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Priority research needs for the conservation of Neotropical migrant landbirds

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ABSTRACT. Partners in Flight (PIF) is a consortium of professional and volunteer scientists and educators that promotes the conservation of landbird species. Central to the PIF conservation effort is the development of Bird Conservation Plans specific to each physiographic region of the United States. Without a coordinated prioritization of research needs, land managers, researchers, and funding agencies seeking to conserve landbirds lack direction. To address this issue, we (the Research Working Group of Partners in Flight) identified research priorities that have emerged recently as a result of Bird Conservation Plan development. Research priorities for the coming decade focus on habitat, specifically the identification of high-quality habitats and landscapes for breeding, migration, and wintering. Identification of the scale of breeding and natal dispersal and describing linkages between wintering and breeding populations are also research priorities for the coming decade. A summary of research priorities for each of the PIF regions (Northeast, Midwest, West, and South) is also provided. Specific research needs associated with priority species and habitats in each physiographic area can be accessed in a searchable database: www. partnersinflight.org/pifneeds/searchform.cfm.

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SINOPSIS. **Prioridades en las investigaciones necesarias para la conservación de aves terrestres migrantes a los neotrópicos**

"Compañeros en el Vuelo" ("CeeV") es un consorcio de científicos y educadores profesionales y voluntarios que promueven la conservación de especies de aves terrestres. Medular al esfuerzo de "CeeV" en conservar, es el desarrollo de "Planes de Conservación de Aves" diseñados especialmente para cada región fisiográfica de los Estados Unidos de Norte América. Sin una lista de prioridades coordinada de necesidades de investigación, los manejadores de terrenos, los investigadores, y las agencias que ofrecen fondos que buscan conservar las aves terrestres carecen de dirección. Para enfrentar esta situación nosotros, el equipo especial de investigación de "CeeV,", hemos identificado prioridades que han surgido recientemente como resultado del desarrollo de un Plan de Conservación de las Aves. Las prioridades en investigación para la próxima década se centran en el hábitat, en particular identificar los hábitats y terrenos de alta calidad para la reproducción, migración e invernación. La identificación de la escala de dispersión incluyendo poblaciones reproduciéndose, natales y conecciones entre las poblaciones invernantes y reproductivas es una segunda prioridad para la investigación en la próxima década. También se incluye un resumen de las prioridades investigativas para cada región de CeeV (Noreste, Medioeste, Oeste y Sur). Las necesidades específicas asociadas con especies prioritarias y con hábitats en cada región fisiográfica (en inglés) puede ser accesada en la siguiente base de datos disponible: www. partnersinflight.org/pifneeds/searchform.cfm.

Key words: conservation planning, dispersal, habitat quality, Partners in Flight, population dynamics

Neotropical migratory birds, defined here as landbirds that migrate south of the United States border for winter, have generated considerable conservation interest (Askins et al. 1990; Bonney et al. 1999). Initial concern over perceived population declines of some migratory songbirds led to the formation of the international bird conservation initiative called Partners in Flight (Finch and Stangel 1993). Partners in Flight (PIF) is a partnership of academic and private researchers, representatives of federal and state natural resource agencies, industry, and non-governmental natural resource or land management groups in the United States, Canada, and Latin America. The program promotes proactive conservation of birds, particularly those that are declining but still common, through communication and coordination among agencies, organizations, and individuals (Stangel 1993; Pashley et al. 2000). Although PIF initially focused on migratory species, PIF now strives to conserve all species of birds, including residents, short-distance migrants, and summer and winter residents. The organization approaches coordinated conservation through an organizational framework that includes five national technical working groups (Research, Monitoring, International, Communications, and Education) and four regional working groups.

Central to the PIF conservation effort is the development of Bird Conservation Plans specific to each physiographic region of the United States. Each plan uses the PIF species prioritization process (Carter et al. 2000) to identify the most vulnerable species in each area, identifies the habitats most critical to those priority species, sets habitat and population objectives for conservation action, and suggests a strategy for achieving those objectives (Pashley et al. 2000). Each plan also recognizes gaps in our current knowledge and lists research and monitoring needs associated with priority species and habitats.

Without a coordinated prioritization of research needs, land managers, researchers, and funding agencies that seek to protect migratory birds lack direction. To address this issue, we (the Research Working Group of Partners in Flight) identified research priorities for the coming decade based on internal deliberations in 1998–2000 and discussions with land managers and personnel from a variety of organizations, including universities and colleges, the U.S. Fish and Wildlife Service, the U.S. Forest Service, state wildlife agencies, the U.S. Environmental Protection Agency, the National Audubon Society, the Wildlife Management Institute, The Nature Conservancy, industry (e.g., forest products, mining, power), and other non-governmental organizations. We first present an overview of current methodologies used to study birds. We do this to emphasize that appropriate research methodologies must be considered in addressing any questions pertaining to migratory birds. We then highlight national- and regional-level priorities for the coming decade.

ASSESSMENT OF CURRENT RESEARCH METHODOLOGY

A central question for bird conservation is "what causes populations to decline?" To estab-

lish cause and effect in bird population change, knowledge of basic natural history, effective monitoring at meaningful spatial scales, and rigorous, controlled tests of hypotheses and their alternatives are needed (James and McCullough 1995). Clearly, much work in this area remains to be done. For example, Sallabanks et al. (2001) reviewed 116 research articles from 1960 to 1998 that addressed bird-forestry relationships. Their review revealed that studies primarily focused on breeding songbirds (67%) and collected data on relative avian abundance (65%). Avian demographics (e.g., nesting success or productivity) were rarely studied (13%). Most studies occurred in northeastern (27%) or northwestern (19%) North America. Clearcutting (72% of studies) was examined more than any other silvicultural technique. In general, the design of studies has been weak, with data being collected at small spatial scales (e.g., stand or sub-stand), over short time periods (e.g., one or two years), and with little replication (most studies in the Sallabanks et al. review had only one replicate per treatment). Much of the research to date has had a narrow temporal and spatial focus and may not be applicable across ecological communities or time periods (Brown 1995).

Although research priorities for migratory birds may change from decade to decade, attention to good scientific methodologies should remain constant. As researchers, scholars, and managers, we should carefully re-examine and strengthen our scientific approach towards migratory birds. More progress is likely to be made when studies are well replicated in time and space, utilize experimental approaches, or are long enough in duration to evaluate potential causes of population change over time (James and McCullough 1995). Indeed, the exciting new advances in our understanding of migratory songbird conservation have been the result of long-term, replicated field studies or experimental approaches. Three examples highlight the use of different methodologies to advance our recent knowledge of migratory bird population dynamics and conservation:

Large-scale, replicated studies. Robinson et al. (1995) monitored over 5000 nests in over 35 research sites throughout the midwestern U.S. and correlated nesting success and parasitism levels with measures of habitat fragmentation. Although correlative in nature, the scale of the replicated project provides strong inference that habitat fragmentation (amount and arrangement) affect reproductive success for a variety of forest-nesting species.

Controlled, experimental approaches. Marra (2001) experimentally tested whether segregation of male and female wintering American Redstarts (*Setophaga ruticilla*) was due to dominance interactions or sex-specific habitat specialization. Removal experiments showed that vacancies in male-biased habitat were filled more rapidly and with greater frequency than those in female-biased habitat and that vacated male territories in mangrove were replaced more often by females than by males. Because most female redstarts are forced to overwinter in these kinds of habitats, they may often be in poor physiological condition prior to departing on spring migration for the breeding grounds. This in turn may influence dynamics of the breeding period by determining their condition and perhaps reproductive success. These results suggest that events that occur during the nonbreeding period play a critical role in the annual dynamics of this migratory species (Marra and Holmes 2001).

Long-term studies of population demography. Finally, long-term studies have proven invaluable in understanding potential causes of population change (e.g., Nolan 1978; Holmes 1994; Roth and Johnson 1993; Payne and Payne 1993). As a recent example, Sillett et al. (2000) determined that adult survival and fecundity of Black-throated Blue Warblers (*Dendroica caerulescens*) are lower in El Niño years and higher in La Niña years. Fecundity, in turn, is positively correlated with subsequent recruitment of new individuals into winter and breeding populations. The results suggest that migratory birds can be affected by shifts in global climate patterns—patterns that potentially would not be detected without long-term demographic data.

Each of these studies may suggest ways in which land-managers can improve habitats or ways in which policy makers can influence migratory bird conservation. Many other studies on migratory birds have been published in the past decade, but the studies that advance knowledge of migratory bird conservation have been largely the result of experiments, long-term studies, or regional studies that are well replicated in space and time.

ASSESSMENT OF RESEARCH PRIORITIES

What kind of research will generate information that can help conserve landbird populations in a world where human populations are exponentially increasing? First, from a conservation perspective, identification of high-quality habitats during all phases of the life cycle remains a priority so that critical habitats can be protected. Second, understanding the scale at which populations interact, including winter and breeding linkages, is needed to identify which part of the annual cycle is most limiting to migratory bird populations. Third, although habitat quality should be assessed and key habitats conserved, more information is needed on potential non-habitat "drivers" of migratory bird abundance, such as global climate change, acid deposition, or pollutants. Finally, improved monitoring is needed for several species that are not well surveyed by existing methodologies. We briefly discuss each of these current priorities and suggest some specific questions for each.

Identify high-quality habitats and landscapes that promote high survival or reproduction across the annual cycle. For many migratory species there is no clear understanding of which habitats are "critical" in terms of fecundity or survival. This applies to habitat during all life-cycle phases, and is a major problem that constrains effective bird conservation (Sherry and Holmes 1996). The definition of "critical" habitat is likely to vary from place to place, and may depend on factors such as local population density, landscape structure, distance from the center of the range, and the intensity of species interactions, which can make generalizations difficult.

Distinguishing between the effects of habitat amount (quantity) and habitat arrangement (configuration, fragmentation) on survival and reproduction also is needed for regional landscape-scale management (Fahrig 1997). Although habitat loss undoubtedly affects bird population numbers, there are strikingly few studies that document how species actually respond to the loss of habitat; such information is critical for policymakers as well as land managers. Determining how to assess essential habitat in a cost-effective manner is a major research priority in the next decade. The quality of habitat should be indexed with respect to critical demographic processes such as birth, immigration, death, and emigration. Although density often is used to identify critical habitats, research is needed to validate this assumption (Vickery et al. 1992). In some instances, density may be correlated with habitat quality, but density may be a poor indicator of habitat quality in other situations (Donovan et al. 1995; Purcell and Verner 1998). Moreover, high-density habitats may simply result from a lack of other, suitable habitat on the landscape. For example, wintering populations of Bicknell's Thrush (*Catharus bicknelli*) on Hispaniola occur in high densities in high elevation forests with high relief, but densities may be high in those habitats simply because <5% of original forests in Hispaniola remain (C. Rimmer, pers. comm.). While direct measures of survival and reproduction ideally would be used to assess habitat quality, more cost-effective, surrogate measures are needed to assess habitat quality across large areas.

Another habitat-related research priority centers on the fact that "optimal" habitat for a given species includes habitat features at many spatial scales, including nest-site, territory, patch, landscape, and even biogeographic scales (e.g., Thompson et al., in press). Habitat selection may be a hierarchical process that includes habitat features at all levels (Johnson 1980); evaluation of the relative importance of each scale for conservation and the potential interaction among scales is a pressing research need. For example, critical habitat for the Wood Thrush (*Hylocichla mustelina*), a priority species for many eastern and midwestern states, includes consideration of not only nest-site substrate, but the patch in which the nest is located, the landscape, the heterogeneity of the landscape in which the patch is located, and the location of the nest within the biogeographic range of the species. Which of these habitat features are most critical from a conservation standpoint? Efforts to produce high-quality habitat at the patch or stand level may be ineffective if the importance of habitat features at that scale are constrained by habitat processes operating at other spatial scales. The use of simple research protocols that can be applied at hundreds or even thousands of study sites by "citizen scientists" offers promise for addressing such multi-scale questions over the entire range of wide-

spread species (Rosenberg et al. 1999; Hames et al. 2001).

A final habitat-related research priority centers on the identification and promotion of land uses that integrate habitat conservation with economic sustainability (e.g., Greenberg et al. 1997; Hagan et al. 1997). For example, in the Neotropics, shade coffee has been shown to provide high-quality winter habitat for a diverse suite of migratory songbirds, even when plantation sizes are <1 ha in size (Wunderle and Latta 2000). In the United States, the Conservation Reserve Program provides important nesting habitat for a variety of grassland and second growth species (Herkert 1998; Best et al. 1998; McCoy et al. 1999).

Identify the frequency and scale of dispersal among populations across species ranges, and determine the primary factors that influence dispersal dynamics. The primary limitation in assessing causes of population change in migratory birds at a given location is a lack of understanding of whether local-scale population change (increase or decrease in numbers) is due to simple shifts in abundance (immigration and emigration), changes in mortality or reproduction at a localized site, or changes in regional or range-wide abundance (Temple and Wiens 1989; Bohning-Gaese et al. 1993). The spatial and temporal scales of analysis clearly influence population trend analyses and their interpretation. For example, Breeding Bird Survey (BBS) trends can differ depending on the scale of observation (Peterjohn and Sauer 1994), and source-sink dynamics can confound the interpretation of long-term trends (Brawn and Robinson 1996). Assuming that species are adequately monitored by existing protocols, relationships between long-term population trends, habitat changes, and extent of population declines may be difficult to interpret without some understanding of the spatial scale that encompasses the population dynamics of a species.

We believe that understanding the scale and frequency at which dispersal (immigration and emigration) occurs, as well as factors that promote or hamper dispersal, should be a primary research priority for many migratory bird species. This type of dispersal occurs within or between given life-cycle periods. For example, in spatially structured populations where sources and sinks for breeding occur, understanding the geographic scale of dispersal among sources and sinks is critical for effective management for two reasons. First, we need to identify source populations to ensure their protection. And second, the scale that encompasses most of the dispersal movements among sites can define a "population" unit that is biologically meaningful.

Additionally, analysis of single-species population trends would be greatly enhanced by linking data from breeding and wintering areas (Chamberlain et al. 1997; Marra et al. 1999). Such linkages, including specific migratory routes, would allow an assessment of habitat conditions across the annual cycle of a species, which may suggest where bottlenecks exist for improving population trends. This will continue to be a research priority.

Non-habitat-related drivers of population dynamics. We emphasize a need to investigate the potential of non-habitat-related causes of population declines. The best habitat management policies will do little to protect bird populations if the causes of population decline are the result of other factors, such as major shifts in the jet stream pathway which many migratory species indirectly "ride" between breeding and wintering grounds. James et al. (1992) discovered that both migrants and nonmigrants exhibited declining population trends in highland areas such as the Ozark Mountains, Adirondack Mountains, and the Cumberland Plateau, and suggested that hypotheses such as the potential effects of acid deposition or other environmental contaminants should be explored. These problems are likely to become more severe in the future, but have received little research attention (James 1998).

Expanded and better-coordinated monitoring efforts, especially for species not well surveyed by conventional methods. We believe that many research priorities depend on well-coordinated monitoring efforts, and monitoring, research, and management should be closely inter-related (DeSante 1998). Clearly, researching the mechanisms of population change must be done in concert with continued and expanded population monitoring. In addition, the evaluation phase of the PIF planning process will require monitoring efforts targeted at detecting desired population response. Virtually all of the highest priority species in the

eastern United States, however, are not well covered by the Breeding Bird Survey (BBS). These species include the Henslow's Sparrow (*Ammodramus henslowii*), the Saltmarsh Sharp-tailed Sparrow (*A. caudacutus*), the Golden-winged Warbler (*Vermivora chrysoptera*), the Cerulean Warbler (*Dendroica cerulea*), Swainson's Warbler (*Limnothlypis swainsonii*), the Bicknell's Thrush, the Swallow-tailed Kite (*Elanoides forficatus*), the Black Rail (*Laterallus jamaicensis*), and nocturnal species such as the Whip-poor-will (*Caprimulgus vociferus*) and the Chuck-will's-widow (*C. carolinensis*). Although this is primarily a monitoring need, research is needed to develop new, targeted techniques, to determine the effectiveness of monitoring efforts, and to combine GIS (geographic information systems) with field techniques.

REGIONAL RESEARCH PRIORITIES

Specific regional research priorities have recently emerged through the PIF planning process. They reflect information PIF perceives as necessary to accomplish population and habitat management objectives. Priority species and habitat types for each physiographic area can be found in PIF conservation plans at www.partnersinflight.org. In addition, specific research needs associated with these species and habitats in each physiographic area can be accessed in a searchable database at www.partnersinflight.org/pifneeds/searchform.cfm.

Northeast priorities. The Northeast Region of PIF extends from Maine to Virginia and West Virginia and includes 12 physiographic areas. Based on the PIF species prioritization process (Carter et al. 2000), the habitats and associated priority species that are highlighted across the Northeast include: (1) boreal-mountaintop habitats (high-elevation conifers) that support a majority of the world's population of the Bicknell's Thrush; (2) maritime marsh and ecotonal communities that support nearly all breeding Saltmarsh Sharp-tailed Sparrows, coastal populations of Nelson's Sharp-tailed Sparrows (*Ammodramus nelsoni*), the Black Rail, the Seaside Sparrow (*A. maritimus*), and the American Black Duck (*Anas rubripes*); (3) naturally disturbed and early-successional shrub-scrub habitats that support the Appalachian Bewick's Wren (*Thryomanes bewickii altus*), now possibly extinct, the Golden-winged Warbler, and the American Woodcock (*Scolopax minor*); (4) natural and agricultural grasslands that support the Henslow's Sparrow, the Upland Sandpiper (*Bartramia laungicauda*), the eastern Grasshopper Sparrow (*Ammodramus savannarum pratensis*), and the Bobolink (*Dolichonyx oryzivorus*); (5) oak-dominated hardwood forests that support Cerulean Warblers, Worm-eating Warblers (*Helmitheros vermivorus*), and associated species; and (6) northern-hardwood and mixed coniferous forests that support Canada Warblers (*Wilsonia canadensis*), Black-throated Blue Warblers, Bay-breasted Warblers (*Dendroica castanea*), and associated species. In addition to these habitats, the value of migration stopover concentration areas is undoubtedly very high, although this has not been quantified. Highest priorities for future research in this region are as follows:

(1) Determining if and how current land-use practices are correlated with population changes of high priority species (specifically, Henslow's Sparrows in relation to mowing and grazing practices; Golden-winged Warblers in relation to agricultural abandonment, beaver activity, and power-line right-of-way management; Cerulean Warblers in relation to silvicultural practices in the Appalachians region, and fragmentation of bottomland/riparian habitats; and Canada Warblers and Wood Thrushes in relation to silvicultural practices).

(2) Determining the relationship between forest-health effects on habitat quality and bird populations. What are the effects of deer browse, exotic insect and fungus pests (gypsy moth, hemlock and spruce adelgids, oak blight, etc.), and acid precipitation?

(3) Determining how critical migration stopover habitats and concentration areas are to migratory bird populations. What is the relative importance of coastal concentration areas and inland stopover habitats in terms of survival and parameters critical for migration (e.g., weight gain)? Which sites and habitats are critical for high-priority species during migration (e.g., the Bicknell's Thrush)? What is the relative value of spring sites versus fall sites in terms of population dynamics? Is there temporal and spatial variation in stopover habitat requirements within and between seasons?

Southeast priorities. The Southeast Region extends from portions of Virginia through Florida, west through Texas and Oklahoma and

north through Arkansas and Kentucky, corresponding to all or parts of 21 physiographic areas. The Caribbean is also an important region for consideration by the Southeast working group. Priority habitats and bird species in the southeast include: (1) bottomland hardwood forests supporting breeding Swallow-tailed Kites, and Cerulean, Black-throated Green (*Dendroica virens waynei*), and Swainson's Warblers; (2) high elevation (spruce-fir) forests harboring many endemic Appalachian subspecies and potentially distinct populations of conservation importance, including Winter Wrens (*Troglodytes troglodytes pullus*), Yellow-bellied Sapsuckers (*Sphyrapicus varius appalachiensis*), Saw-whet Owls (*Aegolius acadicus*), Brown Creepers (*Certhia americana nigrescens*), and Black-capped Chickadees (*Poecile atricapillus practicus*); (3) maritime communities important to saltmarsh sparrows and rails, and utilized as stopover habitat for migrants; (4) fire-dependent, early successional habitats required by Bewick's Wrens, and Golden-winged and Prairie Warblers (*Dendroica discolor*); (5) upland hardwood forests supporting breeding Wood Thrushes and Cerulean, Kentucky (*Oporornis formosus*), Hooded (*Wilsonia citrina*), and Worm-eating Warblers; (6) western grasslands and prairies supporting Mountain Plovers (*Charadrius montanus*), Sprague's Pipits (*Anthus spragueii*), McCown's Longspurs (*Calcarius mccownii*), Baird's Sparrows (*Ammodramus bairdii*), and Lesser Prairie-Chickens (*Tympanuchus pallidicinctus*); (7) western riparian systems inhabited by Bell's Vireos (*Vireo bellii*), Lucy's Warblers (*Vermivora luciae*), Audubon's Orioles (*Icterus graduacauda*), Red-billed Pigeons (*Columba flavirostris*), and Buff-bellied Hummingbirds (*Amazilia yucatanensis*); (8) eastern tallgrass and Florida prairies supporting Henslow's Sparrows, Dickcissels (*Spiza americana*), Sedge Wrens (*Cistothorus platensis*), Yellow Rails (*Coturnicops noveboracensis*), Burrowing Owls (*Athene cunicularia*), Florida Grasshopper Sparrows (*A. s. floridanus*), Florida Prairie Warblers (*D. d. paludicola*), and Crested Caracaras (*Caracara plancus*); and (9) mangrove lowlands and tropical hardwoods supporting Mangrove Cuckoos (*Coccyzus minor*), Black-whiskered Vireos (*Vireo altiloquus*), Cuban Yellow Warblers (*Dendroica petechia gundlachi*), and Short-tailed Hawks (*Buteo brachyurus*). In addition to breeding habitat, the value of these habitats for stopover migrants is likely to be high, although largely unknown. Top research priorities in the Southeast are as follows:

(1) Determining the relative importance and utility of fire (frequency, seasonality, intensity) in maintaining grassland and early successional habitats throughout the southeast. Characteristics that favor occupancy and successful breeding by priority species associated with these habitats (e.g., Golden-winged Warblers, Henslow's Sparrows, Bachman's Sparrows (*Aimophila bachmanii*), Dickcissels, Bewick's Wrens) need to be better understood, as do the management options that promote or permit retention of these features.

(2) Identifying shifts in the occurrence, abundance, and demographic rates of wintering Nearctic-Neotropical migrants in response to conservation actions (e.g., shade-grown coffee) directed at Caribbean resident-endemics. Efforts to conserve resident-endemics are typically a priority in the Carribbean and often provide the only opportunities to address conservation of priority migrant species on Caribbean wintering grounds. An understanding of the impacts of such programs on wintering migrant populations will assist PIF in ensuring that planning and evaluation activities are comprehensive in considering potential impacts to Caribbean wintering populations throughout their annual cycle.

(3) Gathering biological data for use in developing management guidelines for Nearctic-Neotropical migrants. The development of guidelines for conserving priority species outside of the breeding season is limited by an insufficient understanding of aspects of migration ecology that are likely to be highly relevant to ensuring a comprehensive conservation program for many priority species in the southeast. Data of potential relevance in this respect include radar and monitoring data to identify important inland and coastal concentration centers and migration patterns (e.g., temporal and spatial), data characterizing concentration centers (e.g., habitat types, location and juxtaposition within the landscape, temporal importance, potential threats), and data describing the availability and use of soft mast and other foods by migrants.

Midwest priorities. The Midwest is an ecologically diverse region, where mixed- and tallgrass prairies, prairie-wetland mosaics, prai-

rie-savanna mosaics, oak-hickory-pine and boreal-hardwood transition forests each covered vast areas prior to European settlement. With the exception of tallgrass prairie and prairie-savanna mosaics, of which only small remnants remain, the native ecosystems of the Midwest exist today in both fragmented and relatively unfragmented conditions. To further conservation planning in the Midwest, research should seek to foster a better understanding of the following:

(1) The habitat requirements and management needs of Yellow Rails; Black Rails; Black-billed Cuckoos (*Coccyzus erythropthalmus*); Whip-poor-wills; Chuck-will's-widows; Red-headed Woodpeckers (*Melanerpes erythrocephalus*); Bell's Vireos; Eastern Bewick's Wrens (*Thryomanes bewickii bewickii*); Golden-winged Warblers; Cerulean Warblers; Nelson's Sharp-tailed Sparrows; and Orchard Orioles (*Icterus spurius*).

(2) How densities and/or reproductive success of PIF priority bird species vary in response to fragmentation patterns in the following physiographic regions and habitat types: the Cross Timbers of Kansas, Oklahoma, and Texas; the Boreal-hardwood Transition; the Central Mixed-grass Prairie; the Dissected Till Plains; riparian and floodplain forests; wet meadows and shrub wetlands; savanna-woodlands; and the urban-rural interface. Conservation recommendations regarding minimum patch sizes and landscape attributes that will sustain populations of PIF priority species especially are needed for regions where grasslands, shrub lands, savanna, and forest once were naturally interdigitated.

(3) How changes in population trends of high priority species vary with changes in land use. PIF conservation planners have been asked to set specific, numeric population objectives for landbird species at physiographic-area scales and to identify the acreage and configuration of habitats that will produce the desired population targets. Given that existing high-quality habitat is likely to be removed from the land base as a result of increased pressure from the burgeoning human population at the same time conservation efforts are applied, there is a need to be able to predict the overall effect of those changes on populations before realistic population objectives can be quantified.

Western priorities. Research needs in the Western Region span as many issues, habitats and species as does the region, from Alaskan tundra to Mexican-influenced deserts and mountains. While conversion of habitat to agriculture or urban development is a priority issue in certain areas (e.g., California coasts and valleys, Willamette Valley), many habitats are as extensive as they once were; most forest is still forest, and most shrubsteppe is still dominated by sagebrush (*Artemesia* spp.). The condition of these habitats, however, has changed considerably. Floristic composition and structure in western forests has been altered by timber harvest, grazing, changes in the intensity and frequency of fires, and other silvicultural practices resulting in forests that differ greatly from pre-settlement forests (Hejl et al. 1995). For example, fire suppression has resulted in a change in structure of Ponderosa pine (*Pinus ponderosa*) forests from open to closed stands. Priority species that occur in western forests include Olive-sided Flycatchers (*Contopus borealis*), White-headed Woodpeckers (*Picoides albolarvatus*), Swainson's Thrushes (*Catharus ustulatus*), Spotted Owls (*Strix occidentalis*), Williamson's Sapsuckers (*Sphyrapicus thyroideus*), and Flammulated Owls (*Otus flammulatus*). Similarly, shrubsteppe has suffered from overgrazing and cheatgrass (*Bromus tectorum*) invasion, both resulting in unnatural fire regimes, which can eliminate sagebrush entirely if fires are frequent (Paige and Ritter 1999). About 35% of the shrubsteppe in the Columbia Plateau has been eliminated (Hann et al. 1997), and in the west as a whole less than 1% has been spared of grazing (West 1996). Priority species in sagebrush habitats include Sage Sparrows (*Amphispiza belli*), Brewer's Sparrows (*Spizella breweri*), Sage Thrashers (*Oreoscoptes montanus*), Gray Flycatchers (*Empidonax wrightii*), and Greater Sage Grouse (*Centrocercus urophasianus*).

In contrast to the widespread western forests and shrubsteppe communities, riparian woodlands have suffered as much as a 95% decline from alteration, degradation, or destruction in the last 100 yr (Ohmart 1994). Riparian vegetation covers less than 1% of the arid west, yet more breeding birds are found there than in the more extensive uplands (Knopf et al. 1988). Priority birds in riparian habitats include Lewis's Woodpeckers (*Melanerpes lewisii*), Yellow-billed Cuckoos (*Coccyzus americanus*), Willow

Flycatchers (*Empidonax traillii*), Bell's Vireos, MacGillivray's Warblers (*Oporornis tolmiei*), Abert's Towhees (*Pipilo abertii*), Lucy's Warblers, and Red-faced Warblers (*Cardellina rubrifrons*). Research priorities for the West are as follows:

(1) Understanding the relationships between shrubsteppe bird species and landscape patterns and habitat structures that result from grazing, altered fire regimes, and interactions with nonnative and invasive species. Current research in this habitat has focussed on the sage grouse, a declining game species. This species is thought to be an umbrella species for shrubsteppe birds, although this has not been tested. Restoration of shrubsteppe habitats that have been impacted by wildfires and cheatgrass invasion is of conservation interest, yet the response of birds (sage-grouse and other PIF priority species) to various restoration treatments (prescribed fire, mechanical and chemical treatments) needs study.

(2) Doing long-term forest-management and landscape-level investigations for forest habitats in the West (Saab and Dudley 1998; Hejl et al. 1995). For example, studies are needed to determine the effects of altered fire regimes, fragmentation, grazing, invasive species, timber harvest, salvage and logging, and other forest management activities on the reproductive success of priority bird species. Additional questions include how much early successional and old growth forest must be present on the landscape to accommodate habitat specialists and what silvicultural methods mimic natural processes (Hejl et al. 1995).

(3) Determining the effects of timing and intensity of grazing, altered hydrology, non-native invasive species, fire exclusion, wildfire, fragmentation, recreation, and mining on the reproduction and survival of riparian bird species. Riparian woodlands represent the highest priority habitat for bird conservation in many parts of the West. Information on restoration of riparian habitats is needed, such as the time to recovery, best locations for restorations, and the response of birds to restored habitats. Information on the life history requirements and inter-relationships between aquatic taxa and riparian species is needed.

CONCLUDING REMARKS

To date, most avian research of potential value to bird conservation has been primarily descriptive, correlative, often short-term temporally, and narrowly focused in scale (Marzluff and Sallabanks 1998). The research priorities outlined here are the collective opinions of many land managers, policymakers, and researchers from across the United States. Many of our colleagues have identified additional research needed for bird conservation (Marzluff and Sallabanks 1998) that overlap with those expressed here. Sound research alone cannot conserve bird populations; clearly a concerted effort among researchers, managers, policymakers, industry, and the general public is needed if we are to keep our birds common. How can this be accomplished? We urge researchers to become active in local conservation efforts, engage local and regional land planners and land managers and state legislative bodies responsible for natural resources. In your discussions, find out how your skills as a researcher might be used to help solve local or regional problems. In short, we believe that scientists need to become more engaged in bird conservation efforts.

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