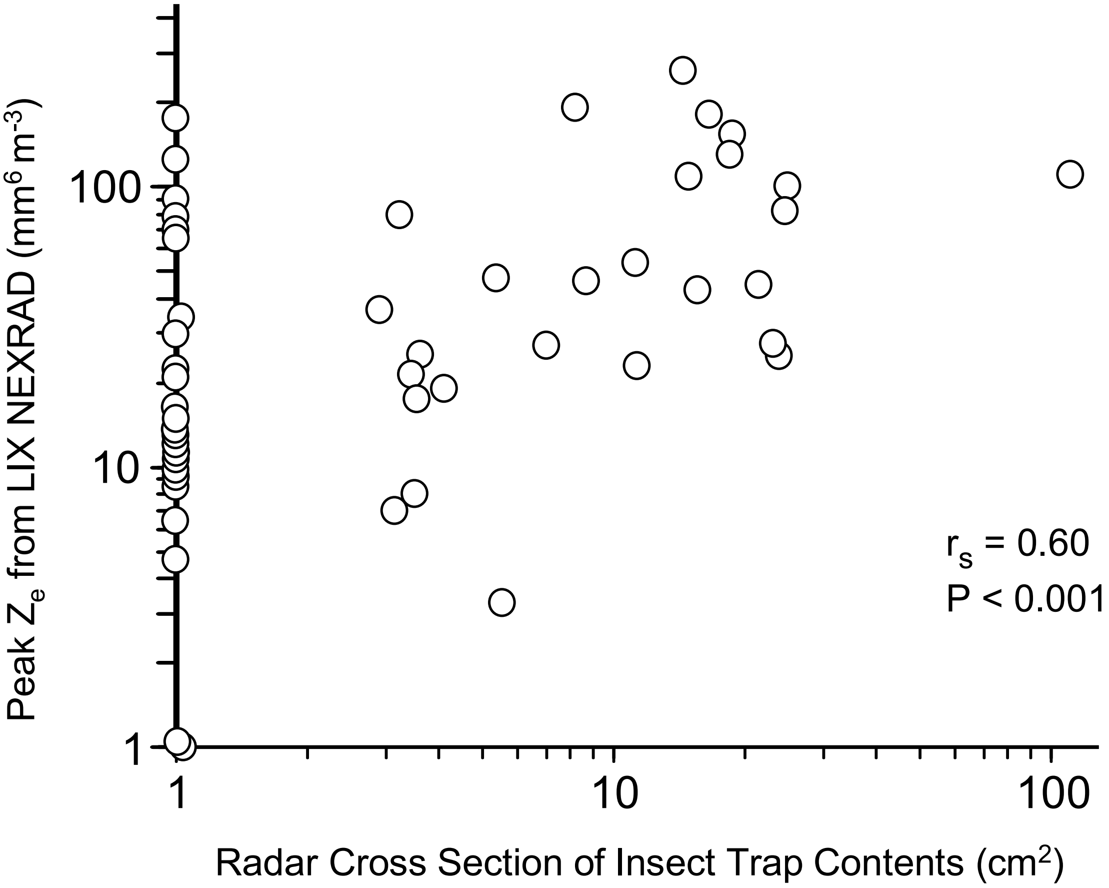


Figure 13.5. Comparison of light-trap loads from SP89 with NEXRAD radar echoes from the LIX site in fall 1999. Each data point represents one night (N = 57). Both data sets were (x+1)-transformed before plotting to allow the use of logarithmic scales.

The observed correlation between insect trap loads and radar reflectivity factors is consistent with the hypothesis that insects are potentially an important — and possibly even the principal — source of nocturnal radar signatures. Of course, a simple correlation between radar reflectivity factors and a measure of insect abundance is no more convincing of a causal relationship than is an analogous correlation between radar reflectivity and bird abundance. Both birds and insects necessarily contribute to radar reflectivity factors, and the important questions concern the relative contributions from each under different circumstances, and whether ecological processes involving the two broad classes of biotic radar targets can be distinguished correctly.

Unfortunately, the light traps used in this study are attractant traps that lure insects using a stimulus that operates with different efficiencies on different insect taxa. Thus, there is no way to use the resulting capture data to estimate absolute aerial densities even crudely. A rigorous determination of the quantitative contribution of insects to reflectivity signatures would require the collection of true volumetric data on insect densities over the Gulf using non-attractant traps such as the Johnson-Taylor suction trap (Johnson and Taylor 1955; Taylor 1962), which continues to be manufactured by Burkard Manufacturing Company <http://www.burkard.co.uk/jttrap.htm>.

13.6 DISCUSSION

(by Robert W. Russell)

This study documented a large diversity of insects on offshore platforms in both spring and fall. Some of the common species recorded in this study are nondiapausing species that can only overwinter in areas far enough south to permit them to survive the coldest winter temperatures. These nondiapausing species are obligate migrants that must recolonize the northern parts of their range each year via northward flights of hundreds of kilometers in spring and early summer, and that evacuate the northern areas via southward flights of similar magnitude in late summer and fall (e.g., fall armyworm: Pair et al. 1987, 1991). While other species are physiologically capable of overwintering as diapausing pupae in most of their range, at least portions of the populations of these species also engage in seasonal long-distance migrations (e.g., corn earworm: Hartstack et al. 1982, 1986; Hendrix et al. 1987; Lingren et al. 1993, 1994; Westbrook et al. 1995a,b, 1997). Many of the migratory moth species recorded on our platforms may have originated from points well beyond the northern Gulf Coast, as the ability of insects to travel to the Gulf Coast region from long distances has been documented unequivocally. For example, a marked black cutworm moth (*Agrotis ipsilon*) released in Ankeny, Iowa, in mid-September was recaptured in Brownsville, Texas, in late September (Showers et al. 1993).

Several previous studies have documented the occurrence of insects on oil platforms in the Gulf of Mexico (Sparks et al. 1975, 1986; Baust et al. 1981; Keaster et al. 1996). Sparks et al. (1975) deployed light traps on four platforms in blocks 32, 125, 198, and 292 of the Eugene Island area off the Louisiana coast (located 32, 74, 106, and 160 km offshore, respectively) for six weeks in fall 1973, and found that corn earworms occurred at all four locations but that their abundance decreased monotonically with distance from shore. In addition to corn earworms, 176 species of insects from 9 orders and 69 families were recorded (Sparks et al. 1986). As part of a study of black cutworm migration, Keaster et al. (1996) deployed pheromone traps on Gulf platforms for unspecified durations in September 1988 and in January 1989-1991; they captured about 1700 insects from nine orders, but the study methods precluded complete identifications and detailed analysis.

The abundance and diversity of insects over the Gulf of Mexico has a number of important ecological implications.

First, while the majority of species are undoubtedly inadvertent visitors to the open Gulf, arriving as a result of passive transport in a blanket of "aerial plankton," several species of dragonflies and moths exhibited behaviors and seasonal patterns indicating that they are "intentional" trans-Gulf migrants. Seasonal trans-Gulf migration in insects has important implications for understanding large-scale biogeographic patterns as well as life-history strategies of the species involved. These implications will be explored more fully in future publications.

Second, the passively transported fauna of smaller insect species provides an important food resource that is used extensively by energy-depleted migrant birds on platforms. The foraging behavior and success of migrant birds is described in detail in Chapter 15.

Third, it is possible that allochthonous input of carbon via mortality of drifting insects could be ecologically significant in food webs of the more depauperate waters of the Gulf. Undoubtedly, the vast majority of smaller insects advected over the Gulf must rapidly deplete their fuel stores, fall to the sea surface, and become part of the marine neuston (Zaitsev 1970). Based on neuston tows in the Gulf of Mexico, Wolf et al. (1986) reported typical densities of up to 290 insects per hectare of ocean surface, with exceptional densities of up to 1350/ha in a convergence zone. While some of these individuals may survive and eventually be washed ashore alive, mortality is surely high (e.g., Howden 1977). The role of terrestrial insects as a component of the marine neuston and pleuston, and their possible involvement in marine ecosystem dynamics, have only rarely been considered (Heydemann 1967; Bowden and Johnson 1976; Cheng and Birch 1977, 1978; Wolf et al. 1986; Peck 1994b). Cheng and Birch (1977) estimated the organic input of terrestrial insects into marine systems to be 2-17 kg km^{-2} year^{-1}, which is only about 0.01% of the primary productivity of relatively unproductive oceans. However, the importance of advective fluxes of insects in marine food chains might be much higher locally in the Gulf of Mexico, because primary productivity in the Gulf is relatively low and insect populations appear to be extremely high compared to other areas. To our knowledge, the possibility that terrestrial insects may figure significantly in Gulf food webs and carbon cycling has yet to be evaluated critically.

Fourth, we often noted blue runners (*Caranx crysos*) as well as the otherwise herbivorous Bermuda chubs (*Kyphosus sectatrix*) consuming insects that fell into the water. It is possible that attraction of drifting insects to platforms creates local concentrations of entomological pleuston that in turn play a role in the attraction of the large schools of fish to the surface waters around platforms.

Finally, the abundance of insects over the Gulf in the fall along with the documented correlation between insect trap loads and radar reflectivity factors casts doubt on simplistic attempts to interpret fall NEXRAD images strictly in terms of bird migration. Indeed, we believe that the problems inherent in distinguishing between birds and insects as the source of NEXRAD signatures have been underappreciated severely in virtually all circumstances other than spring trans-Gulf migration (Chapter 9.1).

As discussed in Chapter 9.2, the pattern of diel timing of ascent into the atmosphere by migrating birds is identical to that for dispersing insects, with large numbers of both taxa typically ascending en masse into the airspace about a half hour after sunset. Complicating the problem of radar target identification is the fact that migratory insects also have seasonal activity patterns that are remarkably similar to those of migrating birds. In a comprehensive study of invertebrate populations of a deciduous forest, the total insect population showed seasonal peaks around May 1 and September 1 (Kendeigh 1979). In a study directly relevant to ours, Beerwinkle et al. (1994, 1995) used pheromone traps along with 3-cm scanning radar to study the phenology and nocturnal flight activity of a variety of agriculturally important noctuid moth pests in the Brazos River Valley of coastal Texas. They found that northward migration-type movements were regular in the spring and southward movements were regular in the fall. The most abundant species in their study was the corn earworm (*Heliothis zea*), which also turned out to be abundant offshore during the fall in our study (Table 13.4). Pheromone trapping indicated seasonal peaks in corn earworm migration at around April 20 and October 5 in one year, and April 25 and September 25 in another year. These dates are nearly identical to the seasonal peaks of passerine bird migration along the northern Gulf Coast (Figures 8.3, 9.25). Even the durations of migration are similar: the bulk of the spring pulse of corn earworms occurred March 30-May 30 in one year and March 5-May 20 in the second year of trapping. Similarly, a fall pulse was evident from August 20-October 25 in one year and August 25-October 25 in the second. The only detectable difference between birds and corn earworms is that activity of the latter continues variably through the summer, with periodic peaks from June 10-August 10.

Ornithologists have routinely underestimated the magnitude of the biomass of migrating and dispersing insects in the atmosphere. Entomologists have documented discrete dispersal events involving ten billion moths and hundreds of tons of airborne moth biomass (Dickison et al. 1986). Beerwinkle et al. (1994) documented large numbers of insects moving southward in northerly winds immediately behind advancing cold fronts from early September through late October in coastal Texas, and measured a peak concentration of >1200 noctuid moths/10^6 m^3 in an altitudinal band between 100 and 600 m on the night of October 16-17. Such an ambient density would have resulted in a NEXRAD-measured dBZ_e value over 24 (see Chapter 4.2, Table 13.3), which is comparable to the heaviest spring trans-Gulf bird migrations recorded in this study (e.g., Figure 8.1). The potential for peak insect movements to rival peak bird movements in terms of biomass and reflectivity suggests that proponents of using surveillance radar to monitor bird migrations both along the Gulf Coast and elsewhere should exercise extreme caution.

In some cases, migrating birds may have velocities that are manifested clearly in radar-measured wind fields that differ dramatically from sonde measurements (e.g., Wilczak et al. 1995). However, obvious contamination of wind profiles by migrating birds does not mean that reflectivity contributions from insects can be ignored. In addition, nocturnal moth migrants are not always good tracers of the wind. Indeed, during the course of our nocturnal studies at VK786 (Table 9.1) we often observed apparent noctuids traveling at angles up to 90° with respect to the wind, and on several occasions we have observed pink-spotted hawkmoths (*Agrius cingulata*) traveling upwind under conditions that were challenging to small warblers. The presence of anomalous velocities in radar-observed wind fields is not alone an adequate criterion for interpreting nocturnal radar signatures solely in terms of bird migration.

Chapter 14

Evaluation of a Method for Monitoring Audible Fall Bird Migration Traffic Over Platforms

Andrew Farnsworth and Robert W. Russell

14.1 INTRODUCTION

A major limitation to fall field work on platforms is that the vast majority of trans-Gulf migrants are aloft over the platforms during the night, and at the beginning of their journeys when they are probably much less likely to use the platforms. Moreover, because nocturnal fall migration over the northern Gulf proceeds at much lower altitudes than does the largely diurnal migration during the spring, large fall trans-Gulf flights are often partially or completely missed by radar. An additional problem is that, even when fall migrants are flying high enough to be detected by radar, vast numbers of migrating sphingid and noctuid moths and other insects often dominate the radar return at night, precluding unequivocal interpretations of bird migration based on radar data alone. Thus, except on rare nights when moon conditions permit the quantification of migration via "moonwatching" (Lowery and Newman 1963, 1966), the ability to obtain independent information on fall migration traffic aloft for comparison with observations of migrants on platforms is compromised.

Although we could not effectively study the flight behavior of nocturnal fall migrants using visual means, we frequently heard large numbers calling as they passed overhead. Birds are thought to vocalize at night during migration as a means of maintaining flock structure and facilitating orientation. We attempted to exploit this behavior and undertook a pilot study in fall 1999 to evaluate an acoustic recording method for monitoring audible bird migration traffic over the platforms.

14.2 BACKGROUND ON STUDIES OF NOCTURNAL VOCALIZATIONS BY MIGRANTS

Nocturnal vocalizations have offered insight into the specific composition of nocturnal flights of migrating birds since the turn of the century (Libby 1899). As early as the 1950s, researchers were actively investigating nocturnal migration by examining bird vocalizations with electronic recording technology (Ball 1952; Graber and Cochran 1959, 1960; Hamilton 1962; Dorka 1966; Graber 1968; Dierschke 1989). Since 1985, Evans and colleagues (Evans 1994; Evans and Mellinger 1999; Evans and Rosenberg 2000) have determined the identity of many nocturnal vocalizations of migrant landbirds by comparing spectrographic analyses of nocturnal flight calls with known diurnal flight calls and correlating seasonal timing and geographic range patterns of these nocturnal recordings with known timing and migration routes of migrants. Groups known to give night-flight calls include cuckoos (Cuculidae), thrushes (Turdinae, especially the species in the genus *Catharus*), warblers (Parulinae), and sparrows (Emberizinae); many non-passerines including herons (Ardeidae), waterfowl (Anatidae), and rails (Rallidae) also give night-flight calls. As a result of the recent advances, it is now theoretically possible — simply by aiming a microphone at the sky — to record and analyze the vocalizations of passing migrants, yielding data on species composition, migration timing and routing, and the volume of nocturnal migration traffic.

14.3 FIELD METHODS

Following the design for a pressure zone microphone (PZM) suggested and successfully implemented in recent onshore studies (Evans 1994; Evans and Mellinger 1999; Evans and Rosenberg 2000), Farnsworth constructed two PZMs and housed them in flower pots to improve durability and shield the microphone from excessive wind noise. The configuration of a PZM looks and acts much like a tympanic membrane: a small microphone centered on a reflective dish which is sealed against moisture with a thin plastic membrane, and which acts in such a way as to amplify the bird vocalization. Housing a PZM in a flower pot also secures its position and maintains its skyward orientation. To protect the plastic membrane surface of the PZM from debris, the pot was covered with lightweight, perforated cloth.

The range of detection of the flower pot PZM varies with conditions, but it can generally record calls in the 6-9 kHz range (most warblers and sparrows) within a cone of detection 300 m high and 250 m wide, as well as in the 2-5 kHz range (most thrushes, grosbeaks, and tanagers) within a cone of detection 600 m high and 1000 m wide (Evans and Rosenberg 2000). The detection heights are well within what are considered the densest layers of nocturnal migration over land.

One of the PZM units was assigned to EW826, but failed shortly after deployment. The other unit was deployed to VK786 on September 9 and successfully operated on 41 nights through November 2. (A mechanical failure precluded operations in early October while replacement parts were gathered and shipped offshore.)

On operational nights, calls were recorded to 8-hour VHS tapes on a Sony SLV-675 hi-fidelity videocassette recorder. Most recordings began at 21:00 CDT (range = 20:44-21:18 CDT) and ended close to 05:00 CDT. A portable Optimus tape deck was used to amplify the signal of the incoming audio stream. At the end of each night, tapes were labeled with the date and time of recording and stored for later analysis in the laboratory.

14.4 LABORATORY ANALYSIS

Farnsworth conducted all laboratory analysis at Clemson University. The VHS tapes were played back into the line level input of a Dell XPS-600 computer with a SoundBlaster 4.61
16-bit sound card to analyze the acoustic record for each night. During playback, software developed by Old Bird, Inc. <www.oldbird.org> was used to detect call notes automatically, following the methods of Larkin et al. (2002). This software examined two basic criteria to detect a call note: aberrations in the slope of incoming smoothed log-magnitude signal energy and concentrations in the Fourier spectrum in a given frequency band. If a signal met these criteria, it was logged with a time and date stamp as a digital .wav file. Once these .wav files were logged, they were examined using a visual spectrographic analysis software package called GlassOFire developed by Old Bird, Inc. This program permitted the viewing of large numbers of digital .wav files as spectrographs, and facilitated the classification of call notes and the rejection of spurious, non-avian detections. The identity of avian detections was also confirmed by reviewing all classified calls through headphones plugged into the computer's sound card.

These techniques were used to analyze a total of 333 hours of recordings made on VK786 over 41 nights during fall 1999. To check the program's efficiency, each 8-h tape was manually audited four times each hour to confirm the detection success of the algorithms employed by the Old Bird, Inc. software. The software's detection rate was approximately 98% of the manual auditory detection rate, and the software correctly detected a small percentage of calls that were missed manually (4%).

Unfavorable recording conditions occurred on 11 nights and necessitated the rejection of all data collected by the PZM during those time periods. Such data are likely not salvageable by any means of corrective recording techniques, representing one of the drawbacks of this methodology in a noisy environment. Environmental noise and platform activities that were not as extreme also significantly affected the recordings, effectively reducing the efficiency of the PZM for any vocalizations in the 2-5 kHz range to zero. As a result, the data presented here mostly represent 6-9 kHz detections of warblers and sparrows and a few lower-frequency vocalizations (e.g., bunting types). Some of these data were also contaminated by environmental noise, making detection possible but identification impossible.

14.5 RESULTS

A summary of number of calls detected on a nightly and hourly basis is provided in Table 14.1. Altogether, 2762 calls were detected during 30 nights of recording, although some of the calls could not be analyzed properly due to contamination by non-avian signals. The last column in Table 14.1 shows the total number of recognizable calls corrected for contamination and recording problems. Table 14.2 presents the identities of known species and their total calls as well as unidentified species and their total calls. Three species (Black-and-white Warbler, Common Yellowthroat, and American Redstart) could be identified specifically, representing approximately 9% (N = 156) of the total identifiable calls (N = 1664). Four call types attributable to species groups defined by Evans and Rosenberg (2000) and representing approximately 15-20 possible species were also identified, but not to the specific level. Call notes in the four species groups made up approximately 54% (873) of the total identifiable calls. Bunting types representing two species in the genus *Passerina* and a single species in the genus *Guiraca* represented approximately 3% (42) of the total identifiable calls. Unidentified calls made up the remaining percentage of approximately 34% (562) of the total identifiable calls.

Table 14.1.

Summary of hourly and nightly numbers of calls recorded over VK786 during fall 1999

		Time (CDT)										Total #
Date	Hours Recorded	21:00-22:00	22:00-23:00	23:00-00:00	00:00-01:00	01:00-02:00	02:00-03:00	03:00-04:00	04:00-05:00	05:00-06:00	Total # Calls	Corrected for Contamination
9-Sep	8.0	0	0	3	23	12	20	39	21	0	118	76
10-Sep	8.0	2	257	196	67	33	58	123	245	36	1,017	659
12-Sep	7.4	1	2	0	0	2	8	0	10	0	23	18
13-Sep	8.0	0	0	0	2	30	7	18	23	8	88	62
14-Sep	8.0	0	45	25	35	10	14	45	33	5	212	143
15-Sep	8.0	10	10	25	9	32	26	3	82	1	198	99
16-Sep	7.0	0	0	0	1	0	0	0	0	0	1	1
17-Sep	8.0	0	1	18	12	5	19	14	47	6	122	76
18-Sep	8.0	1	0	8	4	40	3	16	40	13	125	94
20-Sep	8.0	0	0	0	0	0	0	3	0	1	4	1
21-Sep	8.0	14	8	0	0	0	0	4	0	0	26	2
22-Sep	8.0	0	14	10	13	8	17	15	51	9	137	29
23-Sep	8.0	0	0	0	0	0	1	1	14	0	16	12
24-Sep	8.0	0	4	0	0	0	0	0	0	0	4	2
25-Sep	7.0	0	0	0	0	0	0	0	0	0	0	0
26-Sep	8.0	0	0	0	0	0	0	0	0	0	0	0
27-Sep	8.0	0	0	0	1	0	0	0	0	0	1	0
28-Sep	8.0	0	1	5	1	0	0	0	0	0	7	1
29-Sep	8.0	2	3	7	37	34	13	41	122	46	305	168

Table 14.1.

Summary of hourly and nightly numbers of calls recorded over VK786 during fall 1999

						Time (CDT)						Total #
19-Oct	7.2	0	0	0	0	0	0	0	0	0	0	0
20-Oct	8.0	0	3	3	6	5	4	17	8	2	48	29
21-Oct	8.0	1	0	5	0	0	0	2	2	2	12	4
22-Oct	8.0	0	0	0	0	1	0	1	0	0	2	2
23-Oct	8.0	3	0	0	3	2	0	1	0	0	9	3
24-Oct	8.1	1	1	1	1	1	2	1	0	1	9	9
25-Oct	8.0	0	0	0	0	6	29	41	6	0	82	60
26-Oct	8.0	5	0	0	0	0	1	1	1	7	15	5
27-Oct	8.0	6	2	5	1	2	1	2	63	2	84	54
1-Nov	8.0	4	65	5	5	0	2	0	3	2	86	52
2-Nov	8.0	0	0	0	1	5	2	1	2	0	11	3
Totals	236.7	50	416	316	222	228	227	389	773	141	2,762	1,664

Table 14.2.

Species composition of calling migrants recorded over VK786 during fall 1999

Groups follow the Evans and Rosenberg (2000) classification scheme (Table 14.3). “Bunting type” refers to a group containing two species of the genus *Passerina* and a single species in the genus *Guiraca*. Abbreviations: BAWW = Black-and-white Warbler; COYE = Common Yellowthroat; AMRE = American Redstart; UNID = unidentified.

	Taxon									
Date	BAWW	COYE	AMRE	Bunting Type	Group 2	Group 3	Group 4	Group 5	UNID	Total
9-Sep	2	2	6	3	3	13	2	35	10	76
10-Sep	3	1	43	4	13	163	38	147	247	659
12-Sep	3	2	0	0	0	0	0	7	6	18
13-Sep	2	4	2	1	4	9	1	31	8	62
14-Sep	0	0	8	3	5	31	7	23	66	143
15-Sep	0	1	15	2	1	17	4	43	17	99
16-Sep	0	0	0	0	0	0	1	0	0	1
17-Sep	2	2	5	9	0	13	4	22	19	76
18-Sep	1	3	14	7	3	4	0	49	13	94
20-Sep	0	1	0	0	0	0	0	0	0	1
21-Sep	0	0	1	0	0	0	0	1	0	2
22-Sep	0	2	0	0	0	0	2	5	20	29
23-Sep	0	0	0	0	0	0	0	0	0	12
24-Sep	0	2	0	0	0	0	0	0	0	2
25-Sep	0	0	0	0	0	0	0	0	0	0
26-Sep	0	0	0	0	0	0	0	0	0	0
27-Sep	0	0	0	0	0	0	0	0	0	0
28-Sep	0	0	0	0	0	0	0	0	1	1
29-Sep	2	6	8	3	0	74	7	54	14	168
19-Oct	0	0	0	0	0	0	0	0	0	0
20-Oct	1	0	1	4	0	3	0	9	11	29
21-Oct	0	0	0	0	0	0	0	0	4	4
22-Oct	0	0	0	0	0	2	0	0	0	2
23-Oct	0	3	0	0	0	0	0	0	0	3
24-Oct	0	2	0	0	0	1	0	1	5	9
25-Oct	0	2	0	3	0	4	1	5	45	60
26-Oct	0	0	0	0	0	1	1	0	3	5
27-Oct	0	0	1	3	0	3	3	1	43	54
1-Nov	0	3	0	0	0	9	2	11	27	52
2-Nov	0	0	0	0	0	0	0	0	3	3
30 nights	16	36	104	42	29	347	73	444	562	1,664

Table 14.3.

Some nocturnal call note group classifications

Each grouping represents a “complex” of species with similar call notes. From Table 2 in Evans and Rosenberg (2000).

Group 2	
Blue-winged Warbler	A buzzy “kzeen” or “kzeep” note
Golden-winged Warbler	
Louisiana Waterthrush	
Group 3	
Tennessee Warbler	A sibilant, rising “tseet” or “tsee” note
Nashville Warbler	
Orange-crowned Warbler	
Black-throated Green Warbler	
Vesper Sparrow	
Yellow-rumped Warbler	
White-crowned Sparrow	
Group 4	
Pine Warbler	A descending “tsew” note
Northern Parula	
Field Sparrow	
Yellow-throated Warbler	
Prairie Warbler	
Group 5	
Cerulean Warbler	A buzzy “zeet” note
Blackburnian Warbler	
Magnolia Warbler	
Worm-eating Warbler	
Blackpoll Warbler	
Yellow Warbler	
Bay-breasted Warbler	
Connecticut Warbler	

Figure 14.1 shows the temporal pattern of calls recorded per hour. The peak number of nocturnal calls during one hour (733 calls) occurred approximately 8 hours after the beginning of recording, during the period from 04:00-05:00 CDT. A secondary peak (416 calls) occurred approximately 2 hours after the beginning of recording, during the period from 23:00-00:00 CDT.

We examined the relationship between the frequency of calls recorded during a given night and the abundance of landbird migrants on the platform the following day. Prior to analysis, stopover counts were ln(x+1)-transformed to normalize the highly skewed distribution. Overall, there was not a significant correlation between nocturnal calling and subsequent stopovers ($r_p = 0.21$, N = 30 nights, P = 0.26). However, we noticed that there seemed to be an influence of weather on the relationship between calling and stopovers. Two weather types dominated the overall sample and provided subsamples of sufficient size for analysis (**ECH** and **MCH**; N = 11, 12 nights respectively). We conducted an analysis of covariance (ANCOVA) with synoptic weather type (**ECH** versus **MCH**) as the independent categorical variable and nightly calling frequency as the covariate. This analysis indicated the following: 1) the number of stopovers was significantly positively related to calling frequency ($F_{1,19}$ = 4.91, P = 0.039); 2) the slope of the calling-stopover relationship did not differ between weather types ($F_{1,19}$ = 1.12, P = 0.30); and 3) a given nocturnal call frequency was associated with significantly more stopovers when the weather type was **MCH** ($F_{1,19}$ = 13.1, P = 0.002).

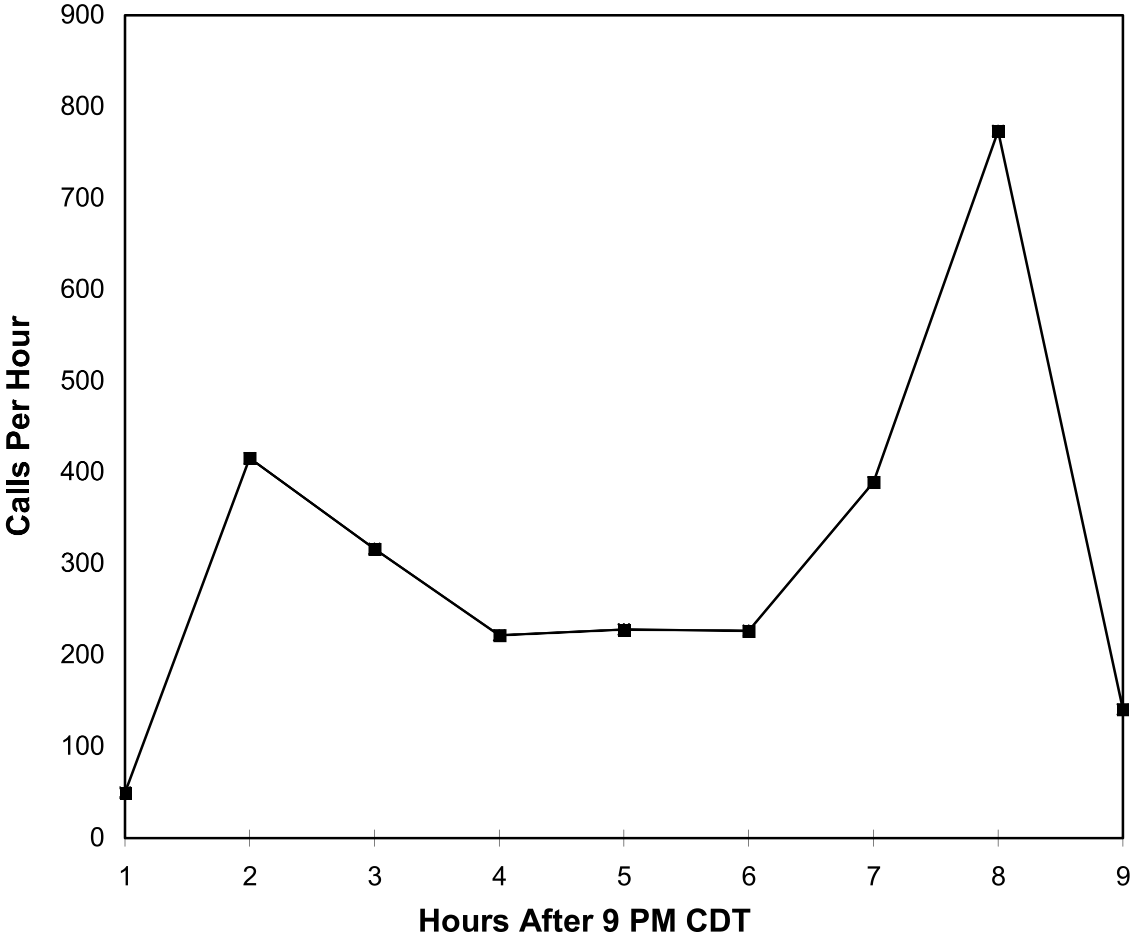


Figure 14.1. Total calls per hour recorded at VK786 during fall 1999.

The apparent weather influence on the magnitude of the relationship between calling and stopovers could result from an influence of weather on likelihood of calling, an influence of weather on likelihood of initiating a stopover, or perhaps both. Fortuitously, we conducted an ancillary study of nocturnal flight behavior that provides some evidence concerning the former possibility. On several days in September 1999, an observer on VK786 conducted visual and auditory censuses of migrants while lying prone on the platform helipad through the night. On the night of September 17-18 (**ECH**), 22 small migrant passerine targets were detected visually and 5 of those were heard calling. On the night of September 21-22 (**MCH**), 67 small migrant passerines were detected visually and 7 of those were heard calling. The proportion of migrants calling was thus more than twice as high on the **ECH** night (23%) than on the **MCH** night (10%), though the difference was not quite statistically significant due to the relatively small sample on the **ECH** night (G = 1.95, P = 0.16). If this was indeed a true difference, it suggests that nocturnal migrants may call less frequently under favorable flight conditions.

14.6 DISCUSSION

The data gathered during this study offered a unique opportunity to examine the behavior of nocturnal calling over water. All previous studies have focused on recording birds in migration over land.

It is interesting to note that two marked peaks occurred in the total number of calls per hour over the course of the night (Figure 14.1). If the nearest stopover habitat is approximately 145 km to the north (Table 2.2), birds departing the coast a half hour after sunset and traveling south at 12 $m \cdot s^{-1}$ would reach the platform shortly before midnight. Thus, it seems likely that the peak in calling occurring at 23:00-24:00 CDT represented the initial wave of migrants leaving the coast of the United States. The major peak occurring at 04:00-05:00 CDT likely represents what occurs with some consistency over land at approximately the same time — a communication of the message to flock and/or to land. It is possible that increased calling over VK786 late in the night resulted from migrants seeking to reform flocks for the remaining diurnal flight across the Gulf of Mexico, or perhaps attempting to find suitable landing sites on the platform.

The finding of a positive relationship between calling frequency and subsequent stopovers, after accounting for effects of weather, suggests that it might be possible to use automated acoustic methods to generate quantitative data on nocturnal migrant traffic in the airspace above platforms. Other recent work has shown that calling does reflect bird density in a weak positive relationship, but the temporal and spatial bounds of the relationship's occurrence and utility are still not well understood (Farnsworth 2001). The presence of a platform may itself represent a bias that positively affects calling rate in migrants, if migrants are calling as a means of communicating to maintain flock organization (Hamilton 1962) or to convey information about location (Farnsworth 2001), including potential landing situations on the platform.

The need for quiet recording locations when sampling nocturnal migration with acoustic sensors has been mentioned frequently (e.g., Graber and Cochran 1959) and would be critical in the planning for any future acoustic work in offshore situations. The adverse acoustic environment usually found offshore (e.g., high winds, platform noise) means that the technique is not likely to be used very frequently. However, in this study, the microphone did not exhibit any signs of corrosion on the element or in its energy supply, making the implementation of this type of sensor in future studies a realistic possibility in terms of the performance of the equipment.

Several other difficulties exist in using this technique to monitor nocturnal migration, e.g., the identity of many migrant species is still poorly understood, the rate at which different species vocalize is not constant, and some species may not vocalize at all. Given these caveats, a conservative approach is best when interpreting acoustic data. However, any knowledge of the magnitude and specific composition of offshore flights during periods when visual observation is unlikely or impossible is potentially very valuable. A recently published audio guide to nocturnal vocalizations (Evans and O'Brien 2002) and increasing popular interest in flight call notes will shed more light on issues of species identity in the very near future, making further studies of this kind a realistic option at least for qualifying nocturnal migration both onshore and offshore.

PART 4

THE IMPACT OF PLATFORMS ON MIGRANT BIRDS

Chapter 15

Stopover Ecology of Migrants on Platforms

Robert W. Russell

15.1 PHYSIOLOGICAL CONDITION OF ARRIVING MIGRANTS

The majority of migrants arriving on platforms appeared to be in fine physical condition. However, initial body condition varied between seasons and among species types and was related to weather.

15.1.1 Spring

In the spring, small neotropical migrants were least frequently in poor condition upon arrival on **BH**, **ECH**, and **GH** days, and most frequently in poor condition on **GF** and especially **MCH** days (Table 15.1; G = 23.7, df = 8, P = 0.0026).

Large neotropical migrants exhibited a pattern similar to that for small species, except that a larger overall proportion of birds arrived in poor condition (Table 15.2; excluding the 2 AE birds: G = 21.8, df = 4, P = 0.0002).

Table 15.1.

Initial body condition of newly arrived small neotropical migrants in relation to synoptic weather type during spring 2000

Proportions are shown.

Weather	Initial Body Condition			
Type	AE	AT	AV	N
BH	0.015	0.088	0.897	522
ECH	0.014	0.096	0.890	291
GH	0.034	0.085	0.881	118
GF	0.012	0.152	0.836	1,182
MCH	0.018	0.193	0.789	57
All types	0.014	0.127	0.859	
N	31	275	1,864	2,170

Table 15.2.

Initial body condition of newly arrived large neotropical migrants in relation to synoptic weather type during spring 2000

Proportions are shown.

Weather Type	Initial Body Condition AE	AT	AV	N
BH	0.009	0.150	0.841	107
ECH	0.000	0.204	0.796	93
GH	0.000	0.195	0.805	82
GF	0.003	0.304	0.694	382
MCH	0.000	0.395	0.605	86
All types	0.003	0.268	0.729	
N	2	201	547	750

15.1.2 Fall

In the fall, small neotropical migrants were least frequently in poor condition on **ECH**, **ELOW**, and **GH** days, and most frequently in poor condition on **BH**, **MCH**, and especially **TLOW** days (Table 15.3; excluding the 13 AE birds: G = 541.6, df = 5, P < 0.0001).

In contrast to the spring, when large neotropical migrants were more likely than small species to arrive in poor condition (Tables 15.1, 15.2), large migrants were more likely than small species to arrive in good condition during the fall (Tables 15.3, 15.4).

Table 15.3.

Initial body condition of newly arrived small neotropical migrants in relation to synoptic weather type during fall 1999

Proportions are shown.

Weather type	Initial Body Condition AE	AT	AV	N
ELOW	0.000	0.072	0.928	208
MCH	0.002	0.284	0.714	2,033
ECH	0.005	0.052	0.943	982
GH	0.004	0.069	0.928	567
BH	0.050	0.200	0.750	20
TLOW	0.002	0.445	0.553	604
All types	0.003	0.217	0.780	
N	13	956	3,445	4,414

Table 15.4.

Initial body condition of newly arrived large neotropical migrants
in relation to synoptic weather type during fall 1999

Proportions are shown.

Weather Type	Initial Body Condition AE	AT	AV	N
ELOW	0.000	0.059	0.941	202
MCH	0.007	0.094	0.899	684
ECH	0.004	0.075	0.920	226
GH	0.023	0.090	0.887	177
BH	0.000	0.053	0.947	19
TLOW	0.014	0.192	0.795	146
All types	0.008	0.095	0.897	
N	12	138	1,304	1,454

In addition, while arrival condition of large migrants was also related to weather type in fall (Table 15.4; excluding the 12 AE birds: G = 18.0, df = 5, P = 0.0029), large species exhibited a rather different pattern in fall than did small species. Specifically, the likelihood of arriving in poor condition on **MCH** days was not dramatically different than on days with other seemingly favorable weather types (Table 15.4). Oddly, large fall migrants were least likely to arrive in poor condition on **BH** days, though the sample size was very small. As was the case for small species, large neotropical migrants in fall were most likely to arrive in poor condition on **TLOW** days.

15.2 FORAGING BEHAVIOR AND SUCCESS

Analyses of foraging behavior were restricted to neotropical migrants, medium- and short-distance migrants, and vagrants. Aerial insectivores often appeared to be foraging on aerial plankton in the lees of the platforms, but because it was impossible to observe their minute prey from a distance, we were unable to characterize their behavior with certainty. Ruby-throated Hummingbirds were often observed approaching red objects or materials, apparently in search of flowers and nectar. Because of the difficulty in ascertaining the motivation for this behavior — as well as the universal absence of real food resources for hummingbirds on platforms — they were also excluded from foraging analyses.

15.2.1 Spring

Overall, 11% of the 7,261 migrant landbirds that undertook stopovers on the platforms over the three springs of study were observed foraging. Likelihood of foraging varied significantly among the three springs studied (1998: 187 of 3,021 [6%]; 1999: 147 of 791 [19%]; 2000: 453 of 3,449 [13%]; G = 137.8, df = 2, P < 0.0001).

Likelihood of foraging was also related to body condition of the migrants upon arrival, though the form of the relationship varied among years. In spring 1998, 168 of 2,881 landbirds that were vigorous upon arrival were subsequently observed foraging (6%), whereas 19 of 101 tired and exhausted migrants were observed foraging (19%). This difference was statistically significant (G = 19.2, P < 0.0001). In spring 1999, 118 of 552 vigorous migrants were observed foraging (21%), whereas 29 of 232 exhausted migrants were observed foraging (13%). This difference was statistically significant (G = 9.0, P = 0.003).

In spring 2000, 350 of 2,780 vigorous migrants were observed foraging (13%), whereas 103 of 577 exhausted migrants were observed foraging (18%). This difference was statistically significant (G = 10.6, P = 0.001). Thus, exhausted migrants were significantly more likely to forage than were vigorous migrants in two years (1998, 2000), whereas vigorous migrants were more likely to forage in the other year (1999).

Overall, 38% of the 787 landbird migrants that were observed foraging over the three springs of study were successful. Likelihood of success varied significantly among the three springs studied (1998: 57 of 187 [30%]; 1999: 40 of 147 [27%]; 2000: 201 of 453 [44%]; G = 19.9, df = 2, P < 0.0001), and was also variably related to body condition of the migrants upon arrival. Likelihood of success by foraging birds was unrelated to initial body condition in two of the three years of study (1998: 30% of 168 vigorous migrants successful, versus 32% of 19 exhausted migrants; G = 0.01, P = 0.91; 2000: 44% of 350 vigorous migrants successful, versus 46% of 103 exhausted migrants; G = 0.09, P = 0.77). In the other year (1999), significantly more vigorous migrants foraged successfully (32% of 118, versus 7% of 29 exhausted migrants; G = 9.2, P = 0.002).

Drinking by migrants on the platforms was very rare, despite the constant availability of fresh water on most platforms. Overall, 0.5% of the 7,261 landbird migrants that undertook stopovers on the platforms over the three springs of study were observed drinking. Likelihood of drinking varied significantly among the three springs studied (1998: 21 of 3,021 [0.7%]; 1999: 11 of 791 [1.4%]; 2000: 7 of 3449 [0.2%]; G = 18.2, df = 2, P = 0.0001), and was also variably related to body condition of the migrants upon arrival. In two of the three years of study, significantly more exhausted migrants were observed drinking than were vigorous migrants (1998: 0.6% of 2,881 vigorous migrants observed drinking, versus 4.1% of 101 exhausted migrants; G = 7.9, P = 0.005; 2000: 0.07% of 2,780 vigorous migrants, versus 0.9% of 577 exhausted migrants; G = 10.0, P = 0.002). In the other year (1999), there was no relationship between body condition and likelihood of drinking (1.4% of 552 vigorous migrants observed drinking, versus 1.3% of 232 exhausted migrants; G = 0.03, P = 0.86).

15.2.2 Interspecific Variation

A comparison of the foraging status and success of the different species groups during the fall is provided in Table 15.5. Long-distance migrants foraged less frequently than did medium-distance migrants, which foraged less frequently than did short-distance migrants and vagrants. These differences are understandable in terms of the migratory goals of the different groups and their proximities to points of original departure. The long-distance migrants presumably departed from nearby points along the northern Gulf Coast with adequate energy stores to complete a trans-Gulf crossing. In contrast, most of the medium- and especially short-distance migrants ended up over water inadvertently (Chapter 9.4) and had probably not deposited adequate energy reserves for a long water crossing. Vagrants were randomly oriented during the fall (Figure 11.6) and many of them had probably expended most of their energy reserves traveling long distances over water from their points of departure. The likelihood of foraging success was similar among all groups except vagrants, which were the most successful — perhaps because they were the most fat-depleted and had the greatest "motivation."

A summary of species-specific foraging status and success is provided in Table 15.6. Among warblers, the following species were observed foraging more than 50% of the time: Pine Warbler, Prairie Warbler, Canada Warbler, Western Palm Warbler, Orange-crowned Warbler, Myrtle Warbler, Mourning Warbler, and Wilson's Warbler. These species are all overshoots (Pine Warbler, Orange-crowned Warbler, and probably some of the Myrtle Warblers), vagrants (Western Palm Warbler, Prairie Warbler), or primarily circum-Gulf migrants that do not routinely cross the widest part of the Gulf (Canada Warbler, Mourning Warbler, Wilson's Warbler). Warbler species observed foraging infrequently (<50%) were all typical trans-Gulf migrants. Among non-warblers, the list of frequent foragers was dominated by small flycatchers and ecologically similar species (gnatcatchers, kinglets).

Among the species shown in Table 15.6, there was a significant correlation between likelihood of foraging and probability of success ($r_p = 0.35$, $N = 48$, $P = 0.014$), though the amount of variance explained was rather low (12.5%).

Table 15.5.

Comparative foraging status of the different species groups in fall 1999

Sample size indicates total number of individuals studied in all synoptic weather types. "Proportion successful" is the proportion of the foraging birds that were successful. The "VAG" group includes both Caribbean and western vagrants.

Species Group	N	Proportion Foraging	Proportion Successful
NEOS	3,217	0.19	0.45
NEOL	1,175	0.12	0.42
MDM	907	0.33	0.44
SDM	276	0.47	0.46
VAG	194	0.46	0.62
Total	5,769	0.22	0.46

Table 15.6.

Species-specific foraging status in fall 1999

Sample size shown is total number of individuals stopping over on platforms. The list excludes species with N < 10 stopovers. "Proportion successful" is the proportion of the foraging birds that were successful. Data on proportion successful are shown only for species with N ≥ 8 individuals observed foraging. Species are listed in descending order of foraging frequency.

Species	N	Proportion Foraging	Proportion Successful
Pine Warbler	13	0.846	0.455
Least Flycatcher	64	0.688	0.705
Acadian Flycatcher	23	0.652	0.733
Blue-gray Gnatcatcher	14	0.643	0.778
Prairie Warbler	25	0.640	0.500
Canada Warbler	18	0.611	0.364
Western Palm Warbler	68	0.603	0.683
Orange-crowned Warbler	60	0.600	0.500
Winter Wren	10	0.600	na
Eastern Phoebe	41	0.585	0.750
Ruby-crowned Kinglet	115	0.574	0.545
Myrtle Warbler	148	0.568	0.464
Mourning Warbler	25	0.560	0.357

Table 15.6.

Species-specific foraging status in fall 1999

Sample size shown is total number of individuals stopping over on platforms. The list excludes species with N < 10 stopovers. "Proportion successful" is the proportion of the foraging birds that were successful. Data on proportion successful are shown only for species with N ≥ 8 individuals observed foraging. Species are listed in descending order of foraging frequency.

Species	N	Proportion Foraging	Proportion Successful
Northern Mockingbird	34	0.559	0.737
"Traill's" Flycatcher	31	0.548	0.647
Chipping Sparrow	39	0.538	0.429
Wilson's Warbler	36	0.528	0.474
Song Sparrow	25	0.520	0.308
Clay-colored Sparrow	51	0.471	0.417
Eastern Kingbird	32	0.469	0.200
Great Crested Flycatcher	44	0.432	0.632
White-crowned Sparrow	10	0.400	na
Savannah Sparrow	102	0.392	0.375
Lark Sparrow	18	0.389	na
Sedge Wren	17	0.353	na
Marsh Wren	156	0.353	0.309
Black-throated Blue Warbler	20	0.350	na
Swamp Sparrow	41	0.341	0.071
Gray Catbird	64	0.328	0.476
Brown Thrasher	49	0.327	0.688
White-throated Sparrow	25	0.320	0.000
House Wren	204	0.319	0.431
Common Yellowthroat	459	0.318	0.219
Eastern Wood-Pewee	40	0.300	0.667
Nashville Warbler	48	0.292	0.429
Yellow Warbler	222	0.284	0.540
Baltimore Oriole	31	0.258	0.125
Scissor-tailed Flycatcher	43	0.233	0.800
Northern Waterthrush	50	0.220	0.545
Black-and-white Warbler	112	0.205	0.348
Yellow-breasted Chat	172	0.186	0.313
Western Meadowlark	54	0.185	0.600
Swainson's Thrush	26	0.154	na
Brown-headed Cowbird	24	0.125	na
Yellow-billed Cuckoo	16	0.125	na
Worm-eating Warbler	25	0.120	na
American Redstart	404	0.111	0.378
Yellow-throated Warbler	27	0.111	na
Scarlet Tanager	18	0.111	na
Summer Tanager	18	0.111	na
Dickcissel	73	0.110	0.250
Kentucky Warbler	31	0.097	na

Table 15.6.

Species-specific foraging status in fall 1999

Sample size shown is total number of individuals stopping over on platforms. The list excludes species with N < 10 stopovers. "Proportion successful" is the proportion of the foraging birds that were successful. Data on proportion successful are shown only for species with N ≥ 8 individuals observed foraging. Species are listed in descending order of foraging frequency.

Species	N	Proportion Foraging	Proportion Successful
Orchard Oriole	35	0.086	na
Tennessee Warbler	148	0.074	0.455
White-eyed Vireo	42	0.071	na
Lincoln's Sparrow	210	0.067	0.500
Hooded Warbler	120	0.067	0.250
Chestnut-sided Warbler	61	0.066	na
Blackburnian Warbler	51	0.059	na
Ovenbird	185	0.054	0.400
Red-eyed Vireo	37	0.054	na
Blue Grosbeak	19	0.053	na
Bay-breasted Warbler	60	0.050	na
Eastern Meadowlark	22	0.045	na
Magnolia Warbler	581	0.043	0.440
Prothonotary Warbler	196	0.041	0.375
White-winged Dove	223	0.040	0.444
Grasshopper Sparrow	80	0.038	na
Common Ground-Dove	27	0.037	na
Northern Parula	199	0.025	na
Black-throated Green Warbler	370	0.024	0.556
Mourning Dove	703	0.011	0.000
Indigo Bunting	322	0.009	na
Cerulean Warbler	16	0.000	na
Rose-breasted Grosbeak	13	0.000	na

15.2.3 Weather Influences

The relationship between foraging status and weather upon arrival is summarized in Table 15.7. Large neotropical migrants, medium- and short-distance migrants, and vagrants were all most likely to forage when arriving on **GH** days. One possible explanation for this pattern is that migrants arriving on **GH** days attempt to compensate for the much weaker winds (and reduced potential for wind assistance) that generally prevail in association with a high pressure system over the Gulf. Small neotropical migrants also foraged more frequently when arriving on **GH** days than on most days with more favorable winds, except that they showed a striking tendency to forage most frequently on **ELOW** days. One possible explanation for this finding is that some of the smaller species arriving offshore on **ELOW** days did so inadvertently as a result of drift by the strong NW winds that generally accompany the **ELOW** type, and consequently had insufficient energy stores to complete the crossing or correct for the displacement.

The relationship between foraging success and weather upon arrival is summarized in Table 15.8. Foraging success was generally rather high, and few consistent patterns emerged. All groups were at least as successful when arriving on **MCH** days as on **ECH** days, presumably reflecting the greater insect biomass advected offshore on **MCH** days.

Table 15.7.

Relationship of foraging status to weather in fall 1999

Data shown are proportions of all individuals stopping over that were ever observed foraging in relation to weather type upon arrival, classified by species group. Only common weather types are shown; meaningful samples were not available for **BH** and **ND** types. Sample size is given in parentheses and indicates total number of stopovers (i.e., both foraging and not). Caribbean and western vagrants are combined into one group due to limited sample sizes.

Species	Synoptic Weather Type				
Group	ECH	ELOW	GH	MCH	TLOW
NEOS	0.18(698)	0.45 (197)	0.31 (1,498)	0.16 (1,337)	0.08 (462)
NEOL	0.11(210)	0.07 (132)	0.27 (171)	0.08 (509)	0.09 (130)
MDM	0.36 (73)	0.31 (290)	0.45 (67)	0.34 (419)	0.17 (46)
SDM	0.42 (31)	0.39 (83)	0.58 (12)	0.54 (132)	0.43 (14)
VAG	0.30 (33)	0.48 (31)	0.68 (28)	0.42 (72)	0.52 (29)

Table 15.8.

Relationship of foraging success to weather in fall 1999

Data shown are proportions of all individuals observed foraging that were ever successful in relation to weather type upon arrival, classified by species group. Only common weather types are shown; meaningful samples were not available for **BH** and **ND** types. Sample size is given in parentheses and indicates total number of individuals observed foraging. Caribbean and western vagrants are combined into one group due to limited sample sizes.

Species	Synoptic Weather Type				
Group	ECH	ELOW	GH	MCH	TLOW
NEOS	0.45 (125)	0.44 (88)	0.49 (152)	0.45 (214)	0.40 (38)
NEOL	0.33 (24)	0.56 (9)	0.36 (47)	0.56 (41)	0.25 (12)
MDM	0.19 (26)	0.49 (90)	0.37 (30)	0.48 (141)	0.38 (8)
SDM	0.46 (13)	0.28 (32)	0.29 (7)	0.54 (71)	0.83 (6)
VAG	0.50 (10)	0.67 (15)	0.53 (19)	0.77 (30)	0.47 (15)

15.2.4 Comparison Between Platform Foraging and “Natural” Foraging

Over the course of the study it became apparent that the foraging behavior of many species in the artificial environment of the platforms closely resembled the foraging behavior of these species in their natural terrestrial environments, despite the profound structural and ecological differences between the artificial and natural habitats. In fall 2000 we conducted a focused study on PN975, MI622, and MP252 to quantify in greater detail the foraging behavior of selected species on platforms. The specific objectives of this study were to test the hypothesis that species-specific behavioral stereotypes are preserved in a completely artificial environment, and to estimate energy intake rates of actively foraging birds in a completely novel environment for comparison to natural stopover habitats.

Species selected for detailed observational work were chosen because of the availability of comparative data on the foraging behavior of these species during stopovers in natural habitats in chenieres along the northern Gulf coast (Chen 1996). We defined searching movements following Chen (1996). "Hop" means any movement made only by legs. "Flutter" means movements made mainly by legs with the support of wings. "Fly" means movements made by the beating of wings. An "attack" is any attempt to capture a prey item, and a successful attack is a capture (i.e., a prey item is captured and consumed). At the beginning of an observation period for an individual migrant, we recorded the start time and the bird's platform microhabitat and began taking observations. All searching movements, attacks, and captures were recorded until the bird moved to a new platform microhabitat or disappeared from view, and the elapsed time was then recorded.

Results from the focused foraging studies are summarized in Table 15.9 and Table 15.10. Among the 9 species for which data were available from both platforms and chenieres, search rate was positively correlated between the two habitats ($r_s = 0.63$, $P < 0.05$) but was significantly higher in chenieres (paired t = 3.91, df = 8, P = 0.0045). Attack rate was positively correlated between the two habitats, though not significantly ($r_s = 0.45$, $P > 0.05$), but again was significantly higher in chenieres (paired t = 6.70, df = 8, P = 0.0002). Thus, relative search rates and attack rates among species tended to be preserved in the artificial platform environment, although all species searched more deliberately and attacked prey less frequently on platforms than in chenieres.

Table 15.9.

Comparison of foraging behavior of fall migrants on platforms to foraging behavior of the same species in coastal chenieres

All cheniere data are from Chen (1996). G and P refer to results from log-likelihood ratio tests (df = 2) of the hypothesis that the relative frequencies of different types of foraging movements were independent of study site.

Species	Location	Total Observation Time (min)	Foraging Movements			N	G	P	Search Rate (moves/ min)
			Hop	Flutter	Fly				
Eastern Wood-Pewee	platforms	61.37	1.000	0.000	0.000	8	---	---	0.13
	chenieres		na	na	na				0.30
Empidonax spp.	platforms	90.48	0.033	0.016	0.951	61	8.83	0.012	0.67
Acadian Flycatcher	chenieres		0.174	0.000	0.826	69			1.70
Pine Warbler	platforms	51.98	0.238	0.000	0.762	42	---	---	0.81
	chenieres		na	na	na	na			na
Hooded Warbler	platforms	58.65	0.811	0.027	0.162	111	3.10	0.22	1.89
	chenieres		0.737	0.038	0.226	1,166			18.20
Magnolia Warbler	platforms	35.12	0.580	0.086	0.333	81	52.3	<0.0001	2.31
	chenieres		0.883	0.048	0.069	4,785			30.90
Myrtle Warbler	platforms	38.43	0.800	0.060	0.140	150	0.19	0.91	3.90
	chenieres		0.813	0.059	0.128	4,643			20.50
American Redstart	platforms	78.67	0.749	0.047	0.204	358	15.9	0.0004	4.55
	chenieres		0.841	0.032	0.127	1,527			26.60
Ruby-crowned Kinglet	platforms	25.58	0.781	0.050	0.169	302	5.54	0.063	11.80
	chenieres		0.825	0.055	0.120	2,882			24.70
Common Yellowthroat	platforms	47.22	0.924	0.014	0.063	733	17.2	0.0002	15.52
	chenieres		0.883	0.049	0.068	837			21.20
Yellow Warbler	platforms	39.28	0.948	0.025	0.028	686	40.9	<0.0001	17.46
	chenieres		0.848	0.065	0.087	790			25.90
House Wren	platforms	14.92	0.981	0.010	0.009	1,022	---	---	68.51
	chenieres		na	na	na	na			na

Table 15.10.

Comparison of foraging rates of fall migrants on platforms to foraging rates of the same species in coastal chenieres

All cheniere data are from Chen (1996).

Species	Chen (1996) Attack Rate (prey items h^{-1})	This Study Attack Rate (prey items h^{-1})	Proportion of Attacks Successful	Successful Attack Rate (prey items h^{-1})	Total Observation Time (min)
Common Yellowthroat	240.0	55.9	0.23	12.71	47.22
Myrtle Warbler	300.0	35.9	0.35	12.49	38.43
American Redstart	216.0	33.6	0.55	18.31	78.67
Yellow Warbler	324.0	30.5	0.35	10.69	39.28
Pine Warbler	*na*	25.4	0.77	19.62	51.98
Eastern Wood-Pewee	84.0	21.5	0.23	4.89	61.37
Magnolia Warbler	270.0	18.8	0.36	6.83	35.12
Ruby-crowned Kinglet	258.0	18.8	0.38	7.04	25.58
Hooded Warbler	144.0	12.3	0.42	5.12	58.65
House Wren	*na*	12.1	0.33	4.02	14.92
Empidonax spp.	84.0	11.9	0.44	5.30	90.48

15.2.5 Energetic Consequences of Foraging on Platforms

Unfortunately, our offshore foraging studies were conducted near the end of a prolonged and intense drought that affected most of the U.S. Gulf Coast. Insect populations offshore during our focused foraging studies in fall 2000 seemed conspicuously lower than in prior seasons, which we believe may have been the result of diminished reproductive rates in source populations on the Gulf Coast caused by the persistent hot and dry weather. Thus, we feel that the foraging rates summarized in Table 15.10 are atypically low for migrants on platforms.

Figure 15.1 shows the results from an opportunistic case study of a Magnolia Warbler and an American Redstart that actively foraged on EW826 during spring 1999, when insect numbers were high. Both birds foraged in the same area on the lee sides of the living quarters all day, though the foraging styles of the two species differed. The American Redstart foraged above the grating, from rails, ladders, and other exposed perches, making sallies to catch flying moths and, especially, moths off the walls. The Magnolia Warbler foraged more steadily largely underneath the grating of the living quarters walkways, picking off moths from a variety of surfaces, and was never seen sallying. The success rate of both individuals seemed high, but appeared to decline through the day as moth availability declined. The resource depression reflected in the birds' foraging performance may have resulted either directly from the reduction in actual numbers owing to consumption by the birds, or indirectly as the moths selected safer roosting locations over the course of the day (Charnov et al. 1976).

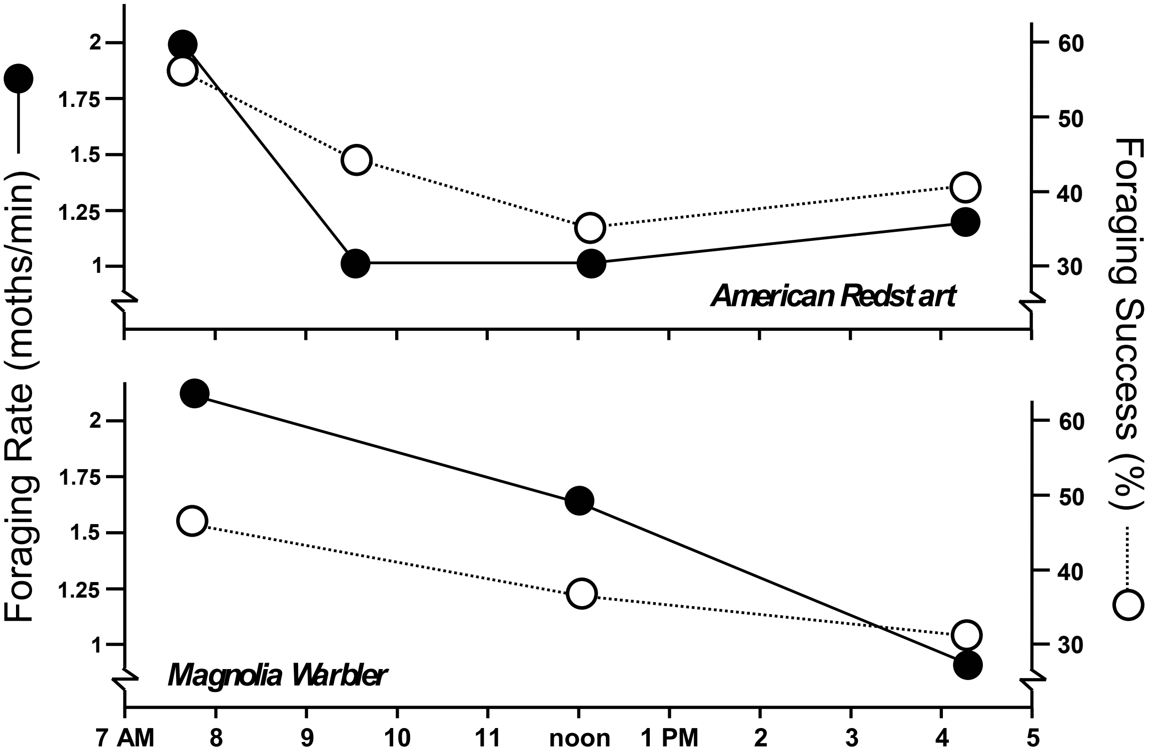


Figure 15.1. Case studies of the foraging performance of two warblers on EW826 on May 7, 1999. Synoptic weather for May 7 was classified as **GF**. Foraging success is defined as the percentage of attacks that were successful. Foraging rate is defined as the number of prey items consumed per minute. Total duration of observations was 43.6 min.

Foraging rates on platforms are not directly comparable to "natural" foraging because warblers rely primarily on lepidopteran larvae (caterpillars) in terrestrial habitats during both migration and breeding seasons in North America, and adult moths are relatively infrequent prey items (Robinson and Holmes 1982; Graber and Graber 1983). However, for comparison we can convert the data in Figure 15.1 to units of energy. The moths being consumed by the warblers on May 7 had an average body length of 10 mm, yielding a dry mass estimate of 6 mg per moth (Table 13.3). Adult Lepidopterans have an average energy content of 21.25 kJ/g dry mass (Bell 1990), which yields an estimated energy content of 0.13 kJ per moth consumed by the warblers on May 7. Assuming a 9-h foraging day, the average foraging rate of the Magnolia Warbler translates into estimated daily intake rates of about 17 g of wet biomass and 111 kJ for the Magnolia Warbler and 14 g wet biomass and 89 kJ for the American Redstart.

Spring migrant warblers studied in the field in an area with large populations of lepidopteran larvae and that behaved as if not limited by food supply achieved consumption rates of 13-17 g wet mass/day or 63-80 kJ/day (Graber and Graber 1983).

Nice and Nice (1950) fed a captive migrant Black-and-white Warbler *ad libitum* for two days. Using the equations in Table 13.3, it can be estimated from the information provided that the warbler consumed 5 g of wet biomass with an energy content of 36 kJ on day 1, and 12 g of wet biomass with an energy content of 82 kJ on day 2.

The maximum possible rates of energy intake and mass gain can be estimated from theory. Estimated maximum rate of metabolizable energy intake (kJ/d) is given by $1713 \cdot M^{0.72}$, where M is given in kg (Kirkwood 1983). Based on a fat-depleted body mass of 6.4 g for small warblers (McClintock et al. 1978), maximum rate of metabolizable energy intake is calculated to be 45 kJ/d. Allometric analysis suggests that maximum fat deposition rate for passerines should scale as $FDR_{max} = 2.22 \times M^{-0.27}$, where FDR is given in daily mass gain as a percentage of lean body mass, and M is lean body mass in kg (Lindström 1991). Again assuming a lean body mass of 6.4 g, maximum fat deposition rate is estimated by this method to be about 0.6 g/d. Lipids from the adipose tissue of migrant birds have a mean energy density of 38.1 kJ/g (Johnston 1970). Assuming efficiency of fat deposition to be about 90% (Kirkwood 1985; Kersten and Piersma 1987), the theoretical maximum fat deposition rate of 0.6 g/d would require an energy intake rate of 25 kJ/d.

In summary, platform-foraging warblers are capable of achieving estimated daily intake rates of 14-17 g wet biomass or 89-111 kJ. These figures compare to observed maximum daily intake rates of 12-17 g wet biomass or 80-82 kJ in small warblers in natural habitats and in the laboratory, and theoretical maximum rates of energy intake of 25-45 kJ/d. Clearly, platforms can at least sometimes provide a foraging environment that is at least as profitable as natural habitats, and that permits migrants to refuel as fast as is physiologically possible.

15.3 MICROHABITAT SELECTION

It was clear that migrants did not use different parts of the platform indiscriminately. Unfortunately, it is not possible to test the hypothesis that migrants selected particular habitats, since we were unable to quantify objectively the relative availability of the different habitat types. Thus, our analyses focus on demonstrating species-specific patterns of habitat selection. The existence of species-specific patterns in the use of different platform habitats confirms indirectly that at least some species select particular habitat types on platforms, because if all species used all habitats randomly, then there should be no detectable differences in habitat use among species.

15.3.1 Spring

Patterns of microhabitat use for longer-staying spring migrants are summarized in Table 15.11. Spring habitat use differed significantly among the ecological groups ($G = 629$, $df = 25$, $P < 0.0001$). Aerial insectivores used high cover and exposed perches. Hawks almost exclusively used exposed perches. Herons primarily used exposed perches and grating. Medium-distance migrants used a wide range of habitats, but appeared to prefer grating. Neotropical migrants used a wide range of habitats, but there was an interesting difference in habitat use between small and large species. Small species primarily selected high cover, whereas large species primarily selected exposed perches. Small neotropical migrants were the only birds that frequently became trapped.

Table 15.11.

Microhabitat use by migrants on platforms during spring 2000

	Usual Habitat						
Group	EP	GG	HC	LC	OD	TR	N
AER	31	4	123	1	2	1	162
HAWK	23	3	0	0	0	0	26
HER	117	157	4	11	9	0	298
MDM	10	25	10	10	5	0	60
NEOL	66	27	22	32	7	3	157
NEOS	84	66	175	31	30	40	426
Total	331	282	334	85	53	44	1,129

15.3.2 Fall

Patterns of microhabitat use for longer-staying fall migrants are summarized in Table 15.12. Fall habitat use differed significantly among the ecological groups (G = 1,764, df = 30, P < 0.0001). Aerial insectivores and hawks mostly used exposed perches. Herons used a wide variety of habitats. Among neotropical migrants, there was an interesting difference in habitat use between small and large species. Small species usually selected high cover, whereas large species usually selected exposed perches. Short- and medium-distance migrants preferred grating. Small neotropical migrants were the only birds that frequently became trapped.

Table 15.12.

Microhabitat use by migrants on platforms during fall 1999

	Usual Habitat						
Group	EP	GG	HC	LC	OD	TR	Total
AER	41	2	7	0	0	2	52
HAWK	141	0	4	0	0	1	146
HER	85	26	6	23	19	0	159
MDM	45	165	4	74	74	1	363
NEOL	314	127	62	68	40	15	626
NEOS	210	162	766	151	115	280	1,684
SDM	23	39	18	22	29	1	132
Total	859	521	867	338	277	300	3,162

15.3.3 Interspecific Variation

Interspecific variation in microhabitat use by migrants during spring and fall is summarized in Tables 15.13 and 15.14, respectively.

Most species were consistent in their patterns of microhabitat use between spring and fall. A list of species that differed between seasons in microhabitat use is presented in Table 15.15. The most notable feature of this list is the number of neotropical migrants that used EP habitat in spring and switched to HC in fall.

Table 15.13.

Interspecific variation in microhabitat use by migrants in spring 2000

Data shown for each species are the proportions of all individuals using each microhabitat. The microhabitat most frequently used by each species is boldfaced. Species are grouped according to most frequently used microhabitat, and listed within each group in descending order of frequency of use of the preferred microhabitat.

	Most Frequent Habitat						
Species	OD	GG	EP	LC	HC	TR	N
grating (GG):							
Chipping Sparrow	0.00	**0.85**	0.10	0.00	0.05	0.00	20
Clay-colored Sparrow	0.09	**0.66**	0.19	0.03	0.00	0.03	32
Lincoln's Sparrow	0.01	**0.53**	0.26	0.16	0.04	0.00	85
Sora	0.07	**0.51**	0.12	0.17	0.10	0.02	41
all shorebirds	0.39	**0.43**	0.09	0.00	0.09	0.00	23
Purple Gallinule	0.05	**0.42**	0.11	0.16	0.26	0.00	19
Common Yellowthroat	0.03	**0.33**	0.15	0.22	0.24	0.03	389
exposed perch (EP):							
Scissor-tailed Flycatcher	0.00	0.00	**1.00**	0.00	0.00	0.00	12
Great Blue Heron	0.11	0.00	**0.89**	0.00	0.00	0.00	19
Peregrine Falcon	0.03	0.03	**0.88**	0.00	0.05	0.00	60
Mourning dove	0.08	0.08	**0.78**	0.03	0.03	0.00	65
Belted Kingfisher	0.00	0.07	**0.77**	0.00	0.16	0.00	44
American Kestrel	0.08	0.17	**0.75**	0.00	0.00	0.00	12
Green Heron	0.02	0.24	**0.71**	0.03	0.02	0.00	200
Chuck-Will's-Widow	0.00	0.00	**0.70**	0.05	0.20	0.05	20
Lark Sparrow	0.06	0.19	**0.69**	0.00	0.06	0.00	16
White-winged Dove	0.07	0.09	**0.66**	0.03	0.14	0.01	100
Eastern Wood-Pewee	0.00	0.04	**0.64**	0.00	0.25	0.07	28
Yellow-breasted Chat	0.00	0.07	**0.64**	0.07	0.14	0.07	14
Yellow-crowned Night-Heron	0.00	0.21	**0.64**	0.00	0.14	0.00	14
White-eyed Vireo	0.00	0.11	**0.63**	0.05	0.21	0.00	19
Bank Swallow	0.08	0.17	**0.58**	0.00	0.17	0.00	12
Cattle Egret	0.05	0.34	**0.58**	0.01	0.02	0.00	587
Great Egret	0.06	0.39	**0.56**	0.00	0.00	0.00	18
Yellow-billed Cuckoo	0.02	0.16	**0.55**	0.16	0.10	0.00	49
Orchard Oriole	0.04	0.11	**0.55**	0.13	0.18	0.00	95
Northern Rough-winged Swallow	0.08	0.23	**0.54**	0.00	0.15	0.00	13
Blackpoll Warbler	0.12	0.09	**0.53**	0.14	0.12	0.00	43
Tree Swallow	0.00	0.05	**0.53**	0.00	0.41	0.00	94
Purple Martin	0.00	0.01	**0.53**	0.02	0.43	0.00	277
Myrtle Warbler	0.04	0.26	**0.52**	0.00	0.17	0.00	23
exposed perch (EP):							
Brown-headed Cowbird	0.07	0.18	**0.51**	0.06	0.19	0.00	89
Cliff Swallow	0.00	0.06	**0.50**	0.00	0.44	0.00	18
Grasshopper Sparrow	0.00	0.42	**0.48**	0.06	0.02	0.02	52
Snowy Egret	0.06	0.47	**0.47**	0.00	0.00	0.00	17

Table 15.13.

Interspecific variation in microhabitat use by migrants in spring 2000

Data shown for each species are the proportions of all individuals using each microhabitat. The microhabitat most frequently used by each species is boldfaced. Species are grouped according to most frequently used microhabitat, and listed within each group in descending order of frequency of use of the preferred microhabitat.

	Most Frequent Habitat						
Species	OD	GG	EP	LC	HC	TR	N
Baltimore Oriole	0.10	0.02	**0.46**	0.00	0.41	0.00	41
Savannah Sparrow	0.03	0.41	**0.46**	0.07	0.02	0.02	59
Barn Swallow	0.02	0.05	**0.44**	0.02	0.42	0.05	257
Prothonotary Warbler	0.21	0.14	**0.43**	0.07	0.14	0.00	14
Ruby-throated Hummingbird	0.04	0.09	**0.43**	0.04	0.26	0.15	54
Summer Tanager	0.17	0.00	**0.42**	0.17	0.25	0.00	12
Yellow Warbler	0.05	0.25	**0.40**	0.13	0.15	0.03	40
American Redstart	0.11	0.13	**0.39**	0.10	0.24	0.04	84
Gray Catbird	0.20	0.14	**0.38**	0.14	0.12	0.03	236
Dickcissel	0.07	0.21	**0.36**	0.07	0.29	0.00	14
Indigo Bunting	0.09	0.13	**0.35**	0.07	0.29	0.07	86
Hooded Warbler	0.06	0.16	**0.33**	0.15	0.29	0.01	141
high cover (HC):							
Bay-breasted Warbler	0.01	0.01	0.03	0.02	**0.78**	0.16	125
Yellow-throated Vireo	0.00	0.07	0.27	0.00	**0.67**	0.00	15
Worm-eating Warbler	0.00	0.00	0.29	0.12	**0.59**	0.00	17
Magnolia Warbler	0.05	0.14	0.06	0.03	**0.58**	0.13	315
Blue-winged Warbler	0.00	0.00	0.33	0.11	**0.56**	0.00	18
Blackburnian Warbler	0.04	0.16	0.00	0.09	**0.56**	0.16	45
Yellow-throated Warbler	0.05	0.10	0.29	0.05	**0.52**	0.00	21
Chestnut-sided Warbler	0.03	0.13	0.16	0.09	**0.47**	0.13	32
Black-and White Warbler	0.03	0.28	0.13	0.07	**0.46**	0.04	150
Black-throated Green Warbler	0.09	0.20	0.13	0.07	**0.44**	0.07	45
Northern Waterthrush	0.00	0.33	0.22	0.00	**0.44**	0.00	27
Tennessee Warbler	0.10	0.20	0.17	0.05	**0.40**	0.08	104
Louisiana Waterthrush	0.00	0.19	0.32	0.03	**0.39**	0.06	31
Scarlet Tanager	0.08	0.15	0.23	0.15	**0.38**	0.00	13
Kentucky Warbler	0.04	0.17	0.19	0.19	**0.38**	0.02	47
Northern Parula	0.05	0.12	0.33	0.12	**0.37**	0.02	60
Ovenbird	0.11	0.21	0.12	0.12	**0.33**	0.11	91
Trapped (TR):							
Red-eyed Vireo	0.03	0.00	0.24	0.06	0.30	**0.36**	33

Table 15.14.

Interspecific variation in microhabitat use by migrants in fall 1999

Data shown for each species are the proportions of all individuals using each microhabitat. The microhabitat most frequently used by each species is boldfaced. Species are grouped according to most frequently used microhabitat, and listed within each group in descending order of frequency of use of the preferred microhabitat.

	Most Frequent Habitat						
Species	OD	GG	EP	LC	HC	TR	N
open deck (OD):							
Savannah Sparrow	**0.37**	0.32	0.22	0.05	0.03	0.01	93
Western Palm Warbler	**0.29**	0.15	0.26	0.12	0.15	0.03	66
all shorebirds	**0.72**	0.08	0.20	0.00	0.00	0.00	25
grating (GG):							
Sora	0.06	**0.72**	0.00	0.08	0.11	0.03	36
Western Meadowlark	0.04	**0.69**	0.27	0.00	0.00	0.00	26
Lincoln's Sparrow	0.06	**0.67**	0.14	0.10	0.03	0.00	137
White-throated Sparrow	0.09	**0.64**	0.00	0.14	0.05	0.09	22
Swamp Sparrow	0.17	**0.63**	0.12	0.07	0.00	0.00	41
Marsh Wren	0.19	**0.62**	0.03	0.17	0.00	0.00	151
Sedge Wren	0.06	**0.59**	0.18	0.18	0.00	0.00	17
Grasshopper Sparrow	0.12	**0.52**	0.18	0.04	0.07	0.07	73
Song Sparrow	0.33	**0.50**	0.13	0.04	0.00	0.00	24
Clay-colored Sparrow	0.24	**0.48**	0.20	0.04	0.04	0.00	46
Eastern Meadowlark	0.21	**0.47**	0.32	0.00	0.00	0.00	19
Common Ground-Dove	0.18	**0.45**	0.23	0.09	0.05	0.00	22
Nashville Warbler	0.12	**0.45**	0.21	0.10	0.10	0.02	42
Common Yellowthroat	0.07	**0.44**	0.07	0.12	0.24	0.05	432
Chipping Sparrow	0.22	**0.41**	0.22	0.11	0.05	0.00	37
Wilson's Warbler	0.07	**0.34**	0.31	0.17	0.10	0.00	29
House Wren	0.12	**0.34**	0.21	0.28	0.05	0.01	127
Canada Warbler	0.00	**0.33**	0.22	0.11	0.28	0.06	18
Yellow-breasted Chat	0.05	**0.32**	0.23	0.23	0.16	0.01	137
exposed perch (EP):							
Peregrine Falcon	0.00	0.00	**0.98**	0.00	0.02	0.00	225
Traill's Flycatcher	0.00	0.03	**0.97**	0.00	0.00	0.00	29
Least Flycatcher	0.00	0.05	**0.91**	0.02	0.02	0.00	57
American Kestrel	0.00	0.00	**0.91**	0.00	0.07	0.02	55
Merlin	0.11	0.00	**0.89**	0.00	0.00	0.00	19
Eastern Phoebe	0.00	0.06	**0.85**	0.03	0.03	0.03	34
Belted Kingfisher	0.00	0.00	**0.85**	0.05	0.10	0.00	20
Eastern Kingbird	0.03	0.03	**0.83**	0.00	0.07	0.03	30
exposed perch (EP):							
Great Crested Flycatcher	0.00	0.00	**0.80**	0.08	0.13	0.00	40
Acadian Flycatcher	0.05	0.00	**0.79**	0.00	0.16	0.00	19
Orchard Oriole	0.00	0.10	**0.72**	0.00	0.14	0.03	29

Table 15.14.

Interspecific variation in microhabitat use by migrants in fall 1999

Data shown for each species are the proportions of all individuals using each microhabitat. The microhabitat most frequently used by each species is boldfaced. Species are grouped according to most frequently used microhabitat, and listed within each group in descending order of frequency of use of the preferred microhabitat.

	Most Frequent Habitat						
Species	OD	GG	EP	LC	HC	TR	N
Barn Swallow	0.02	0.02	**0.72**	0.00	0.20	0.04	123
Scissor-tailed Flycatcher	0.03	0.06	**0.67**	0.00	0.25	0.00	36
Chuck-Will's-Widow	0.04	0.15	**0.65**	0.13	0.04	0.00	48
unid. *Empidonax* flycatcher	0.04	0.08	**0.63**	0.00	0.13	0.13	24
Bank Swallow	0.00	0.00	**0.63**	0.06	0.31	0.00	16
Cattle Egret	0.16	0.10	**0.61**	0.10	0.02	0.00	186
Purple Martin	0.07	0.00	**0.60**	0.13	0.20	0.00	15
Cliff Swallow	0.00	0.00	**0.60**	0.00	0.40	0.00	45
Mourning Dove	0.13	0.16	**0.59**	0.05	0.04	0.01	601
Baltimore Oriole	0.00	0.17	**0.59**	0.03	0.21	0.00	29
Scarlet Tanager	0.00	0.00	**0.56**	0.06	0.33	0.06	18
Summer Tanager	0.00	0.00	**0.56**	0.06	0.33	0.06	18
White-winged Dove	0.14	0.12	**0.55**	0.04	0.15	0.01	179
Ruby-throated Hummingbird	0.01	0.01	**0.54**	0.07	0.27	0.09	74
Pine Warbler	0.15	0.15	**0.54**	0.08	0.08	0.00	13
Eastern Wood-Pewee	0.00	0.00	**0.51**	0.03	0.35	0.11	37
Green Heron	0.11	0.16	**0.51**	0.04	0.18	0.00	45
Northern Mockingbird	0.26	0.06	**0.48**	0.16	0.03	0.00	31
Brown-headed Cowbird	0.14	0.33	**0.43**	0.10	0.00	0.00	21
Ruby-crowned Kinglet	0.08	0.26	**0.43**	0.07	0.16	0.01	89
Myrtle Warbler	0.17	0.14	**0.41**	0.14	0.11	0.02	140
Yellow-billed Cuckoo	0.08	0.08	**0.38**	0.15	0.31	0.00	13
Prairie Warbler	0.29	0.17	**0.33**	0.04	0.17	0.00	24
Lark Sparrow	0.25	0.17	**0.33**	0.17	0.08	0.00	12
Dickcissel	0.07	0.23	**0.32**	0.13	0.20	0.04	69
Orange-crowned Warbler	0.21	0.15	**0.28**	0.21	0.13	0.02	53
low cover (LC):							
Mourning Warbler	0.17	0.21	0.17	**0.38**	0.08	0.00	24
Black-throated Blue Warbler	0.05	0.11	0.11	**0.37**	0.32	0.05	19
Gray Catbird	0.23	0.07	0.17	**0.33**	0.18	0.02	60
Brown Thrasher	0.17	0.17	0.23	**0.32**	0.11	0.00	47
high cover (HC):							
Cerulean Warbler	0.00	0.00	0.00	0.00	**0.92**	0.08	13
Blackburnian Warbler	0.00	0.07	0.02	0.00	**0.83**	0.09	46
Yellow-throated Warbler	0.04	0.08	0.08	0.00	**0.73**	0.08	26
Worm-eating Warbler	0.00	0.09	0.09	0.00	**0.73**	0.09	22
American Redstart	0.02	0.03	0.06	0.05	**0.72**	0.11	372
Bay-breasted Warbler	0.00	0.10	0.00	0.03	**0.71**	0.15	59

Table 15.14.

Interspecific variation in microhabitat use by migrants in fall 1999

Data shown for each species are the proportions of all individuals using each microhabitat. The microhabitat most frequently used by each species is boldfaced. Species are grouped according to most frequently used microhabitat, and listed within each group in descending order of frequency of use of the preferred microhabitat.

	Most Frequent Habitat						
Species	OD	GG	EP	LC	HC	TR	N
Magnolia Warbler	0.01	0.01	0.03	0.04	**0.68**	0.23	516
Chestnut-sided Warbler	0.02	0.06	0.04	0.06	**0.68**	0.14	50
Northern Parula	0.03	0.04	0.02	0.01	**0.67**	0.24	189
Black-throated Green Warbler	0.01	0.21	0.02	0.01	**0.67**	0.07	360
Red-eyed Vireo	0.00	0.06	0.12	0.03	**0.67**	0.12	33
Indigo Bunting	0.01	0.27	0.04	0.05	**0.62**	0.03	311
Black-and-white Warbler	0.02	0.07	0.11	0.08	**0.61**	0.10	106
Tennessee Warbler	0.03	0.10	0.06	0.03	**0.58**	0.21	147
Ovenbird	0.08	0.16	0.07	0.05	**0.56**	0.08	179
Hooded Warbler	0.05	0.02	0.09	0.11	**0.56**	0.18	104
Kentucky Warbler	0.00	0.04	0.00	0.19	**0.56**	0.22	27
Prothonotary Warbler	0.02	0.01	0.14	0.09	**0.54**	0.20	166
White-eyed Vireo	0.10	0.05	0.12	0.07	**0.50**	0.17	42
Blue Grosbeak	0.00	0.26	0.26	0.11	**0.37**	0.00	19
Swainson's Thrush	0.16	0.20	0.12	0.12	**0.32**	0.08	25
Northern Waterthrush	0.16	0.22	0.16	0.07	**0.24**	0.16	45
Trapped (TR):							
Yellow Warbler	0.07	0.13	0.24	0.12	0.17	**0.27**	145

Table 15.15.

Species that differed between spring and fall in preferred microhabitat

Only species with N ≥ 12 in both seasons are included. G and P refer to results from log-likelihood ratio tests of the hypothesis that patterns of microhabitat use were independent of season. All tests were based on 5 degrees of freedom, except in the case of shorebirds (df = 3), which were never recorded as LC or TR.

	Most Frequent Habitat			
Species	Spring	Fall	G	P
all shorebirds	GG	OD	12.9	0.0049
Yellow-breasted Chat	EP	GG	14.5	0.013
White-eyed Vireo	EP	HC	23.0	0.0003
Grasshopper Sparrow	EP	GG	22.9	0.0003
Savannah Sparrow	EP	OD	29.7	<0.0001
Prothonotary Warbler	EP	HC	28.3	<0.0001
Yellow Warbler	EP	TR	18.1	0.003
American Redstart	EP	HC	104.1	<0.0001
Gray Catbird	EP	LC	20.6	0.001
Indigo Bunting	EP	HC	87.9	<0.0001

Table 15.15.

Species that differed between spring and fall in preferred microhabitat

Only species with N ≥ 12 in both seasons are included. G and P refer to results from log-likelihood ratio tests of the hypothesis that patterns of microhabitat use were independent of season. All tests were based on 5 degrees of freedom, except in the case of shorebirds (df = 3), which were never recorded as LC or TR.

Most Frequent Habitat				
Hooded Warbler	EP	HC	69.4	<0.0001
Scarlet Tanager	HC	EP	9.1	ns
Red-eyed Vireo	TR	HC	14.7	0.012

15.3.4 Movement Among Microhabitats

We had initially hypothesized that a migrant's initial habitat would be a function of where it happened to land on the platform, which itself would be largely random, and that preferred habitats would be discovered and utilized after a period of exploration of and movement around the platform. Under this hypothesis, the population of migrants would be expected to settle to an equilibrium distribution among habitats that would be independent of initial habitat. However, among the 1679 fall migrants that showed persistent habitat utilization, 1415 (84%) utilized the same habitat as when detected initially, and initial habitat was a strong predictor of subsequent habitat use (Table 15.16; G = 3191, df = 25, P < 0.0001).

Table 15.16.

Movement among platform microhabitats by small neotropical migrants in fall 1999

Initial	Usual Habitat						
Habitat	EP	GG	HC	LC	OD	TR	N
EP	176	12	13	10	16	0	227
GG	14	135	1	12	11	1	174
HC	9	5	736	10	1	89	850
LC	2	4	5	101	6	0	118
OD	8	4	0	14	78	1	105
TR	0	0	11	4	1	189	205
Total	209	160	766	151	113	280	1,679

15.3.5 Relationships Between Habitat Selection and Foraging Behavior

Fall habitat use was strongly related to foraging status (Table 15.17; G = 762, df = 5, P < 0.0001). Migrants that did not forage avoided open deck habitat and mostly used high cover. Migrants that foraged avoided high cover. Migrants that were trapped almost never foraged.

Foraging success of small neotropical migrants in fall was significantly related to habitat use (Table 15.18; G = 28.4, df = 5, P < 0.0001). The percentage of foragers that were successful was much higher in exposed perch habitat (67%) than in the other habitats (35-45%).

Foraging success of medium-distance migrants was also significantly related to habitat use in fall (Table 15.19; G = 13.4, df = 3, P = 0.0039). As was the case for small neotropical migrants, the percentage of foraging medium-distance migrants that were successful was much higher in exposed perch habitat (76%) than in the other habitats (39-52%).

Table 15.17.
Microhabitat use by small neotropical migrants in fall 1999 in relation to foraging status

Any Foraging?	Usual Habitat EP	GG	HC	LC	OD	TR	N
No	75	78	732	72	27	278	1,262
Yes	135	84	34	79	88	2	422
Total	210	162	766	151	115	280	1,684

Table 15.18.

Foraging success in relation to microhabitat use by small neotropical migrants in fall 1999

The table summarizes data only for those individuals observed foraging.

Success?	Usual Habitat EP	GG	HC	LC	OD	TR	N
No	45	50	22	48	48	2	215
Yes	90	34	12	31	40	0	207
Total	135	84	34	79	88	2	422

Table 15.19.

Foraging success in relation to microhabitat use by medium-distance migrants in fall 1999

The table summarizes data only for those individuals observed foraging.

Success?	Usual Habitat EP	GG	LC	OD	N
No	7	43	27	27	104
Yes	22	28	17	29	96
Total	29	71	44	56	200

Chapter 16

Nocturnal Circulation Events

Robert W. Russell

Early on during the study we discovered that migrants would sometimes arrive at certain platforms shortly after nightfall and proceed to circle those platforms for variable periods ranging from minutes to hours. We were relatively ill-prepared to study these "nocturnal circulations" systematically for two reasons: 1) birds in flight could not be detected visually and identified reliably beyond a distance of a few dozen meters; and 2) the platform observers were already committed to a strenuous daily program of field work, and required the nighttime hours to satisfy basic sleep requirements. Nevertheless, anecdotal observations were made at night as often as possible. Because of the potentially important implications of the nocturnal circulation phenomenon (particularly with respect to possible impacts of platforms), we present a summary of our observations in this chapter, along with tentative interpretations.

Table 16.1 provides a complete enumeration of all circulation events observed in spring 2000, when we put forth our best effort to document this phenomenon. During that season, PN975 recorded 40 events involving 1 to 800+ individuals; GB189 recorded 22 events involving 1 to 1,260 individuals; MI622 recorded five events involving 20 to 700 individuals; HI561 recorded four events involving 2 to 410 individuals; and SM147 recorded two events, one involving a single individual and the other involving 50-100 birds. Circulations were never detected at the other platforms (SP89, EW826, GC18, and VR265; note that VK786 was not available for study in spring 2000).

Circulations clearly occurred because nocturnal migrants were attracted to platform lights. Circulations usually began shortly after sunset and the onset of darkness, undoubtedly involving birds that were in the general vicinity of the platform. On some occasions there were no birds in circulation when the observer retired for the night, but they would be present during the observer's first round prior to sunrise. Once started, circulations usually peaked within an hour or two in terms of numbers of participants, then continued through the night with a gradual diminution of numbers. They invariably ended abruptly at the first indication of ambient light over the horizon, when the birds apparently regained their orientation and then departed.

Circulations were highly variable in size and composition. The numbers of birds involved varied from a single individual to many hundreds of migrants. Although a wide variety of species was recorded in circulations, herons, shorebirds, swallows, and warblers were the dominant components. Certain species seemed especially prone to becoming involved in circulations, including Pied-billed Grebes, Soras, Upland Sandpipers, American Golden-Plovers, Bay-breasted Warblers, and Magnolia Warblers.

Once an individual or flock of migrants began circulating, it typically continued to do so rather uniformly for an indefinite period of time. Passerines typically stayed close to the platform and circulated at nearly constant rates, while flocks of herons and shorebirds often deviated considerably in their circular flight paths. At VK786 in fall 1999, we timed a distinctive flock of 8 small shorebirds as it circled around the platform during a 39-min period. The average duration of each lap was about 2½ min ($\bar{x}$ = 155 s ± 21 se, N = 15 laps) but lap duration ranged from 68 to 307 s. Assuming a flight speed of 10 m/s, this range in lap duration implies that the shorebirds traveled at radii that varied from about 100 to 500 m from the center of the platform.

Perhaps the most striking feature of the circulation events was their directional organization. With just a few exceptions, the vast majority of birds always traveled counterclockwise (with respect to the sea when viewed from above).

Weather clearly played a role in the development of circulations. Clear nights rarely attracted numbers, whereas overcast nights (especially with rain) regularly attracted large numbers. Birds seemed more likely to circulate when haze or extensive cloud cover prevailed and on otherwise moonless nights. Wind direction did not appear to play any role at all in the development of circulations. Major circulation events often occurred on **BH** and **ECH** days with strong winds from favorable directions.

The specific mechanisms involved in the onset and maintenance or continuity of a circulation event remain a matter of speculation. Most of the observers felt that birds are attracted to the lights, and once they get inside the cone of light surrounding the platform they are either reluctant to leave or have a difficult time getting out, seemingly becoming trapped by the surrounding "wall of darkness." The prevalence of circulations on overcast nights suggests that initial attraction to the platform lights occurs when birds become confused or disoriented by the lack of navigational reference points like the stars and moon. Birds seemed more likely to continue circulating for prolonged periods when haze or fog prevailed, perhaps because the "outside world" beyond the cone of platform lighting appeared even darker under such circumstances, making the birds more reluctant to venture out beyond the wall of darkness. These admittedly anthropomorphic characterizations are consistent with the more formal ideas of Herbert (1970), who proposed that birds become spatially disoriented by bright light sources because of the loss of true visual cues to the horizontal.

As described above, flocks of herons and shorebirds often varied dramatically from lap to lap in the radius of their circular flight path. We felt that this behavior represented an intentional effort to probe the wall of darkness surrounding the cone of platform lighting looking for an escape point. Sometimes smaller birds would suddenly disappear from a circulation after circling uniformly for an hour or more. Usually these birds could then be found roosting on the platform. In some cases, disappearances resulted from collisions with the platform or with other circulating birds (Chapter 17). Unexplained disappearances seemed to be most common on windy days, when warblers and other small birds often seemed able to escape the circulation and evidently continue their migration. We suspected that this pattern was an essentially random effect of the migrants being blown by wind and unintentionally reaching a point where they can see the outside world and are no longer trapped within the cone of light.

Reasons for the differences among platforms in frequency of circulation events were not clear. The three platforms where circulations were frequent (PN975, GB189, VK786) were extremely isolated (Figure 2.2), suggesting that the differences could simply arise as a sampling artifact because the more isolated platforms have a larger "hinterland" (Cairns 1989) and can draw from a larger source population of airborne migrants. Casting doubt on this explanation, however, is the fact that circulation events were never recorded at the other two extremely isolated platforms (GC18, EW826; Figure 2.2).

We also noted that the three platforms that routinely recorded significant nocturnal circulations were painted extensively in yellow (PN975) or orange (GB189 and VK786), whereas most of the platforms without frequent circulations were not conspicuously yellow or orange. The exceptions were HI561 and SM147; both were extensively yellow yet recorded few circulations. It is not clear why platform color might influence the development of circulations. From any distance greater than 200 m, platforms usually appeared pinkish yellow or peachy yellow at night due to the sodium vapor lights on most platforms.

One of the field observers who worked on GB189, VK786, and HI561 noted that the prevalence of circulations seemed to be correlated with the amount of "projected light" on the platforms. Specifically, HI 561 has very little projected light; looking at the sea at night only gives an observer a small field of view. In contrast, GB189 and VK786 have extensive light systems with considerably more night visibility.

The impact of circulations on trans-Gulf migrants is difficult to evaluate. Any delay in migration induced by a circulation clearly must have some impact on the migrants involved, because they expend energy during the delay that might otherwise be needed to complete the crossing successfully, particularly if adverse weather conditions are encountered later on. Whether or not the impact of a circulation is significant probably depends on the initial energetic condition of the participants. Migrants that deposited sufficient fat stores prior to departure to maintain them through the entire journey and then some are likely unaffected. However, for migrants that departed with just enough fat to get them to their destination under normal circumstances, prolonged participation in a circulation could be lethal. On a few occasions we observed individually recognizable migrants circulating all night long (i.e., 8+ hours), but on many occasions we observed a particular species making only one or a few passes during an extended event. Migrants that dropped out of circulations had a tendency to become trapped in the well bays or other well-lit interior areas of the platforms; these individuals often appeared to us to be highly stressed. Because of the anecdotal nature of our circulation observations, we are reluctant even to speculate about the average duration of participation in circulations or the typical energetic consequences of participating in these events.

On the other hand, circulations clearly put birds at risk for collision with the platform or with each other (Chapter 17).

Table 16.1.

Summary of all nocturnal circulation events detected during spring 2000

Date shown is that for the beginning of the night. Flight direction is given with respect to the sea surface as a reference. Events are listed by platform from east to west.

Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
SP89	none						
EW826	none						
GC18	none						
SM147	Apr 28	GH	W B2 clear vis 4	CCW	1	Indigo Bunting	Post-sunset on Apr 28. Very hazy.
SM147	May 2	BH	SE B4 p. cloudy vis 4	?	50-100	Bay-breasted Warblers Swainson's Thrushes Spotted Sandpipers 1 Veery 1 Gray Catbird 1 Blackpoll Warbler	Post-sunset on May 2. Thick haze.
VR265	none						

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Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
GB189	Mar 14	ECH	NW B7 heavy rain vis 1	CCW	23	5 unid shorebirds 4 Great Blue Herons 3 Black-crowned Night-Herons 2 Little Blue Herons 2 White Ibises 2 Barn Swallows 1 Great Egret 1 Wilson's Plover 1 Pectoral Sandpiper 1 Osprey 1 Ruby-throated Hummingbird	Circulation observed at ~04:00 on Mar 15 during strong thunderstorm.
GB189	Mar 15	ECH	S B6 overcast vis 2	CCW	5	unid swallows	Post-sunset on Mar 15. No stars visible.
GB189	Mar 31	ECH	SSE B6 overcast vis 4	CCW	6	Barn Swallows	Pre-sunrise on Apr 1.

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Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
GB189	Apr 1	BH	SW B4 overcast vis 3	CCW + CW	121	64 Barn Swallows 15 Purple Martins 15 unid dowitchers 10 Tricolored Herons 5 Tree Swallows 3 Ospreys 2 Green Herons 2 Cliff Swallows 1 Little Blue Heron 1 Great Egret 1 Cattle Egret 1 Lesser Nighthawk 1 Orchard Oriole	Pre-sunrise on Apr 2.
GB189	Apr 2	BH	SSW B5 p. cloudy vis 3	CCW	12	8 Barn Swallows 3 Tricolored Heron 1 Tree Swallow	Pre-sunrise on Apr 3.
GB189	Apr 7	GF	NNW B3 clear vis 4	CW	1	unid swallow	Pre-sunrise on Apr 8.
GB189	Apr 11	BH	SE B4 clear vis 4	CCW	1	Least Bittern	Pre-sunrise on Apr 12.

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Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
GB189	Apr 13	GF	NNE B5 overcast vis 4	CCW	14	6 Cattle Egrets 2 unid warblers 1 Northern Waterthrush 1 Common Yellowthroat 1 Chestnut-sided Warbler 1 Orchard Oriole 1 Baltimore Oriole 1 unid passerine	Post-sunset on Apr 13. Stars visible in about 20% of the sky. At about 22:00, the cloud cover broke and birds seemed to dissipate.
			NNW B3 overcast vis 4	CW	137	112 Cattle Egrets 10 Little Blue Herons 5 Great Egrets 4 Great Blue Herons 3 Snowy Egrets 3 Yellow-crowned Night-Herons 1 Green Heron	Pre-sunrise on Apr 14.
GB189	Apr 24	GF	N B3 clear vis 4	CCW	1	?	Post-sunset on Apr 24. Stars visible in about 90% of the sky.
GB189	Apr 27	GH	WSW B2 clear vis 4	CCW	2	Tree Swallows	Pre-sunrise on Apr 28.

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Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
GB189	Apr 29	GF	ESE B4 clear vis 4	CCW	4	3 Magnolia Warblers 1 Chestnut-sided Warbler	Post-sunset on Apr 29. Stars visible in about 60% of the sky.
GB189	Apr 30	ECH	SE B5 clear vis 3	CCW	3	Bay-breasted Warblers	Post-sunset on Apr 30. Stars visible in about 60% of the sky.
GB189	May 1	ECH	SE B6 clear vis 4	CCW	6	Bay-breasted Warblers	Post-sunset on May 1. No stars visible.

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Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
GB189	May 2	BH	E B6 heavy rain vis 2	CCW	~1260	100 Bay-breasted Warblers 30 *Catharus* thrushes 30 Lesser Yellowlegs 30 unid dowitchers 30 unid peeps 18 Rose-breasted Grosbeaks 16 unid cuckoos 10 American Golden Plovers 10 Greater Yellowlegs 8 Buff-breasted Sandpipers 8 White-rumped Sandpipers 6 Cattle Egrets 6 Barn Swallows 5 Gray Catbirds 3 Sanderlings 3 Scarlet Tanagers 2 Ospreys many others	Post-sunset on May 2. Event began at 20:31 and accelerated very rapidly. ~1200 birds were visible 20:40-23:40. Numbers declined thereafter with wind change. No stars visible.
GB189	May 4	ECH	SE B2 p. cloudy vis 4	?	11	Bank Swallows, other species	Post-sunset on May 4. Stars visible in 90% of the sky.
GB189	May 10	BH	SSE B5.5 overcast vis 4	CCW	6	2 Chimney Swifts 1 Osprey 1 Yellow Warbler 1 Magnolia Warbler 1 unid ♀ tanager	Post-sunset on May 10. Stars visible in about 10% of the sky.

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Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
GB189	May 12	BH	S B6 overcast vis 4	CCW	5	2 unid warblers 1 Black-and-white Warbler 1 Magnolia Warbler 1 Chimney Swift	Post-sunset on May 12. Stars visible in about 10% of the sky.
GB189	May 13	GF	NNE B4 overcast vis 4	CCW	4	?	Post-sunset on May 13. Stars visible in about 10% of the sky.
GB189	May 16	GH	SE B5 p. cloudy vis 4	CCW	1	Least Sandpiper	Post-sunset on May 16. Stars visible in about 60% of the sky.
GB189	May 17	BH	S B6 p. cloudy vis 4	CCW	1	?	Post-sunset on May 17. Stars visible in about 40% of the sky.

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Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
GB189	May 20	BH	E B3 p. cloudy vis 4	CCW	2	1 unid passerine 1 unid warbler	Post-sunset on May 20. Stars visible in about 70% of the sky.
			NE B3 light rain vis 4	CCW	22	6 unid warblers 5 unid passerines 4 Cattle Egrets 3 Common Nighthawks 2 Snowy Egrets 1 Spotted Sandpiper 1 Magnolia Warbler	Pre-sunrise on May 21. No stars visible.
GB189	May 21	BH	E B1 clear vis 4	CCW	10	4 unid passerines 3 unid warblers 3 Common Nighthawks	Post-sunset on May 21. Stars visible in 100% of the sky.

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Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
HI561	Mar 14	ECH	E B8 heavy rain vis 2	CCW	410	100 unid warblers 100 Little Blue Herons 50 Great Blue Herons 30 Great Egrets 25 Yellow-crowned Night-Herons 20 Snowy Egrets 15 Cattle Egrets 15 Black-crowned Night-Herons 15 Purple Martins 12 unid shorebirds 10 Tricolored Herons 10 Green Herons 6 Soras 2 Black-and-white Warblers	Circulation first noticed at 00:30 on March 15.
HI561	Apr 7	GF	N B2 clear vis 4	CW + CCW	2	unid swallows	Pre-sunrise on Apr 8.

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Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
HI561	May 2	BH	SE B7 overcast vis 3	CCW	24	9 unid shorebirds 4 unid warblers 2 Little Blue Herons 2 Cattle Egrets 2 Blackburnian Warblers 2 Bay-breasted Warblers 1 Reddish Egret 1 Black-and-white Warbler 1 Ovenbird	Post-sunset on May 2.
HI561	May 10	BH	S B5 clear vis 4	CCW	2	1 Bank Swallow 1 Northern Rough-winged Swallow	Pre-sunrise on May 11.
MI622	Apr 2	GF	E B4 overcast vis 3	?	77	35 Cattle Egrets 17 Upland Sandpipers 15 unid passerines 3 unid shorebirds 2 Green Herons 1 Great Blue Heron 1 Least Bittern 1 Sora 1 Solitary Sandpiper 1 Lesser Nighthawk	Post-sunset on Apr 2.

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Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
MI622	Apr 11	BH	SE B3 overcast vis 4	?	43	27 Cattle Egrets 12 unid passerines 2 unid white egrets 1 Snowy Egret 1 Little Blue Heron	Pre-sunrise on Apr 12. Thunderstorms associated with approaching cold front visible to N during event.
MI622	May 1	ECH	ESE B4 clear vis 4	?	~20	unid warblers, Indigo Buntings	Post-sunset on May 1.
MI622	May 2	BH	NE B3 overcast vis 4	CW	~700	almost all Magnolia Warblers ~10 Common Yellowthroats 1 Kentucky Warbler 1 Blackburnian Warbler	Post-sunset on May 2. All Magnolia Warblers appeared to be ASY ♂♂. No stars visible.
MI622	May 5	ECH	SE B5 clear vis 4	?	54	50 Magnolia Warblers 4 Common Yellowthroats	Post-sunset on May 5. All Magnolia Warblers appeared to be ASY ♂♂.
PN975	Mar 8	BH	SSE B3 overcast vis 3	CCW	52	45 Tree Swallows 5 Barn Swallows 2 unid warblers	Pre-sunrise on Mar 9. Very hazy, somewhat foggy.
PN975	Mar 13	ECH	SE B3 overcast vis 3	CCW	8	6 Tree Swallows 2 unid warblers	Pre-sunrise on Mar 14. Trace of light rain during event.

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PN975	Mar 14	ECH	NE B7 heavy rain vis 2	CCW	41	10 unid warblers 6 American Golden-Plovers 4 Louisiana Waterthrushes 5 Killdeers 3 Lesser Yellowlegs 2 Green Herons 1 Yellow-crowned Night-Heron 1 Little Blue Heron 1 Sora 1 Upland Sandpiper 1 Willet 1 Greater Yellowlegs 1 Sanderling 1 Least Sandpiper 1 Purple Martin 1 Barn Swallow 1 Yellow-throated Warbler	Post-sunset on Mar 14. Event occurred during thunderstorm with torrential rain and lightning.
			S B3.5 overcast vis 4	?	12	7 Pectoral Sandpipers 2 Tree Swallows 1 Great Blue Heron 1 Black-and-white Warbler 1 Hooded Warbler	Pre-sunrise on Mar 15.
PN975	Mar 16	GF	NNE B5 overcast vis 4	CCW	8	6 unid warblers 1 Black-throated Green Warbler 1 Cattle Egret	Pre-sunrise on Mar 17.

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Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
PN975	Mar 17	GF	N B5 overcast vis 4	CCW	11	5 Black-and-white Warblers 2 Hooded Warblers 1 Purple Martin 1 Willet 1 Yellow-throated Warbler 1 Northern Parula	Post-sunset on Mar 17.
PN975	Mar 18	GF	NNW B6 overcast vis 4	?	~41	~40 unid warblers 1 Great Egret	Pre-sunrise on Mar 19.
PN975	Mar 20	GF	SE B4 clear vis 4	CCW	49	40 Tree Swallows 5 Barn Swallows 2 Black-and-White Warblers 1 Purple Martin 1 Willet	Post-sunset on Mar 20.
		ECH	SE B4 p. cloudy vis 4	?	1	1 Yellow-throated Warbler	Pre-sunrise on Mar 21.
PN975	Mar 23	ECH	E B3 overcast vis 4	CW	70	Tree Swallows	Post-sunset on Mar 23.
PN975	Mar 25	ECH	SE B3.5 clear vis 4	CW	2	Tree Swallows	Post-sunset on Mar 25.

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Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
PN975	Mar 26	GH	SSW B2 p. cloudy vis 3	CW	1	Tree Swallow	Pre-sunrise on Mar 27.
PN975	Mar 27	GF	E B2 overcast vis 3	CCW	345	160 Tree Swallows 40 unid warblers 35 Cattle Egrets 20 unid passerines 20 Upland Sandpipers 13 American Golden Plovers 10 Greater Yellowlegs 10 Willets 9 Least Sandpipers 7 Pectoral Sandpipers 5 Black-bellied Plovers 5 Great Blue Herons 3 unid peep 2 Snowy Egrets 2 Tricolored Herons 1 Yellow-crowned Night-Heron 1 Summer Tanager 1 Black-and-white Warbler 1 Hooded Warbler	Post-sunset on Mar 27. Skies were clear with zero cloud cover during PC5, though it was somewhat foggy. At about 21:00, it suddenly clouded over. During the next 15 minutes, birds appear en masse. At 21:40 it started to clear again and most species suddenly disappeared. This event thus lasted only 40 minutes and was associated with a brief period of cloud cover.
			SE B1 overcast vis 3	CCW	289	280 Tree Swallows 6 unid warblers 2 Barn Swallows 1 Bank Swallow	Pre-sunrise on Mar 28. One of the Barn Swallows was flying CW.

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PN975	Mar 28	BH	SE B3.5 p. cloudy vis 4	?	15	12 Tree Swallows 1 Barn Swallows 1 Least Sandpiper 1 unid warbler	Post-sunset on Mar 28.
			S B3 overcast vis 3	?	32	30 Tree Swallows 2 Barn Swallows	Pre-sunrise on Mar 29.
PN975	Mar 30	GF	E B2 overcast vis 4	CCW	73	23 Cattle Egrets 15 unid warblers 12 Chimney Swifts 5 Little Blue Herons 2 Lesser Yellowlegs 2 Lesser Nighthawks 2 Tree Swallows 1 Tricolored Heron 1 Snowy Egret 1 Green Heron 1 American Golden-Plover 1 Pectoral Sandpiper 1 Barn Swallow 1 Common Yellowthroat 1 American Redstart 1 Black-and-white Warbler 1 Hooded Warbler 1 Blue-winged Warbler 1 Worm-eating Warbler	Post-sunset on Mar 30.

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Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
PN975	Apr 10	BH	SE B3 overcast vis 3	?	10	8 American Golden-Plovers 2 unid passerines	Pre-sunrise on Apr 11.
PN975	Apr 11	BH	E B2 p. cloudy vis 4	?	4	3 unid warblers 1 Purple Martin	Pre-sunrise on Apr 12.
PN975	Apr 12	GF	N B4 overcast vis 4	?	170	40 Common Yellowthroats 40 unid warblers 20 unid passerines 13 Indigo Buntings 9 Blue-winged Warblers 7 Hooded Warblers 6 Northern Parulas 4 Red-eyed Vireos 4 Kentucky Warblers 4 Tennessee Warblers 4 Black-and-white Warblers 3 Worm-eating Warblers 3 Ovenbirds 3 American Redstarts 2 Least Sandpipers 2 Black-throated Green Warblers 1 Merlin 1 Wood Thrush 1 Gray Catbird 1 Scarlet Tanager	Post-sunset on Apr 12. Event began right after sunset with ~80 birds circling. Peak of 120 birds occurred 21:00-22:00. By 23:30 the skies began to clear and there was a distinct reduction in numbers down to 30.

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Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
PN975	Apr 12 (cont.)	GF	N B4 overcast vis 4	?	170	1 Orchard Oriole 1 Rose-breasted Grosbeak	
			N B4 p. cloudy vis 4	?	8	8 Cattle Egrets	Pre-sunrise on Apr 13.
PN975	Apr 13	GF	SE B1 clear vis 4	?	6	3 unid warblers 2 Cattle Egrets 1 Yellow-billed Cuckoo	Pre-sunrise on Apr 14.
PN975	Apr 21	GF	SE B2 clear vis 4	?	2	1 Gray Catbird 1 unid warbler	Post-sunset on Apr 21.
PN975	Apr 25	GF	E B3 clear vis 4	?	9	4 unid warblers 3 unid passerines 1 Red-eyed Vireo 1 Chestnut-sided Warbler	Post-sunset on Apr 25.

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Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
PN975	Apr 26	MCH	E B3.5 clear vis 4	?	36	14 unid warblers 8 Cattle Egrets 3 Red-eyed Vireos 3 unid sparrows 2 Indigo Buntings 2 Common Yellowthroats 1 Little Blue Heron 1 Bank Swallow 1 Gray Catbird 1 Ovenbird	Post-sunset Apr 26.
PN975	Apr 27	GH	SE B3.5 p. cloudy vis 4	?	7	2 unid warblers 1 Barn Swallow 1 Red-eyed Vireo 1 Blackpoll Warbler 1 Black-and-white Warbler 1 Common Yellowthroat	Post-sunset on Apr 27.
			SE B1 p. cloudy vis 4	?	26	25 unid peeps 1 unid passerine	Pre-sunrise on Apr 28.

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Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
PN975	Apr 28	GH	ESE B3 clear vis 4	CCW	69	46 Magnolia Warblers 6 unid warblers 5 Common Yellowthroats 2 Baltimore Orioles 1 Chimney Swift 1 Ruby-throated Hummingbird 1 Gray Catbird 1 Yellow Warbler 1 Blackburnian Warbler 1 Chestnut-sided Warbler 1 Blue-winged Warbler 1 Northern Parula 1 American Redstart 1 Kentucky Warbler	Post-sunset on Apr 28. First bird in circulation was detected at 20:20. Numbers built up very quickly, and were in decline by 22:00 as most landed on the platform or departed. Only a few birds remained at 23:55.
			SSE B2 overcast vis 4	CW + CCW	41	24 Cattle Egrets 6 Dickcissels 3 Little Blue Herons 2 Solitary Sandpipers 1 Great Blue Heron 1 Yellow-crowned Night-Heron 1 Upland Sandpiper 1 Lesser Yellowlegs 1 Lesser Nighthawk 1 Baltimore Oriole	Pre-sunrise on Apr 29. All herons were flying CW; all others CCW.

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Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
PN975	Apr 29	GF	ESE B4 overcast vis 4	CCW	800+	283 Magnolia Warblers 67 Common Yellowthroats 31 Ovenbirds 17 Blackburnian Warblers 15 Tennessee Warblers 12 Little Blue Herons 12 Indigo Buntings 8 Least Sandpipers 4 Yellow Warblers 3 Cattle Egrets 3 Philadelphia Vireos 3 American Redstarts 3 Chestnut-sided Warblers 3 Painted Buntings 2 Gray Catbirds 2 Baltimore Orioles 2 Rose-breasted Grosbeaks 2 Black-throated Green Warblers 2 Black-and-white Warblers 2 Kentucky Warblers 2 Northern Waterthrushes 1 Peregrine Falcon 1 Merlin 1 Purple Martin 1 Barn Swallow 1 Chimney Swift 1 Eastern Kingbird 1 Warbling Vireo 1 Golden-winged Warbler	Post-sunset on Apr 29. Just after sunset birds slowly began to appear around the platform; by 20:50 there were ~100 migrants in circulation. More birds continued to arrive for some time more, with a peak of 800+ at 22:30, when numbers began to land on the platform. By 02:30 on April 30 (when the observer went to bed), there were 50 birds still in flight.

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Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
PN975	Apr 29 (cont.)	GF	ESE B4 overcast vis 4	CCW	800+	1 Summer Tanager 1 Dickcissel 1 Lincoln's Sparrow	
PN975	Apr 29	GF	SSE B5 overcast vis 4	CCW	25	10 Magnolia Warblers 4 Common Yellowthroats 3 Blackburnian Warblers 3 Dickcissels 2 Ovenbirds 1 Cattle Egret 1 Barn Swallow 1 Black-and-white Warbler	Pre-sunrise on Apr 30
PN975	Apr 30	ECH	SE B5 clear vis 4	CCW	18	6 unid warblers 2 Buff-breasted Sandpipers 2 Chimney Swifts 2 Blackburnian Warblers 1 Least Sandpiper 1 Barn Swallow 1 Yellow Warbler 1 Magnolia Warbler 1 Ovenbird 1 Tennessee Warbler	Post-sunset on Apr 30.

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Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
PN975	May 1	ECH	E 3.5 overcast vis 4	CCW	81	20 unid warblers 13 Magnolia Warblers 5 Least Sandpipers 5 Barn Swallows 5 Blackburnian Warblers 3 Great Blue Herons 2 Lesser Yellowlegs 2 Baird's Sandpipers 2 Chimney Swifts 2 Dickcissels 2 Blackpoll Warblers 2 Blackburnian Warblers 2 Ovenbirds 1 Cattle Egret 1 Black-crowned Night-Heron 1 American Coot 1 Sora 1 Upland Sandpiper 1 Ruddy Turnstone 1 Stilt Sandpiper 1 Solitary Sandpiper 1 Merlin 1 Yellow-billed Cuckoo 1 Eastern Kingbird 1 Baltimore Oriole 1 Swainson's Thrush 1 Common Yellowthroat 1 Chestnut-sided Warbler 1 American Redstart	Post-sunset on May 1.

Table 16.1.

Summary of all nocturnal circulation events detected during spring 2000

Date shown is that for the beginning of the night. Flight direction is given with respect to the sea surface as a reference. Events are listed by platform from east to west.

Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
PN975	May 1 (cont.)	ECH	E 2 overcast vis 4	CCW	147	40 Dickcissels 30 Bank Swallows 30 unid passerines 20 Barn Swallows 9 Cattle Egrets 4 Baltimore Oriole 3 Green Herons 3 Brown-headed Cowbirds 1 Little Blue Heron 1 Tricolored Heron 1 Spotted Sandpiper 1 Scissor-tailed Flycatcher 1 Gray Catbird 1 Philadelphia Vireo 1 Bay-breasted Warbler 1 Black-and-white Warbler	Pre-sunrise on May 2.

Table 16.1.

Summary of all nocturnal circulation events detected during spring 2000

Date shown is that for the beginning of the night. Flight direction is given with respect to the sea surface as a reference. Events are listed by platform from east to west.

Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
PN975	May 2	BH	SSE B4.5 overcast vis 4	CCW	229	60 unid warblers 56 Magnolia Warblers 20 Common Yellowthroats 19 Cattle Egrets 13 Blackburnian Warblers 9 Least Sandpipers 8 Lesser Yellowlegs 5 American Redstarts 5 Gray Catbirds 3 Baltimore Orioles 3 Dickcissels 2 Great Blue Herons 2 Little Blue Herons 2 Eastern Kingbirds 2 Eastern Wood-Pewees 2 Black-and-White Warblers 2 Black-throated Green Warblers	Post-sunset on May 2, monitored to 01:30. At the peak of the circulation the observer noticed quite a few birds flying around the flame at the top of the flare tower. The next morning (May 3), an Eastern Wood-Pewee and a Ruby-throated Hummingbird were found barely alive but with their wings and tail nearly burnt off.

Table 16.1.

Summary of all nocturnal circulation events detected during spring 2000

Date shown is that for the beginning of the night. Flight direction is given with respect to the sea surface as a reference. Events are listed by platform from east to west.

Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
PN975	May 2 (cont.)	BH	SSE B4.5 overcast vis 4	CCW	229	2 Chestnut-sided Warblers 2 Tennessee Warblers 2 Yellow Warblers 1 Snowy Egret 1 Green Heron 1 Bank Swallow 1 Blue Grosbeak 1 Indigo Bunting 1 Lesser Nighthawk 1 Nashville Warbler 1 Northern Waterthrush 1 unid passerine 1 White-winged Dove	
PN975	May 4	ECH	SE B5 p. cloudy vis 4	?	1	Cattle Egret	Pre-sunrise on May 5.

Table 16.1.

Summary of all nocturnal circulation events detected during spring 2000

Date shown is that for the beginning of the night. Flight direction is given with respect to the sea surface as a reference. Events are listed by platform from east to west.

Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
PN975	May 5	ECH	SE B5 p. cloudy vis 4	?	118	61 unid warblers 24 Magnolia Warblers 10 Common Yellowthroats 6 Chestnut-sided Warblers 3 Barn Swallows 3 Blackpoll Warblers 3 Black-throated Green Warblers 2 Bay-breasted Warblers 2 Blackburnian Warblers 2 Ovenbirds 1 Lesser Yellowlegs 1 Chimney Swift	Post-sunset on May 5. The majority of Magnolia Warblers were ASY ♂♂.
			SE B5 p. cloudy vis 4	?	4	2 Magnolia Warblers 1 Brown-headed Cowbird 1 unid warbler	Pre-sunrise on May 6.

Table 16.1.

Summary of all nocturnal circulation events detected during spring 2000

Date shown is that for the beginning of the night. Flight direction is given with respect to the sea surface as a reference. Events are listed by platform from east to west.

Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
PN975	May 6	BH	SE B4.5 p. cloudy vis 4	?	206	133 Magnolia Warblers 22 unid warblers 14 Common Yellowthroats 7 Swainson's Thrushes 7 Ovenbirds 6 Baltimore Orioles 5 Barn Swallows 3 American Redstarts 2 Cattle Egrets 1 Rose-breasted Grosbeak 1 Peregrine Falcon 1 Least Sandpiper 1 Philadelphia Vireo 1 Blackburnian Warbler 1 Kentucky Warbler 1 Dickcissel	Post-sunset on May 6.
PN975	May 7	BH	SSE B4.5 clear vis 4	?	1	1 unid *Empidonax* flycatcher	Post-sunset on May 7.
			SE B5 clear vis 4	?	4	2 Magnolia Warblers 1 Barn Swallow 1 unid warbler	Pre-sunrise on May 8.
PN975	May 8	BH	SE B5 clear vis 4	?	1	unid passerine	Post-sunset on May 8.

Table 16.1.

Summary of all nocturnal circulation events detected during spring 2000

Date shown is that for the beginning of the night. Flight direction is given with respect to the sea surface as a reference. Events are listed by platform from east to west.

Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
PN975	May 9	BH	SE B4 clear vis 3	?	94	42 Pectoral Sandpipers 12 Cattle Egrets 9 unid warblers 8 Magnolia Warblers 7 Bank Swallows 6 Tricolored Herons 4 Barn Swallows 1 Peregrine Falcon 1 Spotted Sandpiper 1 Chimney Swift 1 Red-eyed Vireo 1 American Redstart 1 unid small flycatcher	Pre-sunrise on May 10.
PN975	May 10	BH	SE B5 clear vis 4	?	70	45 Magnolia Warblers 7 Ovenbirds 6 Common Yellowthroats 4 Barn Swallows 4 Chestnut-sided Warblers 2 Bank Swallows 1 Rose-breasted Grosbeak 1 American Redstart	Post-sunset on May 10.
PN975	May 10 (cont.)	BH	S B5 clear vis 3	?	53	34 Bank Swallows 11 Barn Swallows 6 Magnolia Warblers 2 unid warblers	Pre-sunrise on May 11.

Table 16.1.

Summary of all nocturnal circulation events detected during spring 2000

Date shown is that for the beginning of the night. Flight direction is given with respect to the sea surface as a reference. Events are listed by platform from east to west.

Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
PN975	May 11	BH	SSE B5.5 overcast vis 3	?	8	5 Barn Swallows 2 Bank Swallows 1 Magnolia Warbler	Pre-sunrise on May 12.
PN975	May 12	BH	SE B4 clear vis 4	?	8	7 Cattle Egrets 1 Peregrine Falcon	Post-sunset on May 12.
PN975	May 13	GF	NE B4 p. cloudy vis 4	?	4	2 unid passerines 1 Barn Swallow 1 Magnolia Warbler	Post-sunset on May 13.
		MCH	E B4 p. cloudy vis 4	?	7	2 Cattle Egrets 2 Barn Swallows 2 unid passerines 1 unid *Catharus* thrush	Pre-sunrise on May 14.
PN975	May 14	MCH	E B3.5 p. cloudy vis 4	?	17	17 unid passerines	Pre-sunrise on May 15. Some of the birds were medium-sized and likely thrushes.

Table 16.1.

Summary of all nocturnal circulation events detected during spring 2000

Date shown is that for the beginning of the night. Flight direction is given with respect to the sea surface as a reference. Events are listed by platform from east to west.

Platform	Date	Synoptic Weather	Local Weather	Flight Direction	Maximum # Involved	Species Composition	Notes
PN975	May 19	BH	SE B3 overcast vis 3	?	101	74 unid passerines 13 unid flycatchers 4 Eastern Wood-Pewees 3 Common Yellowthroats 2 Magnolia Warblers 2 Ovenbirds 1 Lesser Nighthawk 1 Bank Swallow 1 unid swallow	Circulation started about 10 minutes into PC0 on 20 May, with front from the north on the horizon.
PN975	May 20	BH	ESE B4 p. cloudy vis 4	?	32	8 unid warblers 5 unid passerines 5 Magnolia Warblers 5 Ovenbirds 3 Barn Swallows 2 Common Yellowthroats 1 Blackburnian Warbler 1 Yellow-billed Cuckoo 1 unid flycatcher 1 Eastern Kingbird	Post-sunset on May 20. The unid warblers were flying around the lit flare tower, drawn to the large flare (present on this day due to a valve leak leftover from construction). None of the warblers appeared to be injured by the flame.
			NE B3 clear vis 4	?	1	1 Blackburnian Warbler	Pre-sunrise on May 21.
PN975	May 21	BH	ENE B4 clear vis 4	?	15	6 unid passerines 5 unid warblers 3 American Redstarts 1 Magnolia Warbler	Post-sunrise on May 21.

Chapter 17

Sources of Mortality

Robert W. Russell

17.1 SPRING

Among the total of 787 cases of migrant mortality we documented on or near platforms during the three springs of study, a specific cause of death could be ascribed to 758 (96%). Starvation was the most common cause of death (46% of deaths in which a cause was assignable), followed by collision (34%) and predation (14%). Summaries of sources of spring mortality by platform are given in Tables 17.1-17.3 for 1998, 1999, and 2000, respectively.

Table 17.1.

Sources of mortality in spring 1998

Cause of Mortality	GB189	VR265	SM66	PL10	EW826	TOTAL
Starvation	54	22	16	17	21	130
Predation						
Raptors	12	11	2	4	3	32
Gulls/other	1	1	0	0	0	2
Collision	112	11	1	1	1	126
Other	1	0	0	1	0	2
Unknown	0	2	1	0	0	3
TOTAL	180	47	20	23	25	295

Table 17.2.

Sources of mortality in spring 1999

Cause of Mortality	GB189	VR265	SM66	GC18	EW826	TOTAL
Starvation	13	2	10	29	21	75
Predation						
Raptors	1	1	0	13	3	18
Gulls/other	0	0	0	0	0	0
Collision	7	1	0	4	1	13
Other	0	0	0	0	1	1
Unknown	1	4	0	0	0	5
TOTAL	22	8	10	46	26	112

Table 17.3.

Sources of mortality in spring 2000

Cause of Mortality	PN975	MI622	HI561	GB189	VR265	SM66	GC18	EW826	SP89	TOTAL
Starvation	7	9	17	30	18	15	17	18	9	140
Predation										
Raptors	7	40	0	2	2	0	3	1	1	56
Gulls/other	0	23	0	0	0	0	0	2	1	26
Collision	87	11	5	17	0	0	1	1	0	122
Other	6	0	1	4	0	0	0	2	2	15
Unknown	12	3	1	3	1	0	0	1	0	21
TOTAL	119	86	24	56	21	15	21	25	13	380

Differences among years primarily reflected large-scale differences in migration route and the occurrence of a few extreme events.

In spring 1998, the large number of collision deaths at GB189 was almost entirely attributable to an unusual weather situation in which a cold front became stationary over the platform from April 27-30. During that period, conditions were favorable for departure from Mexico, and massive circulations developed around the platform each night as incoming migrants encountered the foul weather and GB189 almost simultaneously. Of the 112 collision deaths at GB189 in spring 1998, 111 (>99%) occurred during the April 27-30 event.

After accounting for the unusual event at GB189 in spring 1998, patterns of mortality in 1999 differed from 1998 in two important ways. First, starvation deaths were nearly 50% less frequent in 1999. The relative scarcity of starvation deaths in 1999 apparently reflected the more benign synoptic weather patterns in April (i.e., around the time of peak migration) in 1999 than in 1998 (Figure 5.2). Second, there was a trend of more deaths toward the east in 1999, whereas the trend was in the opposite direction in 1998. This difference coincided with several other lines of evidence (e.g., see Figures 7.11, 7.12) suggesting that the large-scale trajectory of migration was shifted toward the east in 1999 compared to 1998.

Patterns of mortality in spring 2000 were more similar to 1998. In 2000, the number of collision deaths was dominated by a massive circulation event that developed at PN975 on the night of April 29-30, which accounted for 49 of that platform's 87 collisions for the season (56%).

17.2 FALL

Among the total of 780 cases of migrant mortality we documented on or near platforms during the two falls of study, a specific cause of death could be ascribed to 653 (84%). In contrast to spring, when starvation was the most common cause of death (even when the two extreme collision events at GB189 and PN975 are included in the sample), collision was the most common cause of death in the fall, accounting for 48% of deaths in which a cause was assignable. Predation was relatively more common in the fall (36% of deaths, compared to 14% in spring). However, starvation was uncommon in the fall, with only 76 documented cases in the two years. Summaries of sources of fall mortality by platform are given in Tables 17.4 and 17.5 for 1998 and 1999, respectively.

Table 17.4.

Sources of mortality in fall 1998

Cause of Mortality	GB189	VR265	SM66	PL10	EW826	TOTAL
Starvation	4	5	4	10	13	36
Predation						
Raptors	11	5	1	4	2	23
Gulls/other	0	0	0	0	0	0
Collision	3	21	13	9	8	54
Other	1	4	0	0	1	6
Unknown	4	3	0	0	19	26
TOTAL	23	38	18	23	43	145

Table 17.5.

Sources of mortality in fall 1999

Cause of Mortality	PN975	MI622	HI561	GB189	VR265	SM66	GC18	EW826	SP89	VK786	TOTAL
Starvation	2	2	3	1	1	6	4	3	5	13	40
Predation											
Raptors	95	22	0	7	7	4	14	23	11	31	214
Gulls/other	0	0	0	0	0	0	0	0	0	0	0
Collision	48	16	1	8	9	5	47	3	2	122	261
Other	0	2	1	1	5	1	3	0	4	2	19
Unknown	23	15	1	5	17	1	15	19	1	4	101
TOTAL	168	57	6	22	39	17	83	48	23	172	635

17.3 “OTHER” SOURCES OF MORTALITY

Incidences of mortality attributable to specific causes other than starvation, predation, and collision were rare (Table 17.6). We were surprised by the ability of migrants to avoid what initially seemed to us to be an abundance of potential dangers on the platforms. In fact, most of the birds that died from oiling and poisoning were individuals that were already moribund from starvation.

Table 17.6.

“Other” sources of mortality during the study

Cause of Mortality	Spring 1998	Spring 1999	Spring 2000	Fall 1998	Fall 1999	TOTAL
Drowning	1	0	3	2	1	7
Oiling	1	0	5	2	1	9
Burning	0	0	3	0	0	3
Fans	0	0	2	0	6	8
Entrapment	0	0	0	1	1	2
Poisoning	0	0	0	1	7	8
Workers	0	0	0	0	3	3
TOTAL	2	0	13	6	19	40

17.4 DISCUSSION

Deaths of migrants during this study were attributable to a variety of causes, but most resulted from starvation, predation, and trauma resulting from collision with platforms. Surprisingly, mortality resulting from consumption of toxic chemicals or oiling appeared to be very rare.

With the exception of the extraordinary circulation event at GB189 in spring 1998, it is clear that collisions are generally rare in spring. The reason for this is straightforward: migrants are usually not aloft over platforms at night during the spring. A closer look at the collision deaths in Tables 17.1-17.3 (excluding the April 1998 event at GB189) revealed that most occurred very early in the morning on BH days with strong winds from the south, when the vanguard of northbound migrants actually reached our platforms before the onset of daylight.

In contrast to spring, starvation was relatively rare and collision was the most common cause of death in the fall. Starvation was rare in part because the platforms are much closer to points of departure in the fall (i.e., migrants arriving on platforms have had less time to deplete their fat stores), and in part because food availability was greater in the fall (Figure 13.1). Collision mortality is more significant in the fall because most migrants in that season are aloft over the northern Gulf during hours of darkness.

Mortality of migrants at tall towers and other land-based structures has been reviewed extensively (Weir 1976; Avery et al. 1978; Hebert and Reese 1995; Ogden 1996; Trapp 1998), and the mechanisms involved in platform collisions appear to be similar.

In some cases, migrants simply do not see a part of the platform until it is too late. At VK786 in fall 1999, we made direct observations from the tip of the flare boom at night which indicated that landbird migrants often avoided colliding with the boom only via last-minute evasive movements. It is not clear why these migrants apparently did not see the structure almost until it was too late, since we were able to see them long before they took evasive action. It is possible that nocturnal landbird migrants in flight over the Gulf pay attention primarily to the sky and/or the sea surface; presumably this would reflect the fact that, through most of their evolutionary history (i.e., until the advent of offshore platforms), no selective advantage would have accrued to individuals on the lookout for obstacles in the Gulf.

Another factor that may be involved in attracting migrants and inducing collisions is noise. At VK786, we recovered 5 migrants that died in collisions before September 25 (the approximate peak of the fall migration) and 114 migrants that died in collisions after. Prior to September 25, VK786 was extremely quiet due to the lack of virtually any activity on the platform. After September 25, a large population of workers arrived, construction activities commenced, and the platform was considerably noisier. Thake (1981) hypothesized that birds maintain loose associations by detecting Doppler shifts in calls effected by relative velocity changes in neighboring migrants. The dramatic increase in frequency of collisions at VK786 following the increase in ambient noise levels is consistent with the idea that disruption of the aural environment may inhibit orientation performance and increase the risk of collision.

It is noteworthy that virtually no birds were burned in gas flares in this study. The only platforms that routinely flared gas in this study were VR265 and SP89. At VR265, the primary observer during fall 1999 commented as follows: "We always had a rather small flame. On one or two mornings when there was heavy flyover traffic, I could see up to 5 birds circling, or at least flying in and out of, the light around the flare. I didn't think the flame affected birds at any other times." At SP89, the primary observer during fall 1999 commented as follows: "I never observed a circulation event as described by others. During the fallout on October 12, the birds repeatedly approached the active flare, but did not circle the platform as I imagine a circulation event to be." The absence of a significant impact of offshore gas flares is consistent with observations at terrestrial oil fields around the Gulf Coast indicating that, while many migrants may sometimes be attracted to gas flares, only a small proportion of those attracted are killed (Davies 1940). Our finding that mortality associated with gas flares in the Gulf is rare is also consistent with the conclusion by Bourne (1979) that — despite sensational reports in the popular science literature (e.g., Sage 1979) — verifiable reports of birds burned in gas flares in the North Sea are scarce (Bourne 1979). Most documented incidents of mass mortality in the North Sea were natural, resulting from lost migrants arriving in the fog and dying of starvation rather than incineration (Bourne 1979).

Based on the seasons with heaviest observed collision mortality (spring 1998, fall 1999), an average Gulf platform may cause 50 deaths by collision per year, suggesting that the platform archipelago may cause roughly 200,000 deaths per year. This number may be biased low because some birds that collide with platforms undoubtedly fall into the sea and avoid detection. Nevertheless, the numbers still pale compared to human-related sources of bird mortality on land. At least 100 million — and perhaps as many as a billion — birds die each year from striking plate glass windows, including about 25% (225) of 917 bird species in the U.S. and Canada and many long-distance migrants (Klem 1989,1990; Dunn 1993). Hundreds of millions more are killed each year by communication towers, power transmission lines, cars, pesticides, and domestic and feral cats. Overall, bird mortality currently caused by offshore platforms is negligible within the larger scheme of anthropogenic impacts on migratory birds.

An important caveat to this conclusion is that future development of the eastern Gulf of Mexico may result in a disproportionately large increase in collision mortality in neotropical migrants. This possibility is raised by the numerous lines of evidence suggesting that the main fall migration route of neotropical migrants is across the eastern Gulf of Mexico (Chapter 9), along with the high observed mortality at VK786, at the eastern end of our study area and on the western fringe of the putative fall route (Table 17.5). In addition, future platforms in the eastern Gulf are likely to be geographically isolated due to the economics of deepwater production, and geographical isolation seems to be a factor associated with the development of nocturnal circulations (Chapter 16), which put birds at higher risk of collision.

Chapter 18

Conclusions and Recommendations

Robert W. Russell

18.1 CONCLUSIONS

18.1.1 Ecology of Trans-Gulf Bird Migration

This was the first quantitative study of trans-Gulf migration based on direct evidence and systematic data collection. Previously, most information on trans-Gulf migration was based on remote radar observations, anecdotal reports from ships (e.g., Brooks 1922; Packard 1947; Bullis and Lincoln 1952; Bullis 1954), or casual observations made by platform workers or platform-based marine biologists (Ortego 1977; Pulich and Dellinger 1980; Childs 1998).

Prior to this study, the conventional wisdom had been that spring trans-Gulf migration involves a roughly straight-line, shortest-distance flight from the Yucatan Peninsula to the upper Gulf Coast. Our results support parts of this scenario but also indicate that the situation is considerably more complex. Backtracking from radar images and arrival times on platforms indicates that most spring migrants initiate their flights from the Yucatan Peninsula and/or the northern coast of the Isthmus of Tehuantepec. Radar and direct observational evidence indicates that most trans-Gulf migration takes place over the western Gulf and suggests that the route of migrants is curvilinear and divergent, veering from a probable mean heading of northwest at points of origin, to north off the south Texas coast, to northeast off the Upper Texas Coast and Louisiana. Large flights are usually associated with Eastern Continental High (**ECH**) or Bermuda High (**BH**) synoptic weather patterns, in which winds similarly veer clockwise around the western Gulf. We therefore suggest that the route of trans-Gulf migrants is influenced by the availability of tailwinds, with migrants attempting to minimize the time or energy expenditure required for crossing.

This hypothesis is strengthened by the finding that centers of offshore abundance as well as areas of eventual landfall varied in concert with synoptic weather. On **ECH** days when winds typically had a stronger westward component over the southern Gulf and often maintained a westward component over the northern Gulf, migrants were most abundant on platforms in the far western Gulf and landfall was usually along the Texas coast. In contrast, on **BH** days, when winds had a weaker westerly component over the southern Gulf and usually an eastward component over the northern Gulf, peak offshore abundance shifted eastward and landfall was more likely to take place farther east along the northern Gulf Coast, occasionally as far as the Florida Panhandle. All available evidence indicates that the main migration stream is at least partially “steered” by synoptic-scale winds.

In addition to being subject to geographic displacement via steering by synoptic winds, the migration stream itself showed evidence of having a complex geographic structure. In at least several species of warblers, females apparently take a more direct route across the Gulf, and males tend to take a more westerly route. Species with different goals prefer to depart under different synoptic weather types.

When winds across the northwestern Gulf were unfavorable for trans-Gulf migrants, the usual pattern of clockwise travel was absent. Strong, fast-moving cold fronts sometimes induced a large-scale displacement of the migration stream eastward as far as Florida. Under less adverse conditions, most of the migrants that did undertake the crossing apparently opted for a more direct route toward the Texas coast, where they could be seen in radar images arriving from the SSE instead of continuing on toward the NNE or NE.

The diel timing of spring trans-Gulf migration followed a predictable pattern that was evident both in radar imagery and from direct visual observations on the platforms. Spring migration over the northern Gulf began between early morning and early afternoon, peaked 3-4 h after first detection, and continued until 7-12 h after first detection. Patterns of diel timing varied geographically and were related to weather, again consistent with a strong synoptic steering influence on migration routes across the Gulf.

The bulk of spring trans-Gulf migration detected by radar occurred between March 25 and May 24, but very large flights (>25 million migrants) occurred only in the 3-week period from April 22 to May 13. Waterfowl and herons peaked by early April. Shorebirds had widely varying migration schedules, with different species peaking as early as mid-March and as late as the end of May. Landbird migrants showed peaks throughout the season, but a majority of species peaked in the second half of April. Theoretical analyses of radar data yielded estimated total seasonal estimates of 316 million trans-Gulf migrants in spring 1998 and 147 million trans-Gulf migrants in spring 1999. In both years, about two thirds of all migrants made landfall west of South Marsh Island.

Radar-observed spring migration was characterized by a series of pulses and tended to be “all-or-nothing”, i.e., either significant trans-Gulf migration was evident on radar or else it was essentially entirely absent. Dramatic hiatuses in radar-observed migration were always associated with strong cold fronts that penetrated deep into Mexico and set up persistent northerly winds over most of the Gulf. Conversely, radar-observed migration peaks were almost strictly associated with **ECH** and **BH** days.

Analyses of radar data indicated significant differences in both diel and seasonal timing between 1998 and 1999. The diel timing of migration over the northern Gulf averaged 1-3 h later in 1999 than in 1998, even after accounting for synoptic weather type. In 1999, migration peaks seemed to be approximately Gaussian and symmetric around the peak date of April 22. In contrast, radar-observed migration peaked much later in 1998 and the overall pattern was highly skewed to the left. Reasons for these interannual differences are not clear.

Fall trans-Gulf migration was more difficult to study because the extensive presence of aerial insects precluded quantitative interpretation of radar imagery. In addition, one of the two field seasons was partly compromised by prolonged absences from the platforms due to obligatory evacuations in response to developing tropical weather systems. Nevertheless, we argue that the heaviest trans-Gulf migration traffic in fall originates from the stretch of the northern Gulf Coast running eastward from Alabama. Although we were constrained from sampling much of this area by the absence of platforms in the eastern Gulf during the study period, our contention is supported by observed longitudinal trends in abundance and age ratios. Importantly, we witnessed many massive nocturnal migration events at VK786 in fall 1999 which were effectively unquantifiable due to their magnitude and chaotic character. These massive flights occurred fairly consistently from mid-August through mid-September, despite the scarcity of particularly favorable weather conditions during that period.

Southbound “fall” migrants were observed as early as May 20 and as late as January, but the vast majority of the migration occurred from mid-August to early November. There seemed to be several phases in the fall migration. During the early fall, migration appeared to be obligate and was not strongly influenced by weather. Later in the fall, major trans-Gulf movements were generally associated with cold fronts and northerly winds. Most of the species peaking in early fall are long-distance migrants, whereas species peaking later in the fall are dominated by shorter-distance migrants. Thus, our findings are consistent with the idea that the decision to initiate a migratory flight is influenced more strongly by weather in short-distance migrants, and more strongly by an endogenous time program in longer-distance migrants (Zehnder and Karlsson 2001).

The most prominent players in the early fall movements seemed to be Yellow Warblers and the common warblers breeding in moist southeastern woodlands (Prothonotary, Hooded, Kentucky), along with smaller numbers of Cerulean Warblers and Worm-eating Warblers. Shorebirds were also an important component of this early fall eastern-Gulf migration. The early fall flights frequently occurred on nights with light southerly or easterly winds, and were almost completely invisible on NEXRAD because most migrants flew at low altitudes. Direct observations at VK786 indicated that the direction of flight was most often due south but varied from south-southwest to south-southeast. As with spring, variation in the direction of travel was clearly influenced by wind.

We also detected considerable fall migration over the far western Gulf, where flight direction usually had a westerly component. The western-Gulf route was used by a high proportion of juveniles, and appeared to represent a risk-averse migration strategy favoring a shorter, less risky overwater flight leg at the expense of a more circuitous overall migration route. We suspect that many of the adults traveling over the western Gulf were individuals that reached the northeastern Gulf Coast with inadequate fat stores for a direct trans-Gulf and worked their way westward along the coast, perhaps stopping over along the way. This hypothesis is consistent with findings from experimental work. Orientation cage experiments during September and October at Fort Morgan, Alabama, showed that lean birds oriented to the west-northwest (i.e., parallel to coast), whereas fat birds oriented to the south-southwest, in a direction consistent with intentional trans-Gulf crossing (Sandberg and Moore 1996). Free-flight release tests yielded similar results: fat birds disappeared to the south, whereas lean birds moved inland (albeit to the northeast).

One of the interesting features of the fall migration offshore was the frequent occurrence of a variety of species that do not typically winter south of the northern Gulf Coast. These species were evidently mostly "overshoots" that inadvertently traveled past their intended destinations and found themselves unexpectedly over water at first light, or else circum-Gulf migrants that inadvertently drifted eastward over the Gulf during nocturnal flight. Accordingly, these species were often observed flying north or west during daylight hours, presumably trying to get back to land. This behavior was reminiscent of the daytime reorientation of fall migrants toward the Atlantic Coast following nocturnal wind drift, which has been well documented (Stone 1937; Baird and Nisbet 1960; Murray 1976; Able 1977; Richardson 1978) and seems to involve mostly immatures (Able 1977).

All species displaying behavior suggestive of overshooting were either medium-distance migrants or short-distance migrants. Among the medium- and short-distance migrant species, only Lincoln's Sparrow, Grasshopper Sparrow, and Brown-headed Cowbird showed indications of being intentional trans-Gulf migrants. All other species are presumed to have been over the Gulf inadvertently. Vanishing bearings of overshoots tended to cluster in the W-WSW and NW-NE sectors, with medium-distance migrants tending toward the former and short-distance migrants tending toward the latter. The distinction between the westbound and northbound migrants could result either from facultative individual decisions or from inter-individual differences. In the case of facultative individual decisions, an overshoot migrant may "decide" whether to attempt to head back to the northern Gulf Coast based upon its body condition and remaining fat stores in relation to its assessment of the energy requirements needed to complete the corrective flight. Migrants lacking adequate energy stores for such corrective action may simply travel downwind (usually toward the WSW or SW in the fall) to maximize the amount of time before they deplete their energy stores. Alternatively, westbound birds may be individuals with intended winter destinations along the western (as opposed to northern) Gulf Coast. The fact that medium-distance migrants (which have more southerly wintering distributions) were more likely to be westbound than were short-distance migrants is consistent with the hypothesis of inter-individual variation. However, some short-distance migrants were observed traveling in directions that, if maintained until landfall, would have taken them to points well south of their species' normal wintering range, in support of the hypothesis of condition-dependence.

The year-round observations at GC18 indicated that northbound ("spring") trans-Gulf migration spans late January to early June, and southbound ("fall") trans-Gulf migration and overshooting spans early July to early December. Surprisingly, we found that northbound and southbound migrations overlapped temporally at the extremes: The latest southbound migrant recorded during the study (Common Snipe) occurred on 28 January, and the earliest northbound migrant (Purple Martin) occurred the following day. Southbound migration of Purple Martins began in late April and southbound shorebird migration began in late May, well before the latest northbound migrant was recorded on 8 June (Northern Waterthrush). Overwater movements during the brief interim periods between spring and fall migrations (mid-December to mid-January, mid-June to early July) seemed to be dominated by herons traveling along an east-west axis. The nature of these movements is completely unknown, but deserves further study.

Death of migrants by starvation was fairly common in the spring. Although fat scores were not recorded systematically, most of the spring dead birds categorized as "starved" lacked any trace of furcular or abdominal fat and had fat scores of zero on the Helms and Drury (1960) scale. Similar to migrants landing on ships during overwater flights, which often have essentially no fat reserves (Johnston 1968), starving migrants on platforms usually had conspicuously protruding keels and appeared to have begun to catabolize nonfat dry body components. In contrast, fall collision mortalities typically had obvious furcular fat pads that were either convex or level with the pectoralis muscle, and would have scored 4 or 5 on the Helms and Drury (1960) scale. These observations are consistent with the idea that maximum fat levels are reached at or near points where long nonstop flights begin, i.e., along the Gulf Coast in fall (Caldwell et al. 1963).

Whether migrants are limited by water or energy has long been a contentious question (Carmi et al. 1992; Biebach and Klaassen 1994). Some workers have suggested that water might limit flight range because evaporative water loss exceeds metabolic water production (Yapp 1956). Our observations have a direct bearing on this question. Fresh water was generally always available on all platforms. Sources of water included morning dew, condensation from air conditioners that formed shallow pools on decks or the roof of living quarters, condensation on pipes, cooling water running down the outside of compressors that sometimes formed shallow puddles on production decks, and pools of rain water on the tops of storage barrels. Despite the widespread availability of fresh water, we very rarely observed migrants drinking. Our observation that water consumption by trans-Gulf migrants is very rare, together with the observation that desperate migrants that have depleted their fat reserves and begun to catabolize nonfat dry body components showed no signs of dehydration (Johnston 1968), indicate that water is not a limiting factor to trans-Gulf migrants.

18.1.2 The Impact of Platforms on Migrant Birds

Platforms have three primary proximate impacts on migrant birds: 1) they provide habitat for resting and refueling; 2) they induce nocturnal circulations; and 3) they result in some mortality through collisions.

The availability of suitable habitats en route where migrants can safely replenish energy reserves is critical to successful migration, especially in the vicinity of major ecological barriers such as the Gulf of Mexico (reviewed by Moore and Simons 1992). Differences in stopover durations and rates of mass gain by migrants among different stopover sites are thought to be related to the intrinsic suitability of the different habitats available (Moore and Simons 1992). The suitability of a habitat is difficult to quantify, but presumably reflects food supply (Martin 1980,1985; Hutto 1985; Russell et al. 1994), competition (Moore and Yong 1991; Carpenter et al. 1993a,b), safety from predators (Metcalfe and Furness 1984; Lindström 1989,1990; Moore et al. 1990), shelter from severe weather (Gass and Lertzman 1980), and the physical structure of the habitat (Holmes and Robinson 1981; Robinson and Holmes 1982, 1984). Physiognomy is an important determinant of habitat suitability because habitat structure influences how birds are able to move through the habitat, how they are able to detect and capture prey, and which prey they are able to detect.

Platforms appeared to be suitable stopover habitats for most species, and most of the migrants that stopped over on platforms probably benefited from their stay, particularly in spring. Many of these migrants were able to feed successfully, and some appeared to achieve rates of mass gain that exceeded what is typical in terrestrial habitats. Platforms thus exert some selective influence on trans-Gulf migrants, since a positive association between fat levels at migratory departure and subsequent survival (estimated via return rates) has been demonstrated (Pfister et al. 1998). Even the individuals that do not feed probably benefit physiologically from the availability of the platforms. Yapp (1956) suggested that migrants may be affected by sources of fatigue other than total depletion of fat stores, such as excessive accumulation of lactic acid, failure of the nerve-muscle junction, or upset of central nervous coordination. These types of fatigue may be eliminated by simple rest. Many of the migrants that rested quietly on the platforms for hours to days were probably recovering from such sources of fatigue.

Our findings suggest that migrants use platforms in highly nonrandom ways. Migrants selected specific microhabitats on platforms (i.e., used alternative microhabitats nonrandomly), much in the same way that they select specific habitats during terrestrial stopovers (e.g., Moore et al. 1990; Moore and Simons 1992). Preferred platform microhabitats were species-specific and generally consistent between spring and fall.

One of the most interesting, albeit speculative, impacts of platforms involves their possible role in the natural selection of migration strategies. Experimental studies of captive populations (Berthold 1991; Berthold and Helbig 1992) as well as analyses of banding recoveries from populations of recently introduced species (Able and Belthoff 1998) indicate that migratory behavior, including preferred orientation, can evolve very rapidly. Observations from this study suggest that the archipelago of offshore oil platforms may be facilitating the evolution of novel trans-Gulf migration strategies in several species. Cattle Egrets colonized eastern North America only in the last half-century (reviewed by Telfair 1983), but have already become one of the most common species on platforms. The fact that Cattle Egrets were frequently observed at unexpected times of the year and flying in seasonally unexpected directions (e.g., Chapter 12) suggests the existence of a significant pool of genetic variation and the potential for rapid further selection. A rapid evolution of trans-Gulf migration may be implicated in what appears to be a population explosion and major range expansion of White-winged Doves into the southeastern United States. The Eurasian Collared-Dove has recently colonized North America, and began showing up on platforms in fall 1999. Platforms may facilitate the evolution of trans-Gulf migration strategies in certain species by providing “steppingstones” that allow incipient migrants to cross the Gulf successfully via a series of shorter flights. However, critical evaluation of hypotheses concerning selection and life-history evolution will require longer-term data than are currently available.

Another intriguing possibility concerning selective influences of platforms concerns the life-history ecology of Peregrine Falcons. Although the spectacular recovery of Peregrine Falcons has generally been attributed to the ban on DDT along with extensive reintroduction efforts (reviewed by Enderson et al. 1995; Cade et al. 2000), it seems reasonable to consider whether the growth of the platform archipelago in the Gulf may be involved. Indeed, since the first platform was installed in 1942, the period 1975-1985 saw the most dramatic increase in the size of the platform archipelago of any 10-year period, with a net addition of 1,395 platforms (i.e., new platforms installed minus those removed; Minerals Management Service 2004). This period was coincident with the recovery period of exponential population growth of Peregrine Falcons. The majority of juveniles in the North American population of this species (which was listed as Federally endangered until recently) now uses oil platforms in the northern Gulf during the fall for resting and hunting. Peregrines often appear on platforms immediately before weather events that induce large landbird movements, and now appear to be “anticipating” ephemeral periods of high resource availability. This adaptive behavior may be a precursor to evolutionary changes in the life history of the species, since an ecologically similar species — Eleonora’s Falcon — has evolved a strategy of breeding on islands in the Mediterranean during the fall, when abundant trans-Mediterranean migrant landbird prey are available for provisioning young. In other words, we hypothesize that Peregrine Falcons may be in the early stage of a dramatic life-history evolution through natural selection occurring via the Gulf platform archipelago, and we predict that Peregrine Falcons will establish a breeding population on platforms in the near future.

The existence of the platform archipelago also has potential selective implications for overshooting migrants (Chapter 9.4). During the fall, many shorter-distance migrants that spend the winter along the Gulf Coast (such as wrens and sparrows) inadvertently overshoot the coastline during nocturnal migratory flights and end up over Gulf waters. These overshoot migrants, which are evolutionarily ill-equipped to deal with the rigors of overwater migration, were among the heaviest users of platforms during the fall, and the availability of platform rest stops probably enabled many individuals to return to land successfully. This alleviation of selection pressure may in turn be implicated in large-scale southward shifts in the wintering distributions of some of these species. Long-term Christmas Bird Count (CBC) data may be useful for documenting trends in winter distributions of overshooting migrants in the Gulf region for tests of the “selection reduction hypothesis.”

According to the latest MMS database (Minerals Management Service 2004), the number of platforms in the northern Gulf of Mexico peaked at 4,064 in 2001 and has since been in decline as a result of removals outpacing new installations. Future evaluations of the possible influence of platforms on the evolution of migration strategies will have to take into account the changing size, structure, and spatial extent of the platform archipelago.

18.2 RECOMMENDATIONS

18.2.1 Use of Platforms as Ecological Observatories

Gulf platforms provide a unique opportunity for monitoring migratory bird populations. Unlike most terrestrial habitats, platforms concentrate migrants in a small area that can be surveyed comprehensively in a highly standardized and repeatable fashion. With the exception of the extremely important effects of weather (which can be controlled for and factored out using multivariate statistical methods), platform counts are free from a variety of important biases that affect censusing schemes in natural terrestrial environments (e.g., temporal trends in vegetation development) and can provide useful samples of ambient migration traffic. Unlike migrants observed in terrestrial environments, migrants detected on platforms are effectively “caught in the act” of migrating. Platform monitoring may yield powerful time series for detecting trends in populations of common migratory species and for answering questions about the interrelationships among various environmental factors, migration, and population dynamics.

We suggest that attention be paid to the possibility of developing and maintaining a network of decommissioned platforms as permanent “observatories” for long-term ecological research. Dokken (1993) has previously advocated the idea of converting a platform to a permanent offshore research station, and suggested that the annual cost for operating such a station might be $300,000 to $400,000, including staffing and research expenses but excluding transportation (which presumably could be supplied by the cooperating petroleum companies). Although such costs would be prohibitive for ornithological research alone, designation as general ecological observatories would provide novel opportunities in multiple research areas and would permit cost-sharing among a wide variety of agencies and organizations.

During this study we also monitored the occurrence and behavior of fishes and seabirds in the vicinity of our study platforms. This opportunistic work suggested a complex series of ecological interactions centered on platforms. Platforms appear to attract surface-dwelling macrozooplankton and "baitfish," either by behavioral attraction or by mechanical entrainment in convergent flows induced by the platform substructures. In addition, terrestrial insects advected offshore are attracted to platforms and become part of the neuston around platforms. This diverse neustonic fauna in turn appears to attract predatory fishes such as blue runners and tunas. Obligate surface-feeding seabird species are in turn attracted to the vicinity of the schools of predatory fish, where they take buoyant scraps from the fish feeding frenzies. These complex trophic relationships merit further attention, because concentration of marine bird populations in the vicinity of platforms may be a conservation concern in the event of oil spills. Our seabird observations also suggested that Gulf populations of several species (e.g., Black Tern, Cory's Shearwater) are concentrated in the vicinity of platforms, and consequently highly vulnerable to anthropogenic impacts. Understanding the mechanisms underlying the attraction of some species to platforms, and the lack of attraction or even repulsion in other species, is an important first step toward the formulation of seabird management and conservation plans, and could probably best be accomplished via a devoted platform observatory where, for example, experiments could be conducted with deployments of fish oil slicks to determine the area from which seabirds potentially attracted to platforms are drawn (e.g., Haney et al. 1992).

During this study we discovered an unexpected abundance of terrestrial insects offshore and expanded our focus to include insect monitoring using both visual censuses and quantitative sampling methods. In addition to the passively transported fauna of smaller insect species (the "aerial plankton"), we discovered that several species of dragonflies and moths are "intentional" trans-Gulf migrants. Trans-Gulf migration in insects has important implications for understanding large-scale biogeographic patterns as well as life-history strategies of the species involved. On many occasions we detected insects on floating debris. Rafting on floating debris and long-distance transport on the sea surface as pleuston may be significant modes of dispersal and long-distance colonization (Peck 1994b); however, the relative biogeographical significance of transport in pleuston versus direct aerial transport (Peck 1994a) remains poorly known. A more speculative but potentially important implication of the aerial plankton is the possibility that allochthonous input of carbon via mortality of drifting insects could be ecologically significant in food webs of the more depauperate waters of the Gulf (Chapter 13). A better understanding of the insect biodiversity over and on the Gulf thus has implications for a wide variety of environmental issues, including the foraging success of migrant birds on platforms, regional pest management strategies (since many of the common offshore species are known to be important agricultural pests on the Gulf coastal plain), the relative importance of different dispersal modes in insect biogeography, and perhaps even carbon fluxes in marine ecosystems of the Gulf. Monitoring of insect biodiversity over the Gulf could best be accomplished on devoted platform observatories, where non-attractant traps such as the Johnson-Taylor suction trap (Johnson and Taylor 1955; Taylor 1962) could be deployed permanently to collect long-term time series of true volumetric data on aerial insect densities.

Many other important applications can easily be envisioned for permanent offshore ecological observatories. A blood sampling program would permit blood chemistry studies to monitor levels of organochlorines and other pesticides and environmental pollutants that may be accumulated by migrants on wintering grounds and transported to the U.S. from other countries (Elliott and Shutt 1993; Mora 1997). Automated weather instrumentation could be housed for long-term meteorological studies. Full-time staff members could regularly monitor hydrographic structure and current dynamics with standard oceanographic sampling equipment, and the observatories could be used as bases for launching periodic plankton and fish sampling programs. As totally artificial large-scale environments, platforms-turned-observatories could be made available to academic researchers as habitat laboratories for experimental studies of bird foraging behavior (Chapter 15).

18.2.2 Management of the Platform Archipelago

This study suggests that, during the spring, the vast majority of trans-Gulf migrants are not influenced by platforms and simply pass high overhead en route to the northern Gulf Coast or points beyond. Those migrants that do drop out of the migration stream and interact with platforms probably realize a slightly positive net benefit from the existence of the platform archipelago. For these individuals, platforms provide a place to rest, replenish energy reserves, and find refuge from severe weather. Most of the mortality that occurs on platforms in the spring is the result of physiological damage that occurs prior to arrival on platforms, as a result of complete exhaustion of energy reserves and the onset of catabolism of essential tissues, and would result even in the absence of the platforms.

In light of this, there is little need for specific management recommendations with respect to spring trans-Gulf migration. Keeping platforms as clean as possible, and in particular, keeping decks and pans free from residual oil, is probably the most effective way that petroleum companies can maintain a safe environment for their spring migrant visitors, and cleanliness is presumably already fully addressed within existing environmental regulations.

Our findings suggest that the heaviest trans-Gulf migration in fall emanates from the stretch of the northern Gulf Coast running eastward from Alabama, and thus that the majority of fall migrants may travel over waters in which there are currently virtually no platforms. Historically, only a very limited amount of exploration and appraisal activity took place in the eastern Gulf, and most of the discoveries were noncommercial (Gohrbandt 2001). Subsequently, the waters of the MMS Eastern Planning area off Alabama and Florida were formally closed to exploration and production activities because of congressional actions and presidential moratoria in response to opposition by Florida. However, the verification in 1995 of 2.6 tcf of potentially recoverable natural gas reserves from a 1987 gas find in the Destin Dome area—together with breakthroughs in seismic data analysis and deepwater production technology—have rekindled interest in the eastern Gulf. With the new political climate that is emphasizing increased domestic oil and gas production, the status of the eastern Gulf as one of the nation's last petroleum frontiers is apparently overriding the historical objections by Florida, and Lease Sale 181 (Wetuski 2001) seems destined to be the start of a longer-term reopening of the eastern Gulf to the petroleum industry. The industrial development of the eastern Gulf will inevitably become an important component of the ecological context for fall trans-Gulf migration.

Nocturnal collisions of fall migrants were the most significant adverse impact of platforms documented in this study. Although the overall numbers of migrants killed were relatively small, the highest mortality occurred at Viosca Knoll 786, which is on the western boundary of the hypothesized principal fall migration corridor (and on the eastern boundary of the MMS Central Planning Area). The high fall mortality at Viosca Knoll 786 suggests that the development of the eastern Gulf will not be benign to migrating birds. Although subsea production systems are likely to figure prominently in the eastern Gulf, permanent structures above the surface of the water are inevitable, and they will certainly cause some mortality in low-altitude night-migrating landbirds during the fall migration season (July-November). In addition, the economics of deep-sea platform-based production dictate that the eastern Gulf will probably be populated by a relatively small number of major platforms that are geographically isolated. Since isolation is suspected to be implicated in the likelihood of nocturnal circulation events (Chapter 16), circulations and their attendant problems (collisions and probably exhaustion) will also be associated with development of the eastern Gulf.

We therefore suggest that the Minerals Management Service should consider implementing an ongoing platform monitoring program in the eastern Gulf of Mexico as that area is developed by the petroleum industry. The observer program operated by NOAA's National Marine Fisheries Service (NMFS) may serve as a useful model for developing such a platform monitoring program. Since 1972, NMFS has been deploying trained fishery observers to collect catch and bycatch data from commercial fishing vessels in a variety of different fisheries (National Marine Fisheries Service 1998, 2003). Nearly 20 different fisheries are monitored by observer programs annually along all U.S. coasts. The trained observers collect data for a range of conservation and management issues as well as to ensure regulatory compliance.

The impact of nocturnal circulation events (Chapter 16) on both spring and fall trans-Gulf migrants remains poorly known, and this phenomenon should be examined in a focused observational study using night-vision optics and thermal imaging equipment. The goals of such a study should be to quantify in greater detail the dimensions of the circulation phenomenon, to try to determine why some platforms often induce circulations and others never do, to assess the rate of turnover during major circulation events, and to model the energetic impact on migrants of participation in circulations with respect to synoptic weather, geography, and taxon.

If fall collision mortality in the eastern Gulf proves to be significant or if results from the study of circulations suggest that the adverse impacts of this phenomenon should be addressed, experiments should be undertaken to evaluate the role of different color schemes and lighting regimes in the attraction of migrants to platforms. In some cases, simple changes in light signatures have seemingly resulted in dramatic reductions in avian attraction and mortality at tall lighted structures on land during migration (e.g., Jones and Francis 2003). One interesting idea that was arrived at independently by several of the field observers was that the continuity of lighting around a platform may dictate whether circulations occur or not; specifically, it is suspected that lighting completely around a platform (i.e., with no dark areas) is necessary for circulations to develop and be maintained. If this is the case, then a simple system incorporating baffles or more directional lighting might completely eliminate circulations.

During this study we were surprised to find that very few people involved in the offshore petroleum industry are aware of the existence of trans-Gulf bird migrations. Virtually all platform workers attributed the presence of birds on platforms to navigational errors, storm events that blew the birds offshore, and a variety of other inventive explanations. Once informed, a number of platform workers became interested in learning more about the migrations and wanted to find out how they might be able to assist in our studies or to assist the migrant birds themselves. We suggest that production of a colorful informational brochure about trans-Gulf migration for distribution to offshore workers and other people involved in the industry would be a useful way to promote a wider awareness of the ecological importance of the Gulf, which in turn may be an incentive to platform workers to help maintain a safe environment for avian visitors to platforms.

18.2.3 International Outreach

The Bay of Campeche has a well-developed oil and gas exploration and production infrastructure. However, to our knowledge, no information is available concerning the possible influence of Mexican platforms on trans-Gulf migrants. Available evidence suggests that a large proportion of spring trans-Gulf migrants probably travels over the Bay of Campeche (Chapter 7). These migrants are aloft over Mexican platforms during hours of darkness near the beginning of their journey, so the circumstances are very similar to those encountered by fall trans-Gulf migrants initiating southbound flights across the eastern Gulf of Mexico. Thus, significant mortality events associated with circulations and/or direct collisions probably occur at least occasionally on Mexican platforms. Our understanding is that Mexican platforms routinely burn gas, and persistent haze resulting from the smoke would likely exacerbate any unfavorable nocturnal interactions. Efforts during this study to communicate with Pemex (the Mexican national petroleum company) to exchange information and perhaps launch an exploratory study on Mexican platforms were unsuccessful, but should be continued in the future.

The Cuban sector of the southeastern Gulf of Mexico also has significant hydrocarbon potential, and Cuba recently decided to offer deepwater acreage in the Cuban Exclusive Economic Zone to foreign companies for exploration and development on a production-sharing basis (Pérez and Blickwede 2000). This Cuban deepwater acreage extends to the maritime boundaries with Mexico and the U.S., and its development could affect both spring and fall bird migrations (e.g., Figures 7.10, 9.7). The northernmost of the 59 Cuban blocks available is just 100 km south of the acreage offered in OCS Lease Sale 181, suggesting that platforms could eventually stretch in a continuous band along the pathway traveled by many fall trans-Gulf migrants.

Trans-Gulf migrants are by definition international travelers, so conservation strategies targeting these species must consider the international implications of their migrations. Biologists interested in the ecology and conservation of trans-Gulf migrants should initiate outreach efforts to involve international colleagues in the development of a network for information exchange concerning events in all geographic sectors of the Gulf.

LITERATURE CITED

Able, K. P. 1970. A radar study of the altitude of nocturnal passerine migration. *Bird-Banding* 41:282-290.

Able, K. P. 1972. Fall migration in coastal Louisiana and the evolution of migration patterns in the Gulf region. *Wilson Bull.* 84:231-242.

Able, K. P. 1977. The orientation of passerine nocturnal migrants following offshore drift. *Auk* 94:320-330.

Able, K. P. and J. R. Belthoff. 1998. Rapid "evolution" of migratory behaviour in the introduced house finch of eastern North America. *Proc. R. Soc. Lond.* B 265:2063-2071.

Alerstam, T. 1978. A graphical illustration of pseudodrift. *Oikos* 30:273-308.

[AOU] American Ornithologists' Union. 1998. *Check-List of North American Birds.* 7th ed. American Ornithologists' Union, Washington, D.C.

Askins, R. A., J. F. Lynch, and R. Greenberg. 1990. Population declines in migratory birds in eastern North America. *Curr. Ornithol.* 7:1-57.

Avery, M. L., P. F. Springer, and N. S. Dailey. 1978. *Avian Mortality at Man Made Structures: An Annotated Bibliography*. United States Fish and Wildlife Service, Washington D.C. 108 pp.

Baird, J. and I. C. T. Nisbet. 1960. Northward fall migration on the Atlantic coast and its relation to offshore drift. *Auk* 77:119-149.

Ball, S. C. 1952. Fall bird migration on the Gaspe Peninsula. *Bull. Peabody Mus.* 7:1-211.

Barry, R. G. and A. H. Perry. 1973. *Synoptic Climatology: Methods and Applications*. Methuen, London. 555 pp.

Baust, J. G., A. H. Benton, and G. D. Aumann. 1981. The influence of off-shore platforms on insect dispersal and migration. *J. Econ. Entomol.* 27:23-25.

Beerwinkle, K. R., J. D. Lopez, Jr., P. G. Schleider, and P. D. Lingren. 1995. Annual patterns of aerial insect densities at altitudes from 500 to 2400 meters in east-central Texas indicated by continuously-operating vertically-oriented radar. *Southwest. Ent. Suppl.* 18:63-79.

Beerwinkle, K. R., J. D. Lopez, Jr., J. A. Witz, P. G. Schleider, R. S. Eyster, and P. D. Lingren. 1994. Seasonal radar and meteorological observations associated with nocturnal insect flight at altitudes to 900 meters. *Environ. Entomol.* 23:676-683.

Bell, G. P. 1990. Birds and mammals on an insect diet: a primer on diet composition analysis in relation to ecological energetics. *Stud. Avian Biol.* 13:416-422.

Berthold, P. 1990. Spatiotemporal programs and genetics of orientation. *Experientia* 46:363-371.

Berthold, P. 1991. Genetic control of migratory behaviour in birds. *Trends Ecol. Evol.* 6:254-257.

Berthold, P. and A. J. Helbig. 1992. The genetics of bird migration: stimulus, timing and direction. *Ibis* 134:35.

Biebach, H. and M. Klaassen. 1994. Is flight range limited by water or energy? *J. Orn.* 135:399.

Bjorges, R. R. 1987. Bird kill in northwest Alberta. *Can. Field-Nat.* 101.

Bourne, W. R. P. 1979. Birds and gas flares. *Mar. Poll. Bull.* 10:124-125.

Bowden, J. and C. G. Johnson. 1976. Migrating and other terrestrial insects at sea. Pp. 97-117 in: L. Cheng (ed.), *Marine Insects*. North-Holland Publishing Company, Amsterdam.

Brooks, A. 1922. Notes on crossing the Mexican Gulf from Key West to Galveston. *Auk* 39:119-120.

Bullis, H. R. Jr. 1954. Trans-Gulf migration, spring 1952. *Auk* 71:298-305.

Bullis, H. R. Jr. and F. C. Lincoln. 1952. A trans-Gulf migration. *Auk* 69:34-39.

Buskirk, W. H. 1968. The arrival of trans-Gulf migrants on the northern coast of Yucatán in fall. M.S. Thesis, Louisiana State Univ., Baton Rouge.

Cade, T. J., J. H. Enderson, C. G. Thelander, and C. M. White. 1988. Migration statistics as Peregrine population estimators? Pp. 141-143 in: T. J. Cade, J. H. Enderson, C. G. Thelander, and C. M. White (eds.), *Peregrine Falcon Populations: Their Management and Recovery*. The Peregrine Fund, Inc., Boise, Idaho.

Cade, T., H. Tordoff, and J. Barclay. 2000. Re-introduction of peregrines in the eastern United States: an evaluation. *Re-introduction News* 19:19-21.

Cairns, D. K. 1989. The regulation of seabird colony size: a hinterland model. *Am. Nat.* 134:141-146.

Caldwell, L. D., E. P. Odum, and S. G. Marshall. 1963. Comparison of fat levels in migrating birds killed at a central Michigan and a Florida Gulf Coast television tower. *Wilson Bull.* 75:428-434.

Carmi, N., B. Pinshow, W. P. Porter, and J. Jaeger. 1992. Water and energy limitations on flight duration in small migrating birds. *Auk* 109:268-276.

Carpenter, F. L., M. A. Hixon, R. W. Russell, D. C. Paton, and E. J. Temeles. 1993a. Interference asymmetries among age-sex classes of rufous hummingbirds during migratory stopovers. *Behav. Ecol. Sociobiol.* 33:297-304.

Carpenter, F. L., M. A. Hixon, E. J. Temeles, R. W. Russell, and D. C. Paton. 1993b. Exploitative compensation by subordinate age-sex classes of migrant rufous hummingbirds. *Behav. Ecol. Sociobiol.* 33:305-312.

Charnov, E. L., G. H. Orians, and K. Hyatt. 1976. Ecological implications of resource depression. *Am. Nat.* 110:247-259.

Chen, C.-C. 1996. Foraging behavior and habitat selection of insectivorous migratory songbirds at Gulf Coast stopover sites in spring. Ph.D. Dissertation, Louisiana State Univ., Baton Rouge. 150 pp.

Cheng, L. and M. C. Birch. 1977. Terrestrial insects at sea. *J. Mar. Biol. Assoc. U.K.* 57:995-997.

Cheng, L. and M. C. Birch. 1978. Insect flotsam: an unstudied marine resource. *Ecol. Entomol.* 3:87-97.

Childs, J. 1998. Avian diversity and habitat use within the Flower Garden Banks National Marine Sanctuary. *Gulf of Mexico Sci.* 16:208-225.

Cochran, W. W. 1985. Ocean migration of Peregrine Falcons: is the adult male pelagic? Pp. 223-237 in: M. Harwood (ed.), *Proceedings of Hawk Migration Conference IV*. Hawk Migration Association of North America, Rochester, New York.

Cooke, W. W. 1905. Routes of bird migration. *Auk* 22:1-11.

Crawford, R. L. 1981. Bird casualties at a Leon County, Florida TV tower: a 25-year migration study. *Bull. Tall Timbers Res. Sta*. 22:1-30.

Davies, W. B. 1940. Gas flares and birds. *Condor* 42:127.

Dickison, R. B. B., M. J. Haggis, R. C. Rainey, and L. M. D. Burns. 1986. Spruce budworm moth flight and storms, further studies using aircraft and radar. *J. Appl. Met.* 25:1600-1608.

Dierschke, V. 1989. Automatisch-akustiche Erfassung des nächtlichen Vogelzuges bei Helgoland im Sommer 1987. *Die Vogelwarte* 35:115-131.

Dokken, Q. 1993. Flower Gardens Ocean Research Project: using offshore platforms as research stations. *Marine Tech. Soc. J.* 27(2):45-50.

Dorka, V. 1966. Das jahres- und tageszeitliche Zugmuster von Kurz- und Langstreckenziehern nach Beobachtungen auf den Alpenpässen Cou/Bretolet (Wallis). *Ornithol. Beob.* 63:165-223.

Dunn, E. H. 1993. Bird mortality from striking residential windows in winter. *J. Field Ornithol.* 64:302-309.

Dunn, J. L. and K. L. Garrett. 1997. *A Field Guide to Warblers of North America*. Houghton Mifflin, Boston. 656 pp.

Elkins, N. 1988. *Weather and Bird Behavior*. Second ed. T. & A.D. Poyser, Calton, Staffordshire, England. 239 pp.

Elliott, J. E. and L. Shutt. 1993. Monitoring organochlorines in blood of sharp-shinned hawks (*Accipiter striatus*) migrating through the Great Lakes. *Environ. Toxicol. Chem.* 12:241.

Enderson, J. H., W. Heinrich, L. Kiff, and C. M. White. 1995. Population changes in North American peregrines. Trans. N. Amer. Wildl. Nat. Res. Conf. 60:142-161.

Evans, P. R. 1966. Migration and orientation of passerine night migrants in northeast England. *J. Zool.* 150:319-369.

Evans, W. R. 1994. Nocturnal flight call of Bicknell's Thrush. *Wilson Bull.* 106:55-61.

Evans, W. R. and D. K. Mellinger. 1999. Monitoring grassland birds in nocturnal migration. Stud. Avian Biol. 19:219-229.

Evans, W. R. and M. O'Brien. 2002. *Flight Calls of Migratory Birds: Eastern North American Landbirds*. Old Bird, Inc., Ithaca, NY. [multimedia CD-ROM]

Evans, W. R. and K. V. Rosenberg. 2000. Acoustic monitoring of night-migrating birds: a progress report. Pp. 151-159 in: R. Bonney, D. N. Pashley, R. J. Cooper, and L. Niles (eds.), Strategies for Bird Conservation: The Partners in Flight Planning Process; Proceedings of the 3rd Partners in Flight Workshop; 1995 October 1-5; Cape May, NJ. Proceedings RMRS-P-16. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Faaborg, J. 2002. *Saving Migrant Birds: Developing Strategies for the Future*. Univ. of Texas Press, Austin. 244 pp.

Farnsworth, A. 2001. The density of nocturnal bird migration: a comparison between Doppler radar and acoustic measures. M.S. Thesis, Clemson Univ., Clemson, SC.

Fisher, R. A. 1930. *The Genetical Theory of Natural Selection*. Oxford Univ. Press, Oxford.

Fyfe, R. W., S. A. Temple, and T. J. Cade. 1976. The 1975 North American Peregrine Falcon survey. *Can. Field-Nat.* 90:228-273.

Gass, C. L. and K. P. Lertzman. 1980. Capricious mountain weather: a driving variable in hummingbird territorial dynamics. *Can. J. Zool.* 58:1964-1968.

Gauthreaux, S. A. Jr. 1970. Weather radar quantification of bird migration. *BioScience* 20:17-20.

Gauthreaux, S. A. Jr. 1971. A radar and direct visual study of passerine spring migration in southern Louisiana. *Auk* 88:343-365.

Gauthreaux, S. A. Jr. 1972. Behavioral responses of migrating birds to daylight and darkness: a radar and direct visual study. *Wilson Bull.* 84:136-148.

Gauthreaux, S. A. Jr. 1992. The use of weather radar to monitor long-term patterns of trans-Gulf migration in spring. Pp. 96-100 in: J. M. Hagan, III and D. W. Johnston (eds.), *Ecology and Conservation of Neotropical Migrant Landbirds*. Smithsonian Institution Press, Washington, D.C.

Gohrbandt, K. H. 2001. West Florida shelf and slope: prime target for gas, oil in eastern Gulf of Mexico. *Oil & Gas J.* 99(24):41-48.

Graber, J. W. and R. R. Graber. 1983. Feeding rates of warblers in spring. *Condor* 85:139-150.

Graber, R. R. 1968. Nocturnal migration in Illinois -- different points of view. *Wilson Bull.* 80:36-71.

Graber, R. R. and W. W. Cochran. 1959. An audio technique for the study of the nocturnal migration of birds. *Wilson Bull.* 71:220-236.

Graber, R. R. and W. W. Cochran. 1960. Evaluation of an aural record of nocturnal migration. *Wilson Bull.* 72:252-273.

Haila, Y., J. Tiainen, and K. Vepsäläinen. 1986. Delayed autumn migration as an adaptive strategy of birds in northern Europe: evidence from Finland. *Ornis Fennica* 63:1-9.

Hamilton, W. J., III. 1962. Evidence concerning the function of nocturnal call notes of migratory birds. *Condor* 64:390-401.

Haney, J. C., K. M. Fristrup, and D. S. Lee 1992. Geometry of visual recruitment by seabirds to ephemeral foraging flocks. *Ornis Scand.* 23:49-62.

Hartstack, A. W., Jr., J. D. Lopez, R. A. Muller, W. L. Sterling, E. G. King, J. A. Witz, and A. C. Eversull. 1982. Evidence of long range migration of *Heliothis zea* (Boddie) into Texas and Arkansas. *Southwest. Ent.* 7:188-201.

Hartstack, A. W., J. D. Lopez, R. A. Muller, and J. A. Witz. 1986. Early season occurrence of *Heliothis* spp. in 1982: evidence of long-range migration of *Heliothis zea*. Pp. 48-60 in: A. N. Sparks (ed.), Long-Range Migration of Moths of Agronomic Importance to the United States and Canada: Specific Examples of Occurrence and Synoptic Weather Patterns Conducive to Migration. USDA-ARS-43.

Hebert, E. and E. Reese. 1995. *Avian Collision and Electrocution: An Annotated Bibliography.* <http://www.energy.ca.gov/reports/avian_bibliography.html>

Hebrard, J. J. 1971. The nightly initiation of passerine migration in spring: a direct visual study. *Ibis* 113:8-18.

Helms, C. W. and W. H. Drury, Jr. 1960. Winter and migratory weight and fat field studies on some North American buntings. *Bird-Banding* 31:1-40.

Hendrix, W. H. III, T. F. Mueller, J. R. Phillips, and O. K. Davis. 1987. Pollen as an indicator of long-distance movement of *Heliothis zea* (Lepidoptera: Noctuidae). *Environ. Entomol.* 16:1148-1151.

Herbert, A. D. 1970. Spatial disorientation in birds. *Wilson Bull.* 82:400-419.

Heydemann, B. 1967. Der Uberflug von Insekten uber Nord- und Ostsee nach Untersuchungen auf Feuerschiffen. *Deutsche Entomologische Zeitschrift*:185-215.

Hill, N. P. and J. M. Hagan, III. 1991. Population trends of some northeastern North American landbirds: a half-century of data. *Wilson Bull.* 103:165-182.

Holmes, R. and S. Robinson. 1981. Tree species preferences of foraging insectivorous birds in a northern hardwood forest. *Oecologia* 48:31-35.

Howden, H. F. 1977. Beetles, beach drift, and island biogeography. *Biotropica* 9:53-57.

Howell, S. N. G. and S. Webb. 1995. *A Guide to the Birds of Mexico and Northern Central America*. Oxford Univ. Press, Oxford. 851 pp.

Hutto, R. 1985. Seasonal changes in the habitat distribution of transient insectivorous birds in southeastern Arizona: competition mediated? *Auk* 102:120-132.

Johnson, C. G. and L. R. Taylor. 1955. The development of large suction traps for airborne insects. *Ann. Appl. Biol.* 43:51-62.

Johnston, D. W. 1968. Body characteristics of Palm Warblers following an overwater flight. *Auk* 85:13-18.

Johnston, D. W. 1970. Caloric density of avian adipose tissue. *Comp. Biochem. Physiol.* 34:827-832.

Jones, J. and C. M. Francis. 2003. The effects of light characteristics on avian mortality at lighthouses. *J. Avian Biol.* 34:328.

Keaster, A. J., J. A. Grundler, and M. A. Jackson. 1996. Noctuid moths and other insects captured in wing-style traps baited with black cutworm (Lepidoptera: Noctuidae) pheromone on offshore oil platforms in the Gulf of Mexico, 1988-1991. *J. Kansas Ent. Soc.* 69:17.

Kendeigh, S. C. 1979. *Invertebrate Populations of the Deciduous Forest: Fluctuations and Relations to Weather*. Illinois Biological Monographs 50. Univ. of Illinois Press, Urbana.

Kersten, M., and T. Piersma. 1987. High levels of energy expenditure in shorebirds; metabolic adaptations to an energetically expensive way of life. *Ardea* 75:175-187.

Kiff, L. F. 1988. Changes in the status of the Peregrine in North America: an overview. Pp. 123-139 in: T. J. Cade, J. H. Enderson, C. G. Thelander, and C. M. White (eds.), *Peregrine Falcon Populations: Their Management and Recovery*. The Peregrine Fund, Inc., Boise, ID.

Kirkwood, J. K. 1983. A limit to metabolisable energy intake in mammals and birds. *Comp. Biochem. Physiol.* 75A:1-3.

Kirkwood, J. K. 1985. Food requirements for deposition of energy reserves in raptors. Pp. 295- 298 in: I. Newton and R. D. Chancellor (eds.), *Conservation Studies on Raptors*. International Council for Bird Preservation Technical Publication No. 5. International Council for Bird Preservation, Cambridge, MA.

Klem, D. Jr. 1989. Bird-window collisions. *Wilson Bull.* 101:606-620.

Klem, D. Jr. 1990. Collisions between birds and windows: mortality and prevention. *J. Field Ornithol.* 61:120-128.

Komdeur, J., S. Daan, J. Tinbergen, and C. Mateman. 1997. Extreme adaptive modification in sex ratio of the Seychelles Warbler's eggs. *Nature* 385:522-525.

Konrad, T. G., J. J. Hicks, and E. B. Dobson. 1968. Radar characteristics of birds in flight. *Science* 159:274-280.

Larkin, R. P., W. R. Evans, and R. H. Diehl. 2002. Nocturnal flight calls of Dickcissels and Doppler radar echoes over south Texas in spring. *J. Field Ornithol.* 73:2-8.

Libby, O. G. 1899. The nocturnal flight of migrating birds. *Auk* 16:140-146.

Lindström, Å. 1989. Finch flock size and risk of hawk predation at a migratory stopover site. *Auk* 106:225.

Lindström, Å. 1990. The role of predation risk in stopover habitat selection in migrating bramblings, *Fringilla montifringilla*. *Behav. Ecol.* 1:102-106.

Lindström, Å. 1991. Maximum fat deposition rates in migrating birds. *Ornis Scand.* 22:12-19.

Lingren, P. D., V. M. Bryant, Jr., J. R. Raulston, M. Pendleton, J. Westbrook, and G. D. Jones. 1993. Adult feeding host range and migratory activities of corn earworm, cabbage looper, and celery looper (Lepidoptera: Noctuidae) moths as evidenced by attached pollen. J. Econ. Entomol. 86:1429-1439.

Lingren, P. D., J. K. Westbrook, and V. M. Bryant, Jr. 1994. Origin of corn earworm (Lepidoptera: Noctuidae) migrants as determined by citrus pollen markers and synoptic weather systems. *Environ. Entomol.* 23:562-570.

Lowery, G. H. Jr. 1945. Trans-Gulf spring migration of birds and the coastal hiatus. *Wilson Bull*. 57:92-121.

Lowery, G. H. 1946. Evidence of trans-Gulf migration. *Auk* 63:175-211.

Lowery, G. H. 1951. A quantitative study of the nocturnal migration of birds. *Univ. Kansas Publ. Mus. Nat. Hist.* 3:361-472.

Lowery, G. H., Jr. and R. J. Newman. 1963. Studying bird migration with a telescope. Spec. Publ. Mus. Zool., Louisiana State University, Baton Rouge, LA.

Lowery, G. H., Jr. and R. J. Newman. 1966. A continent wide view of bird migration on four nights in October. *Auk* 83:547-586.

Lynch, J. F., E. S. Morton, and M. E. Van der Voort. 1985. Habitat segregation between the sexes of wintering Hooded Warblers (*Wilsonia citrina*). *Auk* 102:714-721.

Marra, P. P. 2000. The role of behavioral dominance in structuring patterns of habitat occupancy in a migrant bird during the nonbreeding season. *Behav. Ecol.* 11:299-308.

Marra. P. P. and R. T. Holmes. 2001. Consequences of dominance-mediated habitat segregation in American Redstarts during the nonbreeding season. *Auk* 118:92-104.

Martin, T. E. 1980. Diversity and abundance of spring migratory birds using habitat islands on the Great Plains. *Condor* 82:430-439.

Martin, T. E. 1985. Selection of second-growth woodlands by frugivorous migrating birds in Panama: an effect of fruit size and plant density? *J. Trop. Ecol.* 1:157-170.

McClintock, C. P., T. C. Williams, and J. M. Teal. 1978. Autumnal bird migration observed from ships in the western north Atlantic Ocean. *Bird-Banding* 49:262.

Metcalfe, N. B. and R. W. Furness. 1984. Changing priorities: the effect of pre-migratory fattening on the trade-off between foraging and vigilance. *Behav. Ecol. Sociobiol.* 15:203-206.

Minerals Management Service. 2004. Gulf of Mexico Region products/free data: Platform information and data available in ASCII files for downloading. <http://www.gomr.mms.gov/homepg/pubinfo/freeasci/platform/freeplat.html>. Revised 1 July 2004.

Møller A. P. 2001. Heritability of arrival date in a migratory bird. *Proc. Biol. Sci.* 268:203-206.

Moore, F. R., P. Kerlinger, and T. R. Simons. 1990. Stopover on a Gulf Coast barrier island by spring trans-Gulf migrants. *Wilson Bull.* 102:487-500.

Moore, F. R. and T. R. Simons. 1992. Habitat suitability and stopover ecology of Neotropical landbird migrants. Pp. 345-355 in: J. M. Hagan, III and D. W. Johnston (eds.), *Ecology and Conservation of Neotropical Migrant Landbirds*. Smithsonian Institution Press, Washington, DC.

Moore, F. R. and W. Yong. 1991. Evidence of food-based competition among passerine migrants during stopover. *Behav. Ecol. Sociobiol.* 28:85-90.

Mora, M. A. 1997. Transboundary pollution: persistent organochlorine pesticides in migrant birds of the southwestern United States and Mexico. *Environ. Toxicol. Chem.* 16:3-11.

Morton, E. S. 1990. Habitat segregation by sex in the hooded warbler: experiments on proximate causation and discussion of its evolution. *Am. Nat.* 135:319-333.

Morton, E. S., J. F. Lynch, K. Young, and P. Mehlhop. 1987. Do male hooded warblers exclude females from nonbreeding territories in tropical forest? *Auk* 104:133-135

Muller, R. A. 1977. A synoptic climatology for environmental baseline analysis: New Orleans. *J. Appl. Meteorol.* 16:20-33.

Muller, R. A. 1979. Synoptic weather types along the central Gulf Coast: variability and predictability. Pp. 133-144 in: R. L. Rabb and G. G. Kennedy (eds.), *Movement of Highly Mobile Insects: Concepts and Methodology in Research*. North Carolina State Univ. Graphics, Raleigh.

Muller, R. A. and C. L. Wax. 1977. A comparative synoptic climatic baseline for coastal Louisiana. *Geoscience and Man* 18:121-129.

Murray, B. G., Jr. 1976. The return to the mainland of some nocturnal passerine migrants over the sea. *Bird-Banding* 47:345-358.

National Marine Fisheries Service. 1998. *Managing the Nation's Bycatch: Priorities, Programs and Actions for the National Marine Fisheries Service*. National Marine Fisheries Service. 192 pp.

National Marine Fisheries Service. 2003. *Evaluating Bycatch: A National Approach to Standardized Bycatch Monitoring Programs*. NOAA, NMFS, Silver Springs, MD. 88 pp.

Nice, M., and C. Nice. 1950. The appetite of a Black and White Warbler. *Wilson Bull.* 62:94-95.

Niles, D. M., S. A. Rohwer, J. A. Jackson, and J. D. Robins. 1969. An observation of midwinter nocturnal movement and tower mortality of Tree Sparrows. *Bird-Banding* 40:322-323.

Nisbet, I. C. T. 1959. Calculation of flight directions of birds observed crossing the moon. *Wilson Bull.* 71:237-243.

Nisbet, I. C. T. and W. H. Drury, Jr. 1967. Orientation of spring migrants studied by radar. *Bird-Banding* 38:173-186.

Ogden, L. J. E. 1996. *Collision Course: The Hazards of Lighted Structures and Windows to Migrating Birds*. World Wildlife Fund Canada and the Fatal Light Awareness Program. 46 pp.

Oliver, A. D. and J. B. Chapin. 1981. Biology and illustrated key for the identification of twenty species of economically important noctuid pests. Louisiana Agricultural Experiment Station, Bulletin No. 733.

Ortego, B. 1977. Birding on an oil production platform. *LOS News* 78:8-9.

Packard, F. M. 1947. Notes on the occurrence of birds in the Gulf of Mexico. *Auk* 64:130-131.

Pair, S. D., J. R. Raulston, D. R. Rummel, J. K. Westbrook, W. W. Wolf, A. N. Sparks, and M. F. Schuster. 1987. Development and production of corn earworm and fall armyworm in the Texas high plains: evidence for reverse fall migration. *Southwest. Ent.* 12:89-99.

Pair, S. D., J. R. Raulston, J. K. Westbrook, W. W. Wolf, and S. D. Adams. 1991. Fall armyworm (Lepidoptera: Noctuidae) outbreak originating in the lower Rio Grande Valley, 1989. *Fla. Ent.* 74:200-213.

Parrish, J. D. and T. W. Sherry. 1994. Sexual habitat segregation by American Redstarts wintering in Jamaica: The importance of resource seasonality. *Auk* 111:38-49.

Paynter, R. A., Jr. 1951. Autumnal trans-Gulf migrants and a new record for the Yucatan Peninsula. *Auk* 68:113-114.

Paynter, R. A., Jr. 1953. Autumnal migrants on the Campeche Bank. *Auk* 70:338-349.

Peck, S. B. 1994a. Aerial dispersal of insects between and to islands in the Gálapagos Archipelago, Ecuador. *Ann. Entomol. Soc. Amer.* 87:218-224.

Peck, S. B. 1994b. Sea-surface (pleuston) transport of insects between islands in the Galápagos Archipelago, Ecuador. *Ann. Entomol. Soc. Amer.* 87:576-582.

Pennycuick, C. J. 1989. *Bird Flight Performance: A Practical Calculation Manual*. Oxford Univ. Press, Oxford, England.

Pérez, G. H. and J. F. Blickwede. 2000. Cuba deepwater exploration opportunities described in southeastern Gulf of Mexico. *Oil & Gas J.* 98(50):42-48.

Peterjohn, B. G., J. R. Sauer, and C. S. Robbins. 1995. Population trends from the North American breeding bird survey. Pp. 3-39 in: T. E. Martin and D. M. Finch (eds.), *Ecology and Management of Neotropical Migratory Birds*. Oxford Univ. Press, New York.

Pfister, C., M. Kasprzyk, and B. Harrington. 1998. Body-fat levels and annual return in migrating Semipalmated Sandpipers. *Auk* 115:904-915.

Pulich, W. M. and T. B. Dellinger. 1980. Bird casualties and sightings on an offshore oil rig in the Gulf of Mexico. *Bull. Tex. Ornithol. Soc.* 13:7-10.

Pulido F., P. Berthold, G. Mohr, and U. Querner. 2001. Heritability of the timing of autumn migration in a natural bird population. *Proc. Biol. Sci.* 268:953-959.

Ralph, C. J. 1981. Age ratios and their possible use in determining autumn routes of passerine migrants. *Wilson Bull*. 93:164-188.

Rappole, J. H., D. W. Warner, and M. A. Ramos. 1977. Territoriality and population structure in a small passerine community. *Am. Midl. Nat.* 97:110-119.

Richardson, W. J. 1978. Reorientation of nocturnal landbird migrants over the Atlantic Ocean near Nova Scotia in autumn. *Auk* 95:717-732.

Rising, J. D. 1996. *A Guide to the Identification and Natural History of the Sparrows of the United States and Canada*. Academic Press, San Diego, CA. 365 pp.

Robbins, C. S., J. R. Sauer, R. S. Greenberg, and S. Droege. 1989. Population declines in North American birds that migrate to the neotropics. *Proc. Natl. Acad. Sci. USA* 86:7658-7662.

Robinson, S. K. and R. T. Holmes. 1982. Foraging behavior of forest birds: the relationships among search tactics, diet, and habitat structure. *Ecology* 63:1918-1931.

Robinson, S. K. and R. T. Holmes. 1984. Effects of plant species and foliage structure on the foraging behavior of forest birds. *Auk* 101:672-684.

Ruck, G. T., D. E. Barrick, W. D. Stuart, and C. K. Krichbaum. 1970. *Radar Cross Section Handbook*. Plenum Press, New York. 949 pp.

Russell, R. W., F. L. Carpenter, M. A. Hixon, and D. C. Paton. 1994. The impact of variation in stopover habitat quality on migrant Rufous Hummingbirds. *Conserv. Biol.* 8:483-490.

Russell, R. W., M. L. May, K. L. Soltesz, and J. W. Fitzpatrick. 1998. Massive swarm migrations of dragonflies in eastern North America. *Am. Midl. Nat.* 140:325-342.

Russell, R. W. and J. W. Wilson. 1997. Radar-observed "fine lines" in the optically clear boundary layer: reflectivity contributions from aerial plankton and its predators. *Boundary-Layer Meteorol.* 82:235-262.

Sage, B. L. 1979. Flare-up over North Sea birds. *New Scientist* 81(15 Feb):464-466.

Sage, R. D. 1982. Wet and dry-weight estimates of insects and spiders based on length. *Am. Midl. Nat.* 108:407-411.

Sample, B. E., R. J. Cooper, R. D. Greer, and R. C. Whitmore. 1993. Estimation of insect biomass by length and width. *Am. Midl. Nat.* 129:234-240.

Sandberg, R. and F. R. Moore. 1996. Migratory orientation of red-eyed vireos, *Vireo olivaceus*, in relation to energetic condition and ecological context. *Behav. Ecol. Sociobiol.* 39:1-10.

Sibley, D. A. 2000. *The Sibley Guide to Birds*. Alfred A. Knopf, New York. 544 pp.

Siebenaler, J. B. 1954. Notes on autumnal trans-Gulf migration of birds. *Condor* 56:43-48.

Skolnik, M. I. 1962. *Introduction to Radar Systems*. McGraw-Hill, New York. 648 pp.

Sparks, A. N., R. D. Jackson, J. E. Carpenter, and R. A. Muller. 1986. Insects captured in light traps in the Gulf of Mexico. *Ann. Entomol. Soc. Amer.* 79:132-139.

Stone, W. 1937. *Bird Studies at Old Cape May*. Delaware Valley Ornithological Club, Philadelphia, PA.

Stutchbury, B. J. 1994. Competition for winter territories in a Neotropical migrant: the role of age, sex and color. *Auk* 111:63-69.

Taylor, L. R. 1962. The absolute efficiency of insect suction traps. *Ann. Appl. Biol.* 50:405-421.

Telfair, R. C., II. 1983. *The Cattle Egret: A Texas Focus and World View*. Kleberg Studies in Natural Resources. Texas Agricultural Experiment Station, Texas A&M Univ., College Station. 144 pp.

Terborgh, J. 1989. *Where Have All the Birds Gone?* Princeton Univ. Press, Princeton, NJ.

Terrill, S. B. 1990a. Ecophysiological aspects of movements by migrants in the wintering quarters. Pp. 130-143 in: E. Gwinner (ed.), *Bird Migration*. Springer-Verlag, Berlin.

Terrill, S. B. 1990b. Food availability, migratory behavior, and population dynamics of terrestrial birds during the nonreproductive season. *Stud. Avian Biol.* 13:438-443.

Terrill, S. B. and R. L. Crawford. 1988. Additional evidence of nocturnal migration by Yellow- rumped Warblers in winter. *Condor* 90:261-263.

Terrill, S. B. and R. D. Ohmart. 1984. Facultative extension of fall migration by Yellow-rumped Warblers (*Dendroica coronata*). *Auk* 101:427-438.

Thake, M. A. 1981. Calling by nocturnal migrants: a device for improving orientation? *Die Volgelwarte* 31:111.

Trapp, J. L. 1998. *Bird Kills at Towers and Other Human-Made Structures: An Annotated Partial Bibliography (1960-1998)*. <http://migratorybirds.fws.gov/issues/tower.html>

Trivers, R. L. and D. E. Willard. 1973. Natural selection of parental ability to vary the sex ratio of offspring. *Science* 179:90-92.

U.S. Fish and Wildlife Service. 1999. Final rule to remove the American Peregrine Falcon from the Federal List of Endangered and Threatened Wildlife, and to remove the similarity of appearance provision for free-flying Peregrines in the conterminous United States. *Fed. Reg.* 64:46541-46558.

Walter, H. 1979. *Eleonora's Falcon: Adaptations to Prey and Habitat in a Social Raptor*. Univ. of Chicago Press, Chicago, IL 410 pp.

Weir, R. D. 1976. *Annotated Bibliography of Bird Kills at Man-Made Obstacles: A Review of the State of the Art and Solutions*. Canadian Wildlife Service, Ontario Region, Ottawa, Canada. 85 pp.

Westbrook, J. K., R. S. Eyster, W. W. Wolf, P. D. Lingren, and J. R. Raulston. 1995a. Migration pathways of corn earworm (Lepidoptera: Noctuidae) indicated by tetroon trajectories *Agric. Forest Meteorol.* 73:67-87.

Westbrook, J. K., J. R. Raulston, W. W. Wolf, S. D. Pair, R. S. Eyster, and P. D. Lingren. 1995b. Field observations and simulations of atmospheric transport of noctuids from northeastern Mexico and the South-Central U.S. *Southwest. Ent. Suppl.* 18:25-44.

Westbrook, J. K., W. W. Wolf, P. D. Lingren, J. R. Raulston, J. D. Lopez, Jr., J. H. Matis, R. S. Eyster, J. F. Esquivel and P. G. Schleider. 1997. Early-season migratory flights of corn earworm (Lepidoptera: Noctuidae). *Environ. Entomol.* 26:12-20.

Westerdahl, H., S. Bensch, B. Hansson, D. Hasselquist, and T. von Schantz. 2000. Brood sex ratios, female harem status and resources for nestling provisioning in the Great Reed Warbler (*Acrocephalus arundinaceus*). *Behav. Ecol. Sociobiol.* 47:312-318.

Wetuski, J. 2001. All eyes look east. *Oil and Gas Investor* 21(4):61-63.

Wheelwright, N. T. and R. E. Seabury. 2003. Fifty:fifty offspring sex ratios in Savannah Sparrows (*Passerculus sandwichensis*). *Auk* 120:171-179.

Wilczak, J. M., R. G. Strauch, F. M. Ralph, B. L. Weber, D. A. Merritt, J. R. Jordan, D. E. Wolfe, L. K. Lewis, D. B. Wuertz, J. E. Gaynor, S. A. McLaughlin, R. R. Rogers, A. C. Riddle, and T. S. Dye. 1995. Contamination of wind profiler data by migrating Birds — characteristics of corrupted data and potential solutions. *J. Atmos. Oceanic Tech.* 12:449-467.

Williams, G. G. 1945. Do birds cross the Gulf of Mexico in spring? *Auk* 62:98-110.

Williams, G. G. 1947. Lowery on trans-gulf migration. *Auk* 64:217-228.

Williams, G. G. 1952. Birds on the Gulf of Mexico. *Auk* 69:428-432.

Wilson, J. W., T. M. Weckwerth, J. Vivekanandan, R. M. Wakimoto, and R. W. Russell. 1994. Boundary layer clear-air radar echoes: origin of echoes and accuracy of derived winds. *J. Atmos. Oceanic Tech.* 11:1184-1206.

Wolf, W. W., A. N. Sparks, S. D. Pair, J. K. Westbrook, and F. M. Truesdale. 1986. Radar observations and collections of insects in the Gulf of Mexico. Pp. 221-234 in: W. Danthanarayana (ed.), *Insect Flight: Dispersal and Migration*. Springer-Verlag, Berlin, Germany.

Woodrey, M. S. and C. R. Chandler. 1997. Age-related timing of migration: geographic and interspecific patterns. *Wilson Bull.* 109:52-67.

Wunderle, J. M., Jr. 1992. Sexual habitat segregation in wintering Black-throated Blue Warblers in Puerto Rico. Pp. 299-307 in: J. M. Hagan, III and D. W. Johnston (eds.), *Ecology and Conservation of Neotropical Migrant Landbirds*. Smithsonian Inst. Press, Washington, DC.

Yapp, W. B. 1956. Two physiological considerations in bird migration. *Wilson Bull.* 68:312-319.

Yarnal, B. 1993. *Synoptic Climatology in Environmental Analysis*. Bellhaven Press, London, England

Yocke, M. A., C. A. Emery, P. Roberts, C. MacDonald, D. Ladner, J. Prouty, and A. Barnett. 2000. *Meteorology of the Northeastern Gulf of Mexico: Data from 1995 to 1997, Final Report*. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2000-075. 88 pp.

Zaitsev, Y. P. 1970. *Marine Neustonology*. Academy of Sciences of the Ukrainian SSR. Translated from Russian by Israel Program for Scientific Translations, Israel.

Zehnder, S. and L. Karlsson. 2001. Do ringing numbers reflect true migratory activity of nocturnal migrants? *J. Orn.* 142:173-183.

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.

MMS Securing Ocean Energy & Economic Value for America