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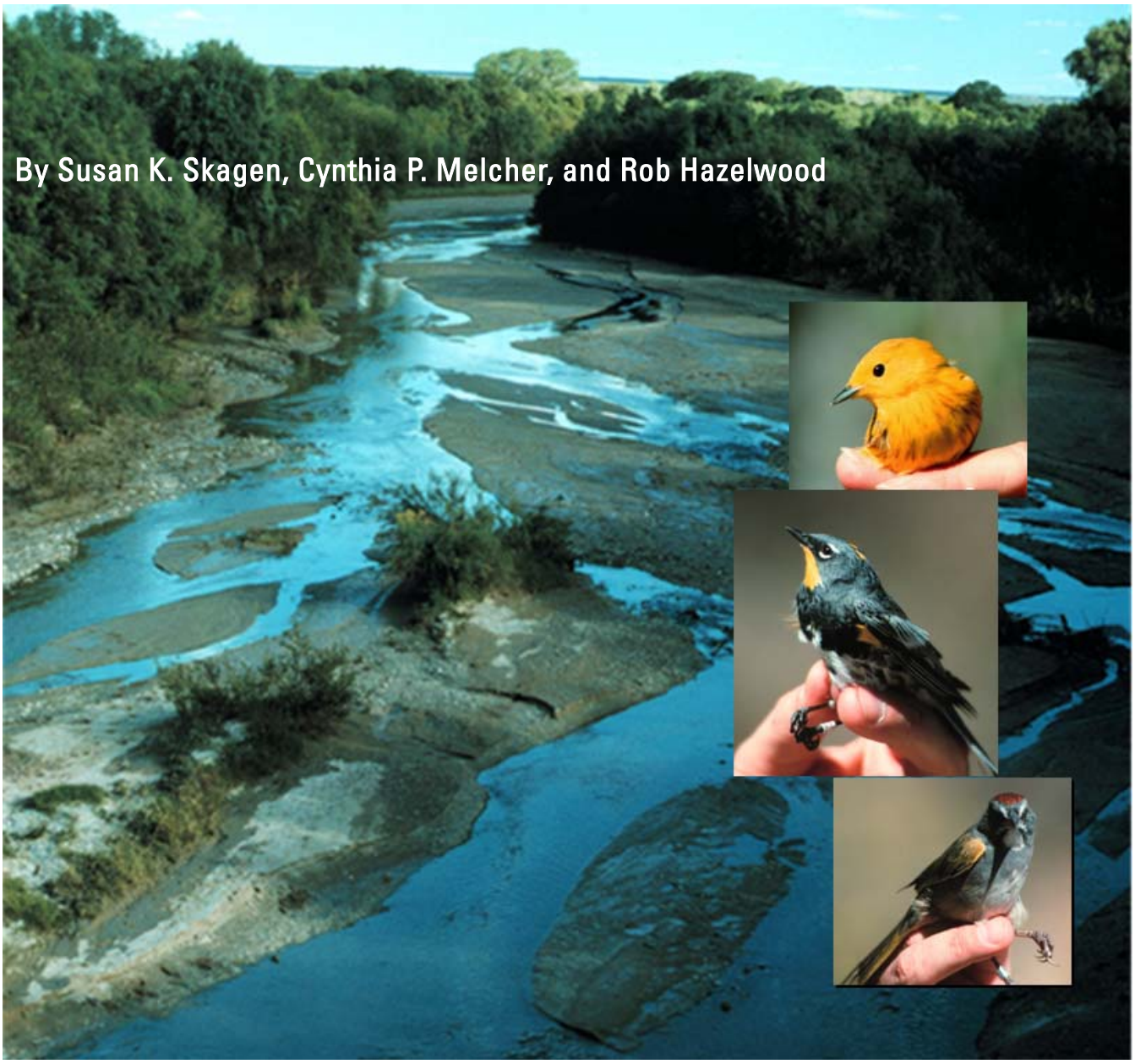
Migration Stopover Ecology of Western Avian Populations: A Southwestern Migration Workshop



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U.S. Department of the Interior
U.S. Geological Survey

Migration Stopover Ecology of Western Avian Populations: A Southwestern Migration Workshop

By Susan K. Skagen, Cynthia P. Melcher, and Rob Hazelwood

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We are extremely grateful for the participation and enthusiasm of workshop attendees. Their work and sharing of ideas are the foundation of this proceedings document.

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Workshop Agenda

Migration Stopover Ecology of Western Avian Populations: Southwestern Migration Workshop, Tucson, Arizona, 20-22 January 2004

Welcome and Introduction – Susan K. Skagen, U.S. Geological Survey

Setting the Stage – the Montana-Mexico Bird Connection

Rob Hazlewood, FWS – Collaborative research: the Montana-Mexico connection

Richard L. Hutto, Univ. Montana - The western bird migration system: opportunity for a collaborative research effort?

Michael L. Scott, USGS – The fluvial geomorphic context of riparian bird habitats

Current Work on Migration across Arid Southwestern Riparian Systems

Susan K. Skagen, USGS – Introduction; the importance of migration stopover sites

David J. Krueper, FWS – Migration studies on the San Pedro River

Eduardo Gómez-Limón – Migration studies on the Santa Cruz River, Sonora, Mexico

Jay D. Carlisle, USD and Idaho Bird Observatory - Migration studies in upland and montane habitats

Deborah Finch, USFS – Migration studies on the Rio Grande River

Charles van Riper, III, and Laura McGrath, USGS - Migration studies on the Colorado River

Susan K. Skagen and Cynthia Melcher, USGS – Migration stopover ecology of western avian populations: patterns of geographic and habitat

Open Discussion

Comparison of Eastern and Western Migration Systems

Wylie C. Barrow, Jr., USGS – Perspective on eastern migration studies

Jeffrey F. Kelly, University of Oklahoma – Towards an east-west comparison

Partnership Perspectives

David J. Krueper, FWS – Update on Region 2 Migratory Bird Office activities

Robert Mesta, FWS – Update on Sonora Joint Venture efforts

Jon Bart, USGS – Coordinated Bird Monitoring

John Alexander, Klamath Bird Observatory – Towards a migration monitoring network in the West

Partner Roundtable – All participants

Techniques and Technology for Migration Research

Introduction

Chris Guglielmo, Univ. Montana - Body condition and rates of lipid deposition

Tom Smith, UCLA Center for Tropical Research – Genetics and connectivity between breeding/wintering areas

Jeffrey F. Kelly, University of Oklahoma – Stable isotope analyses of feathers

Michael Wunder, Colorado State University – Analytical options for combining multiple sources of information

Peter Pyle, Institute for Bird Populations - Bird banding as an information source

Robb Diehl, University of Southern Mississippi – Applications of radar imagery

Linking Bird and Bat Studies

Merlin Tuttle, Bat Conservation International - Linking bird and bat studies

Paul Cryan, USGS, Migration movements of North American tree bats

Future Opportunities and Directions in Migration Research – Open Discussion

Refining the goals of the discussions

Executive Summary

The importance of migration stopover sites in ensuring that migratory birds successfully accomplish their journeys between breeding and non-breeding ranges has come to the forefront of avian research. Migratory birds that breed in western United States (US) and Canada and overwinter primarily in western Mexico migrate across the arid region of northern Mexico and southwestern US. Many of these migrants use lowland riparian stopover habitats, which comprise less than 0.1% of the western U.S. landscape. These habitats represent a significant conservation priority.

Recognizing the importance of migration stopover habitats in the arid southwest, the U.S. Fish and Wildlife Service (USFWS) Region 6 partnered with the U.S. Geological Survey (USGS) to support a project---"Migration stopover ecology of western avian populations: patterns of geographic and habitat distribution." A primary objective of the project was to convene a workshop for avian researchers, conservation professionals, and land managers involved in stopover needs of migratory birds that breed in western North America. The workshop included presentations on our current state of knowledge regarding passerine migration in western North America, techniques and technologies potentially useful in researching migration, and efforts that agencies and other partners are conducting within the realm of migration. Workshop presentations provided a backdrop for subsequent discussions, the goals of which were to identify research needs and initiate a coordinated approach to research of western migration stopover ecology.

Workshop presentations spanned a wide range of concerns and interests. Highlights included indications that mid- and high-elevation riparian and montane shrubland habitats may be as crucial to western migrants in fall migration as lowland riparian habitats are in spring migration. Comparisons of eastern versus western migration systems elucidated large differences in stopover habitats used and the intensity with which certain types are used, underscoring the potential need to develop separate management approaches for eastern and western stopover sites. Presentations on techniques and technology for migration research revealed that rate of lipid deposition can serve as an indicator of habitat quality; that genetics and stable isotope analyses of feathers can be valuable tools to elucidate linkages between breeding and wintering areas; that radar imagery can be used to track large-scale movement patterns and habitat use; and that there are analytical options for combining multiple sources of information. Other presentations focused on partnership perspectives (USFWS and Sonoran Joint Venture), the genesis of a western migration monitoring network, premises of Coordinated Bird Monitoring, and how collaborative efforts could benefit migration research (e.g., combined bird and bat migration studies; linking avian researchers with fluvial geomorphologists; linking research throughout western North America; linking surveys and banding).

Priority research needs and questions identified during the open discussions fell into three main categories: (1) habitat/landscape/climate relationships, (2) en route bird distribution patterns, and (3) general migration ecology. Tasks within these categories included: define the relative importance of various habitat types to migrants in spring and fall, determine what distinguishes high- from poor-quality stopover habitat; determine geographic patterns of loss in stopover habitats; model landscape attributes associated with species richness and abundance; identify effects of climate change and current climate anomalies on plant phonologies, associated insect flushes, and timing of migration; and determine effects of hydrologic changes on riparian vegetation, food availability, and stopover habitat quality.

Workshop participants discussed a coordinated approach for addressing immediate research needs regarding migration patterns and crucial stopover sites and types. They envisioned a three-

tiered, coordinated approach: (1) long-term research to address effects of climate change and other large-scale patterns, (2) intensive, short-term survey and monitoring efforts using a stratified random design within habitats of interest to elucidate regional patterns of distribution and habitat use, and (3) research conducted at existing survey and banding sites to address more in-depth questions (e.g., rates of lipid deposition, microhabitat use, isotope analyses). There was considerable interest in developing common research proposals to blend the broad expertise represented at this workshop. A second meeting is recommended to build on the momentum of these discussions, to facilitate collaborations, and further the goals of integrated approaches to broadscale research on migration stopover ecology.

Cordilleran Flycatcher

Introduction

The vital importance of migration stopover sites to en route land birds has recently come to the forefront of avian research and conservation in western North America (Hutto 1998, 2000; Skagen and others, 1998; Yong and others, 1998; Kelly and others, 1999; Finch and Yong, 2000). Long-distance migration requires exceptional energy reserves, and migratory birds must rest and replenish fat reserves while traveling between wintering and breeding areas. The identification of high-priority stopover sites and migration habitats critical to the long-term persistence of migrating species has been cited as absent but necessary before comprehensive strategies for species protection can be developed (Petit, 2000). Effective conservation of neotropical migrant landbirds must incorporate information on migration as well as breeding and wintering resource needs.

Many long-distance migrants that breed west of the Continental Divide in the United States and Canada overwinter in Mexico west of the Sierra Madre Occidental (Hutto, 1980, 1992). During spring migration, as these birds traverse northward along the western edge of the Sierra Madre Occidental, they may funnel across a relatively narrow swath of land that comprises the arid region of southwestern U.S. and northern Mexico. Many of these species are believed to require riparian stopover habitats, which may be disproportionately important due to their very limited area within that region. Although riparian vegetation covers less than 0.1% of the western U.S. landscape, riparian habitats are among the richest, yet most-threatened, habitats in that region. Despite decades of attention of management agencies to this important habitat, riparian forests continue to be degraded and lost as migratory bird habitats.

The U.S. Fish and Wildlife Service (USFWS) Region 6, recognizing the importance of stopover habitats in the arid southwest to northern breeding birds, supported this project, entitled "Migration stopover ecology of western avian populations: patterns of geographic and habitat distribution," in partnership with the U.S. Geological Survey. This project represents an initial step in linking the breeding, migration, and wintering habitats of western avian species, emphasizing the interdependence of geographic and political regions in providing crucial resources for birds throughout their annual cycles. Although this project focuses on stopover ecology specific to southwestern North America, we fully recognize that the entire western United States provides a myriad of stopover sites for birds migrating to and from more northern states and Canada.

One objective of the project was to convene a workshop for avian researchers, conservation professionals, and land managers involved in migration stopover needs of birds that traverse the southwestern U.S. and northern Mexico. The workshop, held in Tucson, Arizona, 22-24 January 2004, convened 40 scientists and resource professionals. The agenda included presentations on current knowledge of migration in the southwest, techniques and innovative technologies that hold promise for use in future research on this topic, identification of research needs for conserving en route migratory land birds, and initiation of a coordinated approach to future research efforts.

Another objective of the migration stopover ecology project was a meta-analysis to evaluate the migration attributes of selected species relative to species biogeography, and to test the working hypothesis that most neotropical migrants breeding in the western U.S. migrate primarily through riparian habitats within a narrow corridor in Arizona and northwestern Mexico while en route to breeding areas west of the Continental Divide. To that end, Skagen and others synthesized existing bird survey and banding datasets collected during migration at sites in southwestern U.S. and northern Mexico. The preliminary results of these analyses were presented and discussed at the workshop and are summarized briefly herein; the final results appear in Skagen and others (2005). See list of data contributors on page 26.

Workshop Objectives

Specific objectives and charges of the workshop were to:

1. Review the current state of knowledge regarding avian migration patterns across the southwest (including northern Mexico).
2. Discuss the synthesis of survey and banding data to elucidate the abundance, distribution, and habitat use of land birds en route through the arid Southwest to their breeding/wintering grounds.
3. Review current and developing technologies potentially useful for testing hypotheses regarding migration and stopover ecology.
4. Identify the most pressing research issues for effective conservation of passerine migrations.
5. Work towards developing an integrated, coordinated field effort to identify the most-important stopover locations and habitats used by en route migratory land birds that breed in the West.

This paper is a final product of the workshop. Its purpose is to summarize the crucial points made by workshop presenters, outline the directions that participants felt we should take in future research, and identify potential collaborative approaches for that research.

Workshop Presentations

This section outlines the key workshop presentations and provides a brief summary of information, methods, and conclusions provided by presenters.

Session 1: Setting the Stage---The Montana-Mexico Connection

Collaborative Research: The Montana-Mexico Connection (Rob Hazlewood)

Loss and degradation of riparian habitat continues to occur from Montana to Mexico. We have long recognized the importance of riparian habitats to birds, but overall have not been effective at protecting these areas. In Montana, 90% of birds use riparian areas; 45% are riparian obligates, a number of which are declining, sensitive, or federally listed species. We need long-term monitoring to determine the current status of riparian habitats and landbirds that use them, and we need a range-wide and site specific management plans to conserve riparian habitats. This will require protection and restoration of landscapes and river processes in migration stopover habitats as well as in breeding and wintering habitats. Re-licensing of dams on the Madison and Missouri rivers in Montana under the Federal Energy Regulatory Commission and in cooperation with PPL Montana a private power company, has yielded significant cost share funding for avian research and a Conservation Reserve Easement Program designed to protect, enhance and restore riparian habitats along these rivers. This avian research entails the first landscape-scale, long-term project initiated to evaluate the distribution, physiological condition, and nesting success of North American landbirds that breed in the West (see M. Scott, below). The project includes identifying landscapes and habitats important to these migrants in southwestern U.S. and Mexico, and relating winter distribution/physiological condition to vegetation in Sonora. The Montana-Mexico partnership facilitates communication and a regional approach to bird conservation, and may serve as a model for future international endeavors.

The Western Bird Migration System: Opportunity for a Collaborative Research Effort? (Richard L. Hutto)

As illustrated by the wood warblers, the geographic centers of the distributions of neotropical migratory landbird species form two distinct clusters in summer and winter. The clusters occur west and east of the Continental Divide during both the breeding and nonbreeding seasons. Western and eastern migrants remain largely separate during spring and fall migration as well, with the eastern system involving primarily over-water movement between breeding and nonbreeding sites, and the western system involving movement over land. The superimposition of distribution maps of western and eastern warblers also reveals that, in eastern North America, the geographic ranges of warblers overlap more with one another during the breeding than during the nonbreeding season; the opposite is true for the western warbler species. Not only do the western warbler species show greater geographic overlap in winter than summer, but subspecifically distinct populations appear to be well mixed everywhere, most species use a remarkable diversity of habitats in winter, and they tend to occur with other species in huge mixed-species flocks (especially in the highlands, where an average flock includes 18.6 species). Thus, the western migratory system is unique worldwide in a number of respects.

During migration, the western landbird species are unique not only because they migrate primarily over land, but also because they may take different routes north and south, they may stop to molt in the fall, and they may use very different habitats during northward migration than during southward migration. In the Chiricahua Mountains of southeastern Arizona, for example, most bird species migrate through the lowlands in spring and through the highlands in fall. Riparian habitats appear to be especially important during spring migration. Thus, it appears that a relatively large proportion of western migratory landbird species move through a relatively narrow funnel of land that occurs west of the Continental Divide and east of the Gulf of California, and that (at least in spring) the land area used for refueling during migration is even further restricted because of their predominant use of riparian habitat. A collaborative research effort spread across the Southwest would be the fastest way to uncover whether these suggested en route patterns are real. If so, the management implications would be profound because successful refueling during migration may depend on effective management of relatively little land area.

The Fluvial Geomorphic Context of Riparian Bird Habitats (Michael L. Scott)

Riparian corridors dominated by cottonwood and willow species span a large latitudinal gradient from west-central Canada to northwestern Mexico. Water, nutrient-rich soils, and a variety of successional vegetation patches make these habitats more productive and biologically diverse than surrounding uplands---particularly in arid regions. Bird distributions indicate that riparian woodlands provide important nesting habitat for western migratory landbirds, and may provide important migration stopover and winter habitat as well. Avian densities and species richness are greater in lowland riparian forests than in other habitats in western Mexico during winter (Hutto, 1992). However, the relationship between bird use and riparian forest structure, composition and functional status has not been established. Moreover, economic development and concomitant increases in human populations along the US-Mexico border in the last decade have intensified demands on scarce resources like water (Revah, 2000), and pose real threats to the ecological integrity of riparian forests in the form of stream dewatering (damming and diversion, ground water pumping), grazing, and floodplain conversion to agriculture. Such activities result in profound changes in, or loss of, riparian ecosystems and riparian-dependent species. Riparian forests in Mexico are infrequently visited by biologists and poorly monitored for their ecological significance and functional integrity (Nabhan and Holdsworth, 1999). Conservation of migratory bird species

depends upon a clear understanding of their specific habitat requirements and the physical and biotic processes that create and maintain those habitats (Askins, 2000).

We have initiated a study to assess the structural and functional condition of riparian forests and characterize important cottonwood/willow riparian woodlands throughout Sonora. Site evaluations include mapping habitat features relevant to birds and other wildlife, and assessing habitat quality/quantity. Using high-resolution, 1-m panchromatic satellite imagery, we are digitizing riparian vegetation-patch types along 1-km reaches of river. (Studies involving bird surveys also use this imagery, making the integration of bird diversity and abundance with specific structural features of vegetation relatively easy.) Preliminary results from two sites suggest that measures of area of bottomland cleared for agriculture, and patch area of native riparian trees by size class, give a relatively good measure of the quality and quantity of riparian habitat across sites. We are also developing rapid-assessment techniques to identify important riparian habitat on a landscape scale. Techniques include: using metrics such as presence of stream-flow; evidence of channel incision; tree mortality; the proportion of exotics and upland species; grazing intensity (as assessed by stubble height and hedging of woody vegetation); and the structural and functional integrity of vegetation (assessed using measurements of species richness, structural diversity, and size-class distribution of native riparian species).

Session II: Current Work on Migration Across Arid Southwestern Riparian Systems

Migration Studies on the San Pedro River (David J. Krueper)

Riparian systems of the Southwest region comprise heterogeneity of habitats and elevational gradients. Migration patterns of landbirds that use these habitats are difficult to characterize due to simultaneous occurrences of pass-through migrants and local breeders, migration occurring nearly year-round, migration patterns that range from a broad front and "sky-island hopping" to the use of lowland riparian corridors/oases and higher-altitude systems, post-breeding and irruptive movements, and seasonal and annual variations. From 1986-1995, we conducted avian surveys, banding, and MAPS stations to evaluate species-use patterns in cienega, desert-scrub, mesquite-grassland, and cottonwood-willow riparian habitats along and near the San Pedro River in southeastern Arizona.

During spring migration, birds concentrated in riparian oases and corridors; in fall migration, however, birds dispersed widely over the landscape. Timing of migration and bird densities differed between species and years, but timing of spring migration may be the most critical. Migration was more protracted in fall than spring. In spring, vireos and warblers peaked in early May. Wilson's Warblers peaked in early May, and, in fall, they moved through from late August through September. In fall, Yellow-rumped Warblers began moving through in August and September and peaked in the second week of October. Overall, migrants were more numerous than residents, with insectivores being the dominant guild. In mesquite, bird abundances were greater in fall than in spring.

Migration Studies on the Santa Cruz River, Sonora, Mexico (Eduardo Gómez-Limón)

Along the Santa Cruz River in northern Sonora, Mexico, surface and groundwater mining, grazing, vegetation clearing, sand and gravel mining, trash, and drought are degrading riparian habitats, particularly near towns/cities. To monitor bird trends in these habitats, we initiated bird surveys along the Santa Cruz in 2000-01, and continued them in 2003. Our objectives were to develop an initial bird-species list (breeding and pass-through migrants) and conduct public outreach. With the help of young students (public education component), each year we ran eight surveys along 60 km of river at 51 5-min points in cottonwood-will riparian woodland, farmland,

grassland, mesquite, and oak hills habitats. We detected 189 species, including 16 flycatchers and 12 warblers. There were 24 riparian obligates (including Belted Kingfisher, Gray Hawk, and Yellow-billed Cuckoo), 10 of which are in immediate need conservation action (e.g., Abert's Towhee; Partners in Flight, 2004). Monitoring work and public outreach involving youth should continue. We are working with the Mexican government to designate the river as an important bird area.

Considering the Potential Importance of Western Montane Habitats During Autumn Landbird Migration (Jay D. Carlisle)

The topographic and climatic gradients of western ecosystems make for a unique laboratory in which to investigate stopover ecology. In particular, the late summer heat and aridity across much of the Intermountain West and Great Basin may have important ramifications shaping migration and molt strategies of western migrants. To date, most investigations of migration in the West have focused on riparian systems, which are clearly critical to migrants and deserving of conservation measures. However, the extent to which autumn migrants utilize non-riparian habitats has received little attention, and if we limit our focus to lowland riparian areas we may miss other important migration stopover habitats. Data from a number of western states suggest that montane habitats might serve an important role for many landbird migrants during the late summer molt period and autumn migration, a time period when many lowland areas of the west, including some riparian systems, are extremely arid (Austin, 1970; Greenberg and others, 1974; Blake, 1984; Hutto, 1985).

From 1997–2002 mist-netting and count surveys were used to characterize avian communities during fall migration in montane habitats (1525-1830 m) in the Boise Foothills near Boise, Idaho (Carlisle and others, 2004). Habitats consisted of coniferous forest, willow-dominated riparian draws, montane deciduous shrubland, and shrub-steppe; two or more of these habitats often occurred in a mosaic pattern. We counted more than 80 species and captured more than 85 species (75-155 new captures/100 mnh), at least 50 of which are regular migrants. The most common species captured were Ruby-crowned Kinglet, Oregon (Dark-eyed) Junco, White-crowned Sparrow, MacGillivray's Warbler, Dusky Flycatcher, Yellow-rumped Warbler, Orange-crowned Warbler, Spotted Towhee, Nashville Warbler, Warbling Vireo, Chipping Sparrow, Yellow Warbler, and Western Tanager. While there was some inter-annual variation, migrants were most abundant in the two deciduous habitats whereas a few species occurred at their highest abundances in coniferous forest and shrub-steppe (Carlisle and others, 2004). Additional (unpublished) data from Idaho suggest that mosaics of montane habitats may provide a wide array of food resources (including diverse arthropods and the fruits of montane deciduous shrubs) important to fall migrants. Thus, including non-riparian and montane habitats in future stopover ecology studies will likely allow for a more complete understanding of migrant habitat needs in the west.

Molt-migration, in which migrants interrupt migration to molt during extended stopovers, is a phenomenon that is also likely shaped by the summer aridity of the west. Recent studies have established that a high proportion of western landbird migrants postpone their prebasic flight feather molt until after the onset of autumn migration (e.g., Rohwer and others, in press). Many of these species are known to exhibit an early autumn migration (often departing breeding grounds by July) to the Mexican Monsoon region of northern Mexico and the southwestern US, taking advantage of the productivity flush associated with the summer monsoons in this region for molting. We know almost nothing about the habitat associations of molt-migrants during this time period; however, inter-annual variability in rainfall patterns as well as rainfall clines associated with the 'sky islands' in this region suggest that an ability to track resources may be required for

molt-migrants as they select molting and stopover areas. Investigation of this molt-migration phenomenon and associated conservation needs should be a high priority.

Migration Studies on the Colorado River: Neotropical Migrant Birds (Charles van Riper, III)

In just one century, riparian habitat along the lower Colorado River has declined from ~170,000 ha [primarily cottonwood (*Populus fremontii*), willow (*Salix gooddingii*), honey mesquite (*Prosopis pubescens*), and native shrubs] to 40,000 ha. Of the present remaining riparian habitat, 40% is pure tamarisk (*Tamarix ramosissima*), 43% is a mix of native vegetation and tamarisk, 16% is honey mesquite and native shrub, and < 1% is mature pure cottonwood and willow. No pure stands of cottonwood and willow >20 ha remain. It's unclear how loss of native riparian habitat along the lower Colorado River has affected migratory birds, but because foraging constraints at stopover sites may be most severe during migration, food availability may be the most important factor in habitat requirements and selection among birds migrating along the Colorado River corridor.

To elucidate migration patterns of neotropical warblers along the lower Colorado River corridor in northern Mexico, Arizona, and southern Utah, we conducted bird surveys and mist-netting; sampled invertebrates and vegetation; studied plant phenology; and, documented avian foraging behaviors during 1999-2003. We found that many fewer migrating birds utilize the Colorado River corridor during the southward fall migration, when compared to the spring migration period. In spring, relative warbler abundance tracked the flowering of honey mesquite, which attracted significantly more invertebrates than non-flowering mesquite or non-native plants. Migrating warblers partitioned themselves in terms of arrival/departure dates, and species whose breeding ranges extend farthest north exhibited more-protracted migration periods. Neotropical warblers also partitioned themselves in terms of foraging locations (heights), and foraging locations in honey mesquite differed from those in tamarisk.

We also evaluated effects of habitat-management practices along the Colorado River corridor by comparing native (cottonwood-willow) versus non-native (tamarisk) types in terms of foraging use by migratory warblers. More migrating birds utilized native habitat for foraging during the stopover period. We did, however, observe a threshold in tamarisk dominated habitat where overall bird abundance increased dramatically with a >20% native tree species component (details below).

Migration Studies on the Colorado River: Migrating Warblers Use Flowering Trees as Cues to Locate Insect Resources within Lower Colorado River Stopover Habitat (Laura McGrath and Charles van Riper, III)

Shifting tree phenology during spring migration presents avian insectivores with an assortment of visual cues and foraging opportunities. Flowering trees represent microhabitats where migrants can find concentrated food resources (arthropods). We examined dominant riparian tree species' phenological patterns (leafing and flowering phases) in concert with insect abundance and richness to test whether leaf-gleaning insectivorous birds choose foraging locales based on the flowering condition of those trees. Arthropod abundance and species richness were greater on honey mesquite (*Prosopis glandulosa*) than on any other tree species, and migrant birds foraged more intensely, stayed longer, and visited more frequently those mesquite trees with high degrees of flowering. Over half of bird diets were comprised of arthropods associated with mesquite flowering. Finally, the arrivals and abundances of leaf-gleaning, insectivorous migrants correlated with the peak bloom of honey mesquite, not with cottonwood (*Populous fremontii*), screwbean mesquite (*Prosopis pubescens*), Goodding's willow (*Salix goodingii*), or tamarisk (*Tamarix* sp).

Our results demonstrate that flowering condition is one cue that migrant avian insectivores utilize on the Colorado River to find abundant arthropod prey while in transit during spring migration.

Migration Stopover Ecology of Western Avian Populations: Patterns of Geographic and Habitat Distribution (Susan K. Skagen and Cynthia P. Melcher)

Migration stopover resources, particularly riparian habitats, are of critical importance to landbirds migrating across the arid southwestern U.S. and northern Sonora, Mexico. To explore the effects of species biogeography and habitat affinity on migration patterns, we synthesized existing survey and banding datasets collected during spring migration in the borderlands region of the U.S. and Mexico. We used a model selection procedure to determine the importance of geographic factors in explaining variation in abundances of 35 long-distance and short-distance migrants. Longitudinal and latitudinal trends were fairly consistent between survey and banding data. Abundances and capture rates of 13 and 11 species from survey and banding data, respectively, increased with increasing longitude, and abundances of four species in both datasets decreased with increasing longitude. Abundance patterns of riparian associates were only weakly influenced by biogeography; riparian birds were more abundant in western sites than species not as closely tied to riparian habitats. In contrast, biogeography does appear to influence abundance patterns of non-riparian birds, suggesting that they choose the shortest, most direct route between wintering and breeding areas. We hypothesize that riparian obligate birds may, to some degree, adjust their migration routes to maximize time spent in high quality riparian zones, but that when they encounter more hostile landscapes, they are able to find suitable habitat opportunistically. In contrast, generalists would be expected to adhere more closely to a hierarchical model in which the migratory route is determined by biogeographic constraints and habitat selection en route is secondary to direct migration.

Session III: Comparison of Eastern and Western Migration Systems

Perspective on Eastern Migration Studies: Stopover Ecology of Migratory Landbirds in the Gulf Coast Region (Wylie C. Barrow, Jr. and Lori Johnson Randall)

Millions of Nearctic-Neotropical landbirds move through the coastal habitats of the Gulf of Mexico each spring and autumn as they migrate across and around the gulf. Migration routes in the gulf region are not static and they shift year to year and season to season according to prevailing wind patterns. Using data from field and radar studies, we mapped patterns of migration movement and landfall in the Gulf of Mexico region. Map categories include coastal areas where migrant numbers are consistently high, consistently common, sporadically common-abundant, sporadically common, or sparse. Weather surveillance radar data indicates that habitats along the Northwest Gulf coast are consistently used each year.

Patterns of landfall relative to the shoreline vary according to weather, but overall the majority of spring migrants fly past the shoreline to stopover at sites within 100 km of the coast. Flight direction on a given day influences location of land fall; therefore migrant landbirds do not tend to use the same stopover sites year after year. Of the 7690 long-distance migrants banded during two spring field seasons in the Chenier Plain of Louisiana and Texas, seven breeding migrants and zero transient migrants were recaptured in a subsequent year. Due to prevailing southerly winds, the majority of migration movement in autumn is around the western gulf coast.

Transect data collected during spring 1993-1995 in southwest Louisiana and southeast Texas indicate that migration begins in late February, peaks in late April, and drops off by mid May. Transect data collected from the same sites in autumn 1997-1998 indicates that migration is relatively steady from early August through late October, with a slight increase in movement in

mid-September and mid-October. Fewer individuals moved through the region in autumn than in spring, indicating that birds crossing or circumnavigating the Gulf depart from locations farther north.

To ensure successful passage, migrants require access to suitable habitat along the migration route. Enough habitat patches have to be present to allow the successful completion of migration for each species. The "programmed" routes may change to accommodate current landscapes, but suitable habitat must be available along the alternate routes.

Some of the factors that influence stopover habitat use at regional- and landscape-scales include habitat patchiness and habitat type. An adequate data base of the location, status, and inter-patch distance of small habitat patches does not exist. Knowledge of inter-patch distance is important because, besides predominant direction of flight, distance influences the likelihood that migrating birds encounter habitat. Mapping the dispersion and type of wooded patches within each region should be one goal of conservation planners. The predominant flight direction should be considered as well. Patch sizes need be larger where expected use is greatest; this is why knowledge of patterns in migration movement and landfall are needed. Studies on the Mississippi coast indicate that enroute migrants in spring prefer bottomland hardwoods over nearby pine forests; migrant abundance is often high in coastal scrub-shrub habitat types.

High densities of migrants at particular sites do not necessarily mean that the habitats at these locations are particularly good. It may only mean that these were the only habitats available. Stopover areas should be carefully examined at the landscape scale. In many cases, the landscape may concentrate the birds and suitability is a separate issue.

Within-habitat features influence the suitability of a stopover site. Studies along the northern Gulf coast indicate that migrants prefer structurally-complex habitat (e.g., understory thickets, vine tangles, canopy gaps) that provides a variety of foraging substrates and food resources. On the northern gulf coast, insectivorous migrants have demonstrated dietary plasticity by foraging on flowers and fruit in spring and by foraging on fruit in autumn. In more complex habitats, resource patches should be scattered and diverse so as to accommodate a variety of species. In many cases, it may not be necessary to manage for a particular situation; managing for complexity should be enough. The loss of complexity and heterogeneity where exotics predominate may be one of the main problems with their introduction.

Towards an East-West Comparison (Jeffrey F. Kelly)

Literature reviews coupled with our own work indicate that migration ecology of wood warblers differs from east to west. More species breed in eastern U.S. and northern Canada (primarily east of the Rocky Mountains) than in western U.S. and Canada (primarily west of the Rocky Mountains and U.S. Southwest), although the number of genera represented from region to region is less disparate. Evolutionary analyses reveal that western migrants share an evolutionary history that differs from that of eastern species. To a large extent, this may reflect the relative homogeneity and continuity of eastern landscapes versus the fragmented landscapes of the west: different taxa evolving in different landscapes with different constraints likely produced different migration strategies.

On the surface, some migration ecology patterns may appear similar from east to west, but a closer look can reveal significant differences. For example, greater migrant densities are correlated with lower fat gains (most likely due to suppression of insect populations by high densities of insectivores) in eastern and western locations. However, the modal fat score of eastern migrants is 3 or 4, whereas that of migrants along the Rio Grande is 1 or 2. This disparity may reflect differences in distances traveled between stopovers and/or lengths of stay, but it needs further investigation. Along the Gulf coast, age ratios are skewed towards hatch-year birds, but along the

Rio Grande we found <50% hatch-year birds. Frugivory among wood warblers is common in the east, but virtually non-existent in the west, and habitat use appears to vary seasonally in the west more than in the east. For many patterns observed in the east there are no comparable data yet available for western migrants.

Session IV: Partnership Perspectives

Coordinated Bird Monitoring: Fitting the Pieces Together (Jon Bart and Carol Beardmore)

Coordinated Bird Monitoring (CBM) is an effort to help people conserve birds and their habitats by improving bird-monitoring programs. CBM makes free opportunities and advice available rather telling people what they should do. Current oversight for CBM is provided by the U.S. North American Bird Conservation Initiative Committee (NABCI).

Two important CBM Goals are 1) to prepare a North American CBM Plan that includes all species, aspects, spatial scales, and involvement from all major stake-holders, and 2) to develop data repositories. The plan will include recommendations on continental and regional monitoring programs, methods, accuracies, habitat, data management, and reporting; publication is expected some time in 2004. CBM is also developing advice for preparers of bird monitoring plans at the regional and state levels---particularly in conjunction with the states' comprehensive wildlife conservation plans.

Current progress and tasks include long-term programs for estimating population sizes and trends at large spatial scales, and short-term assessments to identify the causes of declines, identify high-quality habitats, estimate population sizes. CBM is also seeking ways of incorporating habitat information with survey data through a hierarchical system of rapid habitat-assessment methods and a coarse, continent-wide, habitat-based stratification system. Detailed guidelines have been developed for designated sites, and are available on the CBM web site: <http://amap.wr.usgs.gov>.

Towards a Migration Monitoring Network in the United States (John D. Alexander and C. John Ralph)

In conjunction with the U.S. Forest Service's Redwood Sciences Laboratory (RSL) and many partners throughout North America, the Klamath Bird Observatory (KBO) is helping to coordinate the development of a North American Migration Monitoring Network, following the model put forward by Carlisle and Ralph (in press) and Bart and Ralph (in press). Multiple methods at multiple scales can significantly increase our overall knowledge of bird migration patterns, demography, trends, and habitat use during spring and fall migration seasons. KBO and RSL have developed a depth of experience with migration monitoring and the coordination of monitoring networks; in 2004 our efforts in this field were recognized through a "Leadership Award" from Partners In Flight, and the Taking Wing Award from the U.S. Forest Service and Ducks Unlimited. Through our collaborative effort and diverse partnerships we have established the Klamath Demographic Monitoring Network (Alexander and others, 2004) and the Tortuguero Costa Rica Integrated Bird Monitoring Program (Ralph and others, in press).

In 1994, an international joint council, including five members from both the United States and Canada, discussed and planned the development of a North American Migration Monitoring Program. This resulted in a series of proposals and two protocols: Recommended methods for monitoring bird populations by counting and capture of migrants (Hussell and Ralph, 1996) and Recommended Methods for Regional Checklist Programs (Dunn, 1995a). As a result, the Canadian Migration Network, made up of 18 monitoring stations across the continent, was established (Dunn 1995b).

In the United States, we have developed a list of potential cooperators who conduct monitoring efforts during the migration seasons and have developed a web-based product to track them (http://www.fs.fed.us/psw/topics/wildlife/birdmon/pif/mnstalst.shtml). We plan to work with this group to realize a continent-wide network of bird migration monitoring stations. We have formed a working group to expedite the formation of such a network. Participants include bird observatories (Klamath, Idaho, Point Reyes), universities (Wisconsin, South Dakota, Cornell), and natural resource agencies (U.S. Forest Service, U.S. Geological Survey, Bureau of Land Management). Possible objectives for this network include: monitoring population trends and studying stopover ecology, population demography, habitat relationships during migration, and population life history (e.g., movements, timing). An underlying principal of the network is to include data collected using multiple monitoring methods. Our long- and short-term goals include: working as a subgroup of the Partners In Flight Monitoring Working Group; keeping a current list of partners; building a migration-related bibliography; developing plans for meeting the objectives; identifying geographic focal areas and sources for support; establishing data-handling policies; and creating an outreach plan. With support from the Bureau of Land Management, KBO and RSL have filled a position that entails furthering the formation of the North American Migration Monitoring Network.

Session V: Techniques and Technology for Migration Research

Assessing Rates of Fuel Deposition and Stopover Habitat Quality for Migratory Birds (Christopher Guglielmo)

Plasma metabolite profiles can reveal information about avian fat deposition in a given habitat. In particular, circulating levels of lipid metabolites (triglycerides, glycerol, and B-OH-butyrate) can be used to predict a bird's metabolic state (feeding, fasting). Increases in triglycerides indicate increases in mass, whereas increases in glycerol or B-OH-butyrate generally reflect decreases in mass. We have been applying this technique to study landscape-level variation in stopover quality. Among Western Sandpipers, my collaborators and I have shown consistent, inter-site differences in plasma triglyceride levels (refueling performance) and have found that they are positively correlated with the availabilities of benthic invertebrates during spring migration. We have also validated the technique in the field by measuring metabolite levels in six passerine species with a variety of dietary habits at known high- and low-quality stopover sites at Long Point, Ontario, Canada. Principal components analysis has proven useful by combining metabolite levels into composite profile scores.

The next step is to employ metabolite profiling to evaluate the quality of alternative stopover habitat types. David Cerasale captured Wilson's Warblers in native willow and non-native salt cedar habitats along the San Pedro River in southeastern Arizona. Body mass did not differ between habitat types, but triglycerides were higher in warblers captured at salt cedar sites, indicating more rapid mass gain there. Arthropod biomass, however, was higher at native sites. In seven weeks of bird surveys, from early April to late May, there was no significant difference in the number of Wilson's Warbler detections between habitat types; however, during all seven weeks, detections of all birds in the Wilson's Warbler feeding guild were greater in native than in non-native habitat. Therefore, interspecific competition (especially with Yellow Warblers) appears to play a significant role in mass gain, even in habitats where arthropod biomass is greater.

Molecular Genetic Approaches to Linking Breeding and Overwintering Areas in Five Neotropical Migrant Passerines (Thomas B. Smith)

Studies of Neotropical migrant songbirds are limited by the difficulty of following single populations through a complete annual cycle. As population regulation may conceivably occur on either the breeding or wintering area, or both, determining levels of connectivity between breeding and wintering populations is fundamental to designing conservation strategies. In species with geographically structured genetic variation, genetic markers can be used to determine the breeding origin of migrating and wintering individuals. To assess the geographic scale at which mitochondrial DNA markers are useful in studies of songbirds, we reconstructed breeding-season phylogeographic variation in five long-distance migrants with widespread breeding distributions in North America: the Yellow-breasted Chat (*Icteria virens*), Nashville Warbler (*Vermivora ruficapilla*), Common Yellowthroat (*Geothlypis trichas*), Wilson's Warbler (*Wilsonia pusilla*), and Swainson's Thrush (*Catharus ustulatus*). We then used this phylogeographic data to genetically screen individuals captured on wintering sites in Latin America.

Genetic structure on the breeding grounds was found on a broad, continent-wide scale, allowing eastern and western populations to be differentiated. This allowed us to assign overwintering individuals to either eastern or western breeding lineages. Eastern and western populations tended to be similarly segregated on the wintering grounds, except in Swainson's Thrush, for which we found coastal breeding populations wintering in Central America and eastern populations wintering in northern South America. Data from band returns confirmed this pattern and further suggest that present day migration routes of Swainson's Thrush may retrace ancestral population expansions. Because connectivity was resolved only at large geographic scales, linking population-level demographic processes on breeding and wintering areas with the genetic markers used here appears unlikely. Greater resolution may be possible when molecular genetic techniques are combined with other sources of information on geographic origin, such as those derived from isotopes. In particular, the use of AFLP molecular markers appear to be of greater utility in determining connectivity than either mitochondrial or microsatellite markers.

Stable Hydrogen Isotope Ratios in the Study of Avian Migration (Jeffrey F. Kelly)

Studies of songbird migration are inherently difficult due to the huge ranges over which birds move rather quickly, their large populations and small body sizes, and the fact that traditional tracking methods don't work on small landbirds. Analysis of stable-hydrogen isotopes (δD) from feathers, however, can translate into maps that depict avian movements along migration routes. Studies that examine isotope ratios of multiple elements (e.g., C, H, O, N, S) provide more resolution than those that use a single element. However, isotope methods cannot overcome a lack of knowledge regarding a species' ecology. Particularly relevant to studies of migration is a thorough understanding of the timing and sequences of molts.

Future studies of migration biology that combine stable isotope data with genetic markers, morphology, parasitology, and abundance information will be insightful. Further understanding of the determinants of isotope ratios in tissues (claws, feathers), refinement of analytical procedures, and identification of other compounds that contain geographic signals (fatty acids, amino acids, and trace minerals) will enable better resolution of migratory ecology.

Some Analytical Options for the Use of Intrinsic Markers in Studies of Avian Migration (Michael Wunder)

Understanding seasonal movements of migratory birds is a substantial challenge that obscures strong inference in studies of natural history and conservation. Traditional banding

techniques rarely yield reliable data about movements of wild populations. Recent advances in the use of stable isotope ecology to study seasonal movements in small migratory birds are promising. However, most analytical models used thus far have been exploratory and no researchers have attempted to validate even basic assumptions of the models. All model assumptions must be reasonably met in order to make strong inference from data or to confirm hypotheses about process or pattern.

I studied isotopic patterns in newly developed feathers from Mountain Plovers captured during summer on the breeding grounds to infer breeding origin of wintering birds. I incorporated both fixed and random effects into a set of models and explored assumptions and validity using an information-theoretic approach. I also explored a set of hierarchical likelihood-based assignment tests that can incorporate probabilities from other data sources, such as relative band recovery rates and abundances.

Descriptive regression models of latitude on isotope values accounted for most of the observed variation (adj. R^2 range 0.75-0.97). Isotope variables were good predictors of latitude in these descriptive models ($P < 0.01$ for $\delta^{13}C$ and δD in all models). However, inference from regression models assumes independent, identically distributed residuals, which was violated by every descriptive model. Substantial structure in the errors was associated with δD. Consequently, northern feathers were consistently assigned more southern latitudes and vice versa. Incorporating sample site as a random effect satisfied the assumption and yielded models that were on the order of $9x10^{35}$ times more likely as the best approximating model than any descriptive model; yet, the isotopes in these random-effects models were poor predictors of latitude ($P > 0.12$ for all isotopes in all models). The most parsimonious descriptive regression model assigned 45% and 4% of known samples to the correct U.S. state and sampling site, respectively. The most parsimonious random effects model correctly assigned 13% and 0% to state and location, respectively, whereas the likelihood-based assignment tests assigned 89% and 77% of known samples to the correct state and site, respectively.

These results illustrate that the effective sample size in migration studies using intrinsic markers is the number of sampling sites, not birds, within the geographic range of interest. The number of birds per site affects only site-level precision, which is apt to be relatively low for most commonly considered isotopes, regardless of sample size. Regression models describe specific isotope datasets well. However, likelihood-based assignment tests offer the most flexibility and reliability for researchers seeking to link space and time with intrinsic markers. Careful study design and the application of such tests will improve the efficacy of stable isotope techniques in the study of avian migration.

Bird Banding as an Information Source (Peter Pyle)

Bird banding can help us gain information not available from point-count or other censusing data. For example, variation in age:sex ratios of birds captured at banding sites can reflect habitat quality. Adult males may exclude other members of their species from higher quality patches and serve as a measure of stopover quality. How age:sex ratios represent habitat selection versus exclusion, and what the differences in age:sex ratios from fall to spring can tell us (reflection of overwinter survival?), can also be investigated.

On the premise that fitter birds are able to acquire greater resources for molting, extent of partial molts (preformative, prealternate) could provide information on a bird's condition. In particular, the number of greater coverts replaced during prealternate molts can indicate body condition. Only a third of bird species, however, undergo prealternate molts.

We can also incorporate data on length of an individual's stopover stay with gains in mass (fat scores are unreliable) and other fitness parameters. Mark-recapture and survivorship models

can be used on daily recapture data to estimate length of stay for an individual or group of individuals.

Recent specimen-based studies have revealed that many adults of Western North American passerine species undergo "molt-migration." July and August are so dry in many western states that adults first migrate to different elevations or latitudes (south) to molt at migration stopover sites---including those influenced by summer monsoons---before moving on to their winter ranges. We need more information on which species undergo molt migration, as well as which habitats/localities they use and what landscape- and habitat-scale features (including relative number/size of habitat patches) are important. The quality of those sites and whether or not birds exhibit fidelity to them, how these habitats influence age:sex ratios and body condition, and how important those sites are to survivorship can also be investigated.

For all of these reasons, I highly recommend the use of bird banding for assessment of stopover-site habitat quality.

Applications of Radar Ornithology (Robb Diehl)

Deployment in the mid-1990's of a Doppler capable Weather Surveillance Radar system (aka WSR-88D) has rekindled interest in radar ornithology in the United States. However, biologists new to this field are challenged by correct interpretation and quantification of radar data for advancing knowledge of avian behavior during flight and migratory stopover. Radar echoes can have numerous non-biological and biological sources (e.g., rain, hail, smoke, insects, bats, landbirds, waterfowl)---identity of which is complicated by range bias (distance from radar station), resolution (spatial and temporal), aspect (orientation of objects relative to radar beam), clutter (airborne objects, human infrastructure, topographic relief), refraction (variable effects of atmospheric conditions), and interactive effects of these factors. Individual radars within the system, although "identical by design," vary idiosyncratically (e.g., pattern of beam obstruction, mode of operation, data calibration, clutter filter adjustment) in ways important to how data are interpreted and quantified. Furthermore, different radar data formats vary in their methods of quantification and their accessibility by non-technical users.

The potential of WSR-88D and related systems for ornithological research remains largely unexplored. To date, the most-anticipated ornithological application of WSR-88D is its ability to identify habitats used by birds during migratory stopover and quantify the level of use. Several minutes after the onset of nocturnal migration, birds are flying high enough to become visible as radar echoes, where stronger echoes represent more birds. Because birds are spatially associated with their source stopover habitats early in migratory flight, we can use radar to estimate relative bird densities associated with specific landscapes or habitat types. This method provides large-scale, quantitative information on where migratory birds stopover and in what numbers or densities, as well as which characteristics of the landscape explain observed distributions of birds.

As research in these habitat-migrant associations continues, new applications of WSR-88D continually emerge. These include understanding broad structure in migratory patterns at regional or continental scales, reconstructing historically important migratory events from archived data, modeling migrant behavior and ecology, assessing risk to migrants posed by natural and anthropogenic hazards, and quantifying the effects of large-scale changes in land use due to numerous causes (e.g., climate change, habitat restoration). In the near future, the range of biological applications will increase considerably as WSR-88D hardware and software are upgraded to improve spatial and temporal resolution and increase the number of radar "moments" available.

Session VI: Linking Bird and Bat Studies

Migration Movements of North American Tree Bats (Paul Cryan)

About 43 species of bats occur in the United States, 8 of which are collectively referred to as tree bats. The habits of tree bats are more similar to those of migratory birds than any other group of mammals. Because of this similarity, the potential for integrating bat and bird migration studies is good. Tree bats roost in trees throughout the year and rarely use caves, mines, or buildings. Four species of tree bats make long-distance seasonal movements: the eastern red bat (*Lasiurus borealis*); the western red bat (*Lasiurus blossevillii*); the hoary bat (*Lasiurus cinereus*); and the silver-haired bat (*Lasionycteris noctivagans*). However, details of their movements are lacking, as there have been few successful efforts to follow movements of individual tree bats. As with many species of migratory birds, banding and radiotracking are not practical for studying long-distance movement by bats. Furthermore, it is very difficult to find tree bats in their roosts during the day, which makes seasonal observations of distribution impractical.

To gain a better understanding of seasonal distributions and movements by tree bats, I mapped the monthly distribution of occurrence records. More than 10,000 occurrence records were acquired for 127 museums. Despite biases associated with these data, the maps show clear changes in seasonal distribution at the continental scale. Hoary bats mainly occur in southwestern North America (NA) during winter. Female hoary bats move to eastern NA during summer, while males mostly occur in western NA. Western and eastern red bats make latitudinal migrations, but few differences in distribution exist between sexes. Silver-haired bats apparently winter in scattered localities throughout NA and generally move north as summer approaches. Relatively high concentrations of male silver-haired bats occur in the southern Rocky Mountains and some areas of the Pacific Northwest during summer, while females are concentrated farther north. All species exhibit trends toward male and female range overlap during late summer and fall. In addition, records do not indicate major movements between North and South America by any of these species. Studying the stable hydrogen isotope composition of hair confirmed long-distance migration by tree bats. Stable isotope analysis revealed that mammal hair incorporates hydrogen from the environment in a way similar to that in bird feathers, thus the technique offers much promise for studying bat migration. Our work indicated movements by hoary bats in excess of 2000 km.

Finer-scale details regarding bat migration are extremely limited. As with migratory birds, several factors are hypothesized to be important to migrating bats: maintaining water (drinking sources) and energy balance (insect prey), adequate shelter (tree roosts), and availability of visual cues for orientation and navigation. It is at these finer scales that questions regarding bat migration parallel those that ornithologists are asking about bird migration. For example, anecdotal evidence suggests that riparian corridors may be important to migrating tree bats, but there are few quantitative data regarding dispersal patterns or specific stopover habitats used. Future directions in the study of migratory bats echo the needs indicated by ornithologists and we envision collaborating with avian researchers. Common research tools employed by both groups include stable isotopes, radar, thermal imaging, acoustic monitoring, distribution mapping, radiotracking, prey sampling, and correlating migration timing to biotic and abiotic events (e.g., weather and vegetation phenology). Collaboration across taxa will likely enhance our understanding of migration in this diverse group of migratory animals.

Summary of Workshop Discussions

Discussion topics and participant interest generally fell into the main categories of research, monitoring, management, and education. Because a primary charge of this workshop was to identify knowledge gaps and research needs, we focus first and foremost on the research discussions. Many workshop participants agreed, however, that monitoring is a critical tool for helping us understand the conservation needs of migrating birds, and that management and education are necessary components of effective conservation endeavors. We therefore give voice to the full range of ideas that emerged during the discussion. Naturally, there is much overlap between these topics, and participants envision that future endeavors in these realms will become better integrated with respect to maximizing the use of funds, sharing data, multi-tasking projects, and cooperating to the extent possible to maximize information gains and, ultimately, avian conservation.

Research

The participants identified future research needs and directions regarding migration stopover ecology, both in general and specifically in the U.S. southwest and northern Mexico. An outlined synthesis, organized by 'area of inquiry,' of those needs and questions is provided below. To some extent, specific needs or questions fell under more than one area of inquiry---this overlap serves to emphasize some of the more-important needs and questions raised at the workshop.

Habitat, Landscape, and Climate Relationships

Workshop participants share the assumption that continuous degradation and loss of stopover habitat, changes in land-use, and climate change are compromising survivorship avian survival during en-route periods. Not only do we need research to test these assumptions, we need to address numerous related questions and information needs.

1. Habitat Type. Evaluate the relative importance of all habitat types in southwestern North America to en route migrants (e.g., lowland cottonwood-willow riparian, shrub willow riparian, riparian habitats altered by non-native plants, mesquite bosque, grassland-oak savannah, forested montane habitats, montane shrublands, shrub-steppe, desert scrub, desert wash, etc.).
    - How does habitat importance vary among guilds, sexes, age-classes? Among seasons?
    - What habitats and locations are being used for molt migration?
    - How do habitat-migrant relations vary at different hierarchical scales (landscape, habitat, patch, microhabitat)?
2. Habitat Quality. Determine what parameters should be used to define and measure stopover habitat quality. How do rates of mass gain by foraging birds, avian densities, and species richness relate to habitat quality?
    - What habitat characteristics distinguish poor quality from high quality stopover habitat? What distinguishes habitats where birds gain more mass per unit of stopover time?
    - Is habitat quality related to the timing, amplitude, or extent of invertebrate flushes or plant flowering?

3. Loss of Stopover Habitat. Determine the geographic patterns of loss of stopover habitats.
    - Do these losses have cumulative effects?
    - Are there differences in how, or which, habitats are being lost in eastern versus western regions of North America?
4. Landscape Relationships. Determine attributes of the landscape that are related to species abundances (landscape composition, extent of habitat of interest, connectivity, elevation.
    - What are the effects of land-use history and recent changes in land use with respect to migration patterns? What additional changes can we expect---and what will be the consequences of---predicted changes over the next 20 years as more people move into the southwestern sunbelt?
5. Climatic and Hydrologic Effects.
    - How are climate change and current climate anomalies affecting plant phenologies and, in turn, flushes of insect populations? Is the timing of migration affected by climate change? How do phenological changes affect migrating birds dependent on the insect flushes and plant flowering?
    - What are the links between hydrologic change, riparian vegetation, food availability, and quality of stopover habitat?
    - What hydrologic conditions are necessary for perpetuation of quality stopover habitats, especially gallery cottonwood forests? What are the threats to maintaining these conditions?

Distribution Patterns

Overall, workshop participants agree that we have serious gaps in our knowledge about patterns of migration distribution---spatial and temporal---in western North America. Developing data repositories and compiling existing data are crucial first steps toward filling the gaps in our knowledge and laying a foundation for future research efforts (for an initial analysis, see Skagen and others, 2005). Specific information needs and research questions pertaining to distribution patterns include:

1. How do species/guilds move across the landscape---in a broad front, along riparian or cordilleran corridors, by hop-scotching across inhospitable terrain to suitable patches of habitat, or other strategies?
2. Are there general, predictable patterns of migration (routes, habitats, elevations) in spring and in fall for each species?
3. Document timing of migration for migrating species (and age-classes); identify annual variation and possible correlates of this variation.
4. How flexible are birds with respect to migration strategies, routes, timing, and/or habitat use? What are the limits to their plasticity?
5. How do meteorological factors affect migration strategies and routes?
6. How do migration distribution patterns relate to patterns of insect flushes, plant phonologies?

7. Is climate change altering migration distribution patterns, spatially and/or temporally?

General Migration Stopover Ecology

Workshop participants agree that the importance of migration stopover sites for maintaining healthy populations of migratory landbirds cannot be overstated. It was also agreed, however, that we lack enough information on basic avian ecology---as it pertains to migration stopovers---to develop appropriate conservation strategies for stopover sites. Specific research needs and questions within the realm of avian stopover ecology include:

1. What genetic information is needed to best preserve biodiversity and maximize adaptive variation across the range of a species? Document genetic variability among 'edges' versus 'centers' of migratory routes.
2. Can linkages be made between breeding/wintering areas and migration stopovers through the use of genetic profiles or stable isotope analyses of feathers?
3. Explore the utility of radar ornithology for identifying migration routes, important stopover areas, and for modeling movement patterns in relation to habitats, abiotic factors, and large-scale landscape features.
4. What are the effects of West Nile Virus, pesticides, and other factors that may affect the health of en route migratory birds?
5. Develop and test empirical and theoretical models describing migration strategies; test the underlying assumptions of existing migration models.

Monitoring

Although a primary charge of this workshop was identify knowledge gaps and discuss research needs, many workshop participants agreed that monitoring is a critical tool for helping us understand the conservation needs of migrating birds. Although the development of monitoring strategies is outside the scope of this endeavor, we wanted to give voice to these ideas. Some of the approaches outlined below are currently being undertaken by other entities. Among the needs and questions identified in relation to monitoring were:

1. Set up a migration monitoring network and list-server. Provide direct links to relevant sites and critical information at all scales. Include Mexican, American, and Canadian organizations and collaborators. Coordinate efforts with researchers and land managers.
2. Compile a meta-database of existing data to help determine future directions in monitoring. Provide for electronic entry and verification. Consider including data from MOSI (monitoring overwinter survival), MAPS, Breeding Bird Survey, existing migration survey and banding data, and the North American Migratory Bird Count. Build in survivorship parameters and/or the means for analyzing survivorship data.
3. Identify gaps in survey and banding coverage. Increase the number of banding stations in the desert Southwest.
4. Standardize protocols.
5. Recruit community volunteers: use public outreach; academic programs to involve students and curriculum development around monitoring; media coverage.

Management and Education

Overall, this workshop was not intended to address management issues, per se. However, a few management-related questions or needs that may be built into research were identified:

1. Should we manage for representative species or attempt to cover all species (e.g., do we focus on local breeders as well as pass-through migrants in the arid southwest)?
2. Determine best practices for preserving biodiversity. Should we manage for the full complement of genetic variability and adaptive variation as it relates to edges and centers of migratory corridors and other migration stopovers?
3. Develop a list of stopover sites believed crucial to conserving migrant landbirds as basis for guiding on-the-ground conservation.
4. Develop restoration guidelines applicable to stopover sites.
5. Develop community connectivity, policy, and law enforcement through public outreach (including media coverage, training, volunteer programs), environmental education, and academic programs involving students---at all levels---from Mexico, the U.S., and Canada. Most Mexican lands important to migratory birds are private; thus, management and restoration efforts must be accompanied by public education (including birdwatching training, bird lists, etc.) and economic considerations to engender support.

Toward A Research Proposal

Participants outlined a potential approach to implement some of the first steps toward improving our understanding of western avian migration. They could envision short 2- to 3-year coordinated, broad-scale studies to potentially address many of the research questions outlined above, although long-term studies are also needed to address the effects of habitat dynamics, natural climate variation, and global climate change. Because the above questions span several spatial and temporal scales, participants explored an overall approach that is 3-tiered, or hierarchical. Efforts at the largest scale could entail considerable public outreach and volunteer mobilization to further quantify broadscale occurrence patterns of birds during migration and to generate public interest, so important for future conservation efforts. At this scale, research and monitoring efforts could effectively be interlinked. At a second tier, patterns of distribution and regional habitat use could be elucidated using a stratified random design to delineate broadscale surveys within habitats of interest. This effort would entail many simultaneous migration surveys via numerous strike teams that move around the region quickly to take repeated snapshots of migration. Radar ornithology could be implemented to refine allocation of field effort within strata, to help elucidate nocturnal migration patterns, and to identify habitats used as stopovers. A third tier could incorporate targeted research at existing banding sites to address in-depth questions (e.g., foraging efficiencies, rates of fuel deposition, habitat use, or bird movements, using molecular techniques). At this scale, efforts should be made to cooperate with existing survey and banding projects to build on existing infrastructures, thus maximizing efficiencies.

Participants offered many additional suggestions regarding initial steps in a coordinated process:

1. Define the region of interest for initial studies. It was generally agreed that initial efforts should focus along the southwestern borderlands, both in the U.S. and Mexico; Important Bird Areas designated on both sides of the border could be incorporated into research designs.
2. Decide which species/guilds we should use for our primary focus; pass-through migrants, local breeders, or both? Determine how to account for species not usually detected on surveys or caught in mist nets. Would it work/be useful to focus on ‘representative species’ rather than trying to cover all species?

3. Define the appropriate sampling periods for collecting spring, molt, and fall migration data.
4. Develop standards for broad habitat classification. Determine which habitats and/or landscape features we should focus on, and the scales at which they should be sampled. In addition to riparian areas, desert washes and montane shrub habitats should not be overlooked.
5. Standardize operational definitions. Develop clear definitions of migration types and strategies; identify and define demographic units that are most useful for migration modeling.
6. Develop experimental/study design for three-tiered approach. Determine protocol for site selection.
7. Develop/refine survey and banding protocols.
8. Encourage use of GIS and other technologies (e.g., radar ornithology) for addressing landscape-level and regional questions regarding habitat availability, fragmentation, connectivity, land-use changes, and how birds respond to these factors. Consider collecting nocturnal vocalization data for supplementing radar information to determine migration movements.
9. Identify existing data layers for GIS analyses or modeling efforts, including National Wetlands Inventory (NWI) data (for developing models with surface and groundwater hydrology variables); leaf-phenology and insect-survey data (for modeling migration timing in relation to flowering and other botanical events, insect flushes); climate data (for modeling effects of climate change on migration timing, leaf phonologies, insect flushes).
10. Explore potential for using long-term, broad-scale survey data as a means of developing research hypotheses on linkages between breeding/migration/ wintering areas: Breeding Bird Survey data and various Audubon data (e.g., surveys of Important Bird Areas, migration surveys, and Christmas Bird counts).
11. Build on existing 'infrastructure' of current survey and banding efforts/ programs for future coordinated work. Capitalize on existing programs for collecting feathers and blood for genetic and stable isotope analyses.

Expanding Collaborations, Funding Potential

Workshop participants discussed the ways in which collaborations could maximize our informational gains for the least expense, and discussed sources of potential funding for the type of work identified as needed in this workshop. Needs relative to collaborative possibilities and funding sources included:

1. Develop lists of potential partnerships and traditional as well as novel funding sources. Identify potential collaborators through existing infrastructures, survey and banding projects. Include U.S. and Mexican collaborators/projects.
2. Strengthen north-south collaboration, including Canada (western Canada in particular) and Mexico, to incorporate breeding, migration, and wintering areas. Continue developing research with multi-national approaches. Consider international exchange programs with refuges, parks, universities, resource agencies, etc.
3. Explore collaborative potential with bat biologists, ichthyologists, and riparian geomorphologists.

Infrastructure, Personnel

Workshop participants identified basic infrastructure needs for the strike-team approach described above:

1. Develop a coordination and communication system to maintain momentum developed at the workshop.
2. Identify or hire a coordinator to identify potential collaborators and projects; develop a database for tracking collaborators, protocols, study sites, etc.; and ensure that data can be standardized across projects. Include collaborators from Cabeza Prieta, Yuma, IBA program, and others---both sides of the U.S.-Mexico border.
3. Develop a central repository for existing and future data; compile the data to set the stage for future work. Consider developing protocols that allow for post-hoc standardization of data. Identify data-rich studies (past, current) on migratory species that may serve as suitable representatives for specific avian guilds.

Conclusions

The workshop was highly successful in fulfilling its stated objectives of reviewing the current state of knowledge on avian migration in the southwest, conveying information on developing technologies, and working towards an integrated field effort for future research. There was clear recognition of the importance of migration stopover issues among the diverse audience, and interest in this topic was keen. This workshop not only emphasized the importance of migration stopover ecology, but again highlighted the importance of riparian conservation. Many agencies recognized the importance of riparian habitats decades ago, yet it appears that such habitats are still being lost or degraded.

Participants concluded that the workshop was extremely valuable to their efforts and conveyed an eagerness to work towards more collaborative research ventures in the future. Expressed research needs spanned many general topics, including habitat and landscape relationships; impacts of climate variation and change; en route distribution; linkages between breeding, migration and wintering areas; modeling migration strategies; and incorporation of emerging technologies into broadscale collaborative research. As envisioned, a coordinated approach to future research would maximize informational gains, improve efficiencies, combine resources and share costs, promote involvement in a common concern, and ultimately provide clear information to managers. There was interest in generating a minimal infrastructure that would create an environment conducive to the exchange of research ideas, facilitate a coordinated approach, but in no way pose barriers to individual research.

We believe that a second workshop would help maintain the momentum of these discussions, facilitate collaborations, and further the goals of integrated approaches to broadscale research on migration stopover ecology. As efforts proceed, we envision annual meetings of all participants and interested parties. The initial workshop focused primarily on the importance of stopover habitats in southwestern North America; subsequent workshops would expand in scope to include more northerly migration stopover habitats as well. The efforts and products of the coordinated research discussed herein address the mission of the U. S. Fish and Wildlife Service regions 2, 6, and 1.

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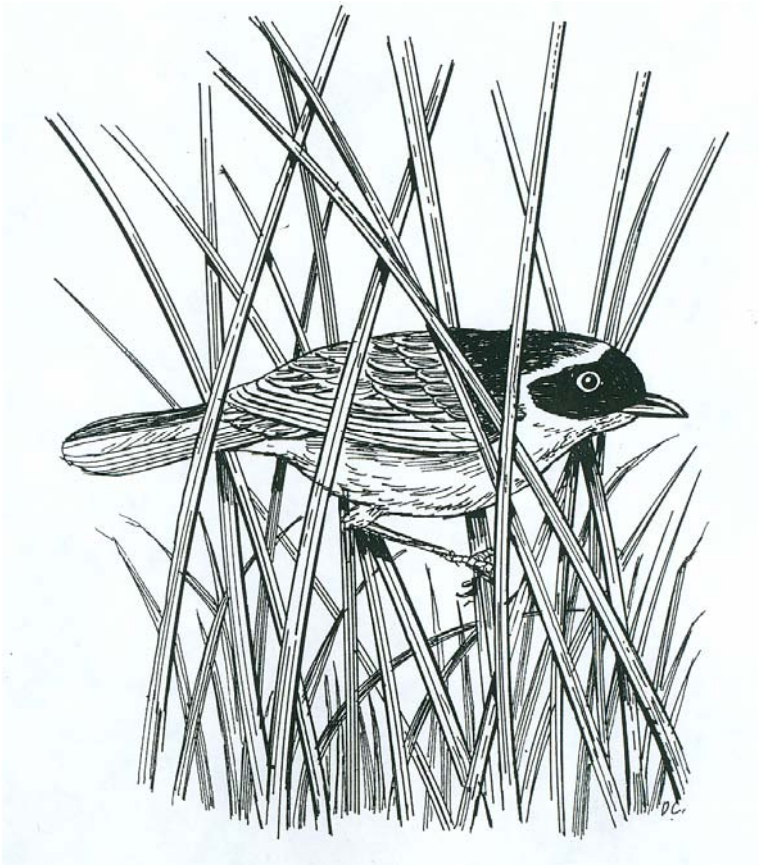

Common Yellowthroat

Yellow Warbler