Lewis's Woodpecker (*Melanerpes lewis*): A Technical Conservation Assessment

Prepared for the USDA Forest Service,
Rocky Mountain Region,
Species Conservation Project

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AUTHORS' BIOGRAPHIES

Stephen C. Abele received his bachelor's degree in wildlife management from Humboldt State University, California in 1992. He is currently working towards a master's degree in wildlife resources from the University of Idaho. His master's research focuses on the breeding biology of Lewis's woodpeckers in a recently burned pine habitat. Before returning to graduate school, he worked as a field biologist for a variety of research projects. He has been involved with research concerning avian ecology in the Rocky Mountain Region for the past six years, with the last two being devoted to Lewis's woodpecker. Currently he is looking for gainful employment.

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Edward O. Garton is a professor of wildlife resources and statistics at the University of Idaho and received his Ph.D. in Ecology from the University of California, Davis in 1976. He has published extensively in peer-reviewed journals the findings of a variety of research studies conducted in the Rocky Mountain Region for over 20 years. His special areas of interest focus on understanding the dynamics and processes of mammal and bird populations, including several species of cavity-nesting birds. He has developed monitoring methods for woodpeckers to help understand the processes that drive population dynamics and species conservation. He has been a consultant to several land management agencies on resource management subjects, including Idaho Fish and Game, USDA Forest Service, Saskatchewan and British Columbia Wildlife Branch, National Park Service and the Biological Resources Division USGS. He has been recognized for his research by awards of Outstanding Researcher from the College of Natural Resources, University of Idaho, outstanding Wildlifer by the Idaho Chapter of The Wildlife Society, as well as being the recipient of a Fullbright Fellowship to Kenya.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF LEWIS'S WOODPECKER

Lewis's woodpecker (*Melanerpes lewis*) is a locally common but patchily distributed woodpecker species usually seen in open forests of western North America. The combination of its sporadic distribution, its diet of adult-stage free-living insects (primarily aerial), its preference to nest in burned landscapes, and its variable migratory behavior makes it a unique member of New World woodpeckers.

The Rocky Mountain Region (Region 2) of the USDA Forest Service lists the Lewis's woodpecker as a sensitive species. Region 2 populations are most strongly represented in south-central Colorado during the winter and throughout Colorado, eastern Wyoming, and the Black Hills of South Dakota during the breeding season. Possible threats to its conservation include the following human-induced changes to the environment: use of agricultural pesticides, introduction of non-native cavity-nesting bird species, suppression of fire, and alteration of natural stream flow patterns. These management actions may affect the structure, availability, and quality of the species' breeding habitats. Primary conservation elements and management considerations include the retention of large snags and the creation of opportunities for snag recruitment (preferably in clumps), the maintenance of understory shrub communities, and the reduction of exposure to agricultural pesticides. Additional habitat considerations include allowing wildfires to burn in lower montane conifers for the creation of burned forest habitat, and managing stream flow patterns and herbivory to promote natural recruitment of cottonwood seedlings, thus retaining and encouraging the development of mature riparian cottonwood woodlands.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). The Lewis's woodpecker is the focus of an assessment because it is designated as a sensitive species in Region 2. Within the National Forest System, a sensitive species is a plant or animal whose population viability has been identified as a concern by a regional forester because of significant current or predicted downward trends in its abundance or habitat capability that would reduce its distribution (FSM 2670.5 (19)). A sensitive species may require special management, so knowledge of its biology and ecology is critical. This assessment addresses the biology and ecology of Lewis's woodpecker throughout its range in Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. In our assessment we do not develop specific management recommendations for the Lewis's woodpecker, but we do try to provide ecological background upon which its management can be based. We also focus on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, we cite management recommendations proposed elsewhere and, when management recommendations have been implemented, we report the results of the implementation.

Scope

The Lewis's woodpecker assessment examines the biology, ecology, conservation status, and management of this species with specific reference to the geographic and ecological characteristics of the Rocky Mountain Region. Although most of the literature on this species originated from field investigations outside the region, this document attempts to place that literature in the ecological and social context of the central Rockies. Similarly, this assessment is concerned with the reproductive behavior, population dynamics, and other characteristics of Lewis's woodpecker in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis, but it is placed in a current context.

In producing the assessment, we reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. Not all publications on Lewis's woodpeckers are referenced in this assessment, nor was all published material considered equally reliable. The assessment emphasizes refereed literature because this is the accepted standard in science. We chose to use some non-refereed literature or reports in the assessment when they provided information unavailable elsewhere. Unpublished data (e.g., Natural Heritage Program records, Partners in Flight 'Watch List') were important in estimating the geographic distribution and conservation status of Lewis's woodpecker. Furthermore, the paucity of field work concerning several important aspects of this species' natural history (e.g., demography) makes the assessment project a constant work in progress.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct experiments that produce clean results in the ecological sciences. Often, we must rely on observations, inference, good thinking, and models to guide our understanding of ecological relations. In this assessment, we note the strength of evidence for particular ideas, and we describe alternative explanations where appropriate.

Publication of Assessment on the World Wide Web

To facilitate their use in the Species Conservation Project, species assessments are being published on the Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, it facilitates their revision, which will be accomplished based on guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior to release on the Web. This report was reviewed through a process administered by the Society for Conservation Biology, employing two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessments.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Lewis's woodpecker was first placed on the National Audubon Society's Blue List in 1975, suggesting that populations were declining. In 1981, the National Audubon Society listed this species as a bird of Special Concern, suggesting that populations were maybe recovering but confirmation would depend on further observation (Tate and Tate 1982). In 1986, the species was listed as a bird of Local Concern by the National Audubon Society, denoting that populations had not shown a decline in the previous year but opinions on the status of the bird were conflicting (Tate 1986). Based on Breeding Bird Survey (BBS; Sauer et al. 2001) and Christmas Bird Count (CBC; National Audubon Society 2002) data from 1966 to 1991 and 1960 to 1989, respectively, Lewis's woodpecker populations may be half of what they were in the 1960s (Tashiro-Vierling 1994). However, both of these survey methods are limited in space (distribution of transects) and time (years of survey). Consequently, these indices may not be adequate for determining regional or local population trends because of the naturally patchy distribution of Lewis's woodpecker and the difficulty in gathering sufficient survey data at these scales. Reported declines in local and regional abundances should be viewed with skepticism (Tate 1981, Behle et al. 1985, Sorenson 1986, Cooper et al. 1998), and attempts to quantify population numbers or trends in the future should be aware of these limitations when designing survey protocols.

The Global Heritage Status Rank of Lewis's woodpecker is G4 (**Table 1**; NatureServe Explorer 2001). This ranking implies that this species is "apparently secure". The National Heritage Status Rank in Canada is N3B (**Table 1**; NatureServe Explorer 2001). Criteria for this ranking specify that during the breeding season the species is very rare and local, found locally in a restricted range, or vulnerable to extinction throughout its range in Canada. Lewis's woodpecker has experienced range contractions in Canada over the last 40 years, and the extent of its distribution is limited with locally occurring populations (Cooper et al. 1998). In the United States, the species' National Heritage Status Rank is N4B and N4N (NatureServe Explorer 2001). This implies that it is "apparently secure" in the breeding and nonbreeding range but may be quite rare in parts of its range with cause for long-term concern.

Lewis's woodpecker is designated a sensitive species by Region 2 of the USDA Forest Service (USFS 2004) and it is categorized as a moderately high priority species on the Partners in Flight National Watch List (Pashley et al. 2000). Partners in Flight recognizes Lewis's woodpecker as a high priority species in montane shrub and coniferous forest habitats of Wyoming (physiographic areas 86 and 64). It has a similar designation in lowland riparian and ponderosa pine (*Pinus ponderosa*) habitats of physiographic area 36, lowland riparian habitat of physiographic area 62, and lowland riparian and coniferous forest habitats of physiographic area 87. However, a paucity of empirical information is available to support these designations.

For the states within Region 2 (except Kansas), Heritage Ranks for Lewis's woodpecker range from S2 to S4, suggesting that this species ranges from "imperiled" to "apparently secure" in its breeding habitat (**Table 1**; NatureServe Explorer 2001). Lewis's woodpecker is considered a transient species throughout the year in Kansas and during the winter in Nebraska and Wyoming. These states assign no rank or a rank of SZN, indicating that the species has no definable occurrence for conservation purposes.

Existing Regulatory Mechanisms, Management Plans, Conservation Strategies

There are no federal or state regulatory mechanisms that specifically address Lewis's woodpeckers. However, they are afforded protection, along with their nests and eggs, from unlawful persecution in the United States by the Migratory Bird Treaty Act (1918) and in the United States and Canada by the Migratory Birds Convention Act (1994). Furthermore, the National Forest Management Act of 1976 (NFMA) requires the assessment of all national

Table 1. Heritage Ranks of Lewis's woodpecker (*Melanerpes lewis*) and county occurrences in USDA Forest Service Region 2 (in bold).

	Heritage Rank		
Location	**Breeding**	**Non-breeding**	**County occurrence**
Global	G4	G4	----
United States	N4B	N4N	----
Canada	N3B	----	----
Colorado	**S4B**	**S4N**	**Arapahoe, Archuleta, Baca, Bent, Boulder, Chaffee, Costilla, Crowley, Custer, Delta, Dolores, Douglas, Elbert, El Paso, Fremont, Garfield, Gunnison, Hinsdale, Huerfano, Jefferson, La Plata, Larimer, Las Animas, Mesa, Mineral, Moffat, Montezuma, Montrose, Otero, Ouray, Park, Pitkin, Prowers, Pueblo, Rio Grande, Saguache, San Miguel**
Kansas	**----**	**SZN**	**----**
Nebraska	**S2B**	**----**	**Dawes, Sheridan, Sioux**
South Dakota	**S3B**	**S3N**	**Custer, Fall River, Meade, Pennington**
Wyoming	**S2B**	**SZN**	**Albany, Big Horn, Carbon, Converse, Crook, Goshen, Lincoln, Natrona, Park, Platte, Sheridan, Weston**

Note: G, N, and S represent global, national, and state heritage ranks, respectively. Numeric ranks indicate conservation status ranging from 1 to 5 (1 = critically imperiled, 2 = imperiled, 3 = vulnerable, 4 = apparently secure, 5 = secure). Z indicates species has no definable occurrence for conservation purposes, usually assigned to migrants or transients. B and N represent breeding and non-breeding season ranks, respectively.

forest lands and the development of management programs based in part on multiple-use principles. In addition to funding public and private research programs, NFMA is in large part responsible for funding the Species Conservation Project.

The U.S. Fish and Wildlife Service has developed a Habitat Suitability Index (HSI) model for Lewis's woodpeckers (Sousa 1983). The HSI suggests that optimal breeding habitat should include 30 percent tree canopy cover, with >50 percent shrub canopy cover, and optimal winter habitat should include 100 percent canopy cover of hard mast producing shrubs and trees, residual corn within 800 meters (m) of the nearest mast storage site, and at least one snag >30.5 centimeter (cm) diameter at breast height (dbh) per 0.4 hectares (Sousa 1983). This model has not been tested.

Management issues and conservation strategies were identified for populations of Lewis's woodpeckers in the Interior Columbia Basin (Wisdom et al. 2000). Management issues of concern included declines in shrub understories; declines in old forests of interior and Pacific ponderosa pine and interior western larch (*Larix occidentalis*); declines in old forests of cottonwood (*Populus* spp.) woodlands; losses of large oak trees (*Quercus* spp.) for mast production; exclusion of fire in montane forests; declines in availability of large snags and trees suitable for nesting, foraging, and mast storage; and potential negative impacts from agricultural pesticides, especially insecticides (DeWeese et al. 1986, Gard and Hooper 1995, Blus and Henny 1997, Wisdom et al. 2000). Recommended practices to improve habitat conditions included maintaining park-like woodlands through silvicultural treatments and prescribed fire; retaining all Oregon white oak (*Quercus garryana*) and ponderosa pine trees taller than 3 m and greater than 30 cm dbh; enforcing fuel wood permits for removal of oaks, pines, and cottonwoods to minimize removal of snags and to minimize the number of roads open to motorized vehicles following timber harvest; encourage maintenance and regeneration of cottonwoods; establish zones of no use of agricultural chemicals surrounding breeding and wintering sites; allow stand-replacing wildfires to burn in lower montane wilderness and other lands managed with a reserve emphasis; develop measures for snag recruitment in unburned forest; and retaining snags in clumps during post-fire salvage logging, leaving various decay classes to lengthen the time those stands are suitable for nesting by Lewis's woodpeckers. As to date, there has not been sufficient time to assess the efficacy of these practices.

The conservation of suitable breeding and wintering habitats is critical for the conservation of Lewis's woodpeckers. Several biologists have recommended the conservation of old ponderosa pine forests and the maintenance of park-like ponderosa pine stands through thinning, prescribed burning, and sparse replanting following harvest (Raphael and White 1984, Linder 1994, Cooper et al. 1998). Design criteria for salvage logging of burned ponderosa pine forest have included retention of snags in clumps rather than uniform distributions (Saab and Dudley 1998, Saab et al. 2002). Conservation of mature cottonwood habitat and retention of snags have also been suggested (Tashiro-Vierling 1994). Management activities, such as mechanical disturbance and manipulation of stream flows, would facilitate cottonwood snag creation and allow for natural cottonwood seedling establishment (Snyder and Miller 1991, Mahoney and Rood 1998). However, a rigorous test of the appropriateness of these approaches for the creation of Lewis's woodpecker habitat has yet to be conducted. In burned forests of Idaho, the best broad-scale predictors of nest occurrence (n=305 nests) were the proximity and area (mean=6.663 ± 0.16 hectares) of burned stands characterized by a pre-fire, 40 to 70 percent crown closure of ponderosa pine/ Douglas-fir (*Psedotsuga menziesii*) (Saab et al. 2002).

Biology and Ecology

Classification and description

Previously considered a monotypic genus (*Asyndesmus*), Lewis's woodpecker is now recognized as a member of the genus *Melanerpes* (American Ornithological Union 1983). In the United States, the genus *Melanerpes* is one of five genera that make up the family *Picidae* (typical woodpeckers), which along with seven other families constitute the order *Piciformes* (Gill 2000). Classification within the *melenerpini* tribe was endorsed due to shared behavioral (Bock 1970, Tobalske 1996), morphological (Burt 1930, Goodge 1972), plumage (Goodwin 1968, Pyle and Howell 1995), and genetic characteristics (Sibley and Ahlquist 1990, Moore 1995). The genus *Melanerpes* is comprised of six species, of which the red-headed woodpecker (*Melanerpes erythrocephalus*) is considered to be the most closely related to the Lewis's woodpecker. Both species are suggested to have descended from a common ancestor of the acorn/ red-fronted woodpecker (*Melanerpes cruentatus*) line (Short 1982). This close association is based on similar ecology and behavioral characteristics combined with largely non-overlapping distributions (Bock 1970, Bock et al. 1971, Short 1982). Currently there are no recognized subspecies or known geographic variations across the range of Lewis's woodpecker.

The oldest known fossil evidence of Lewis's woodpecker was discovered in the Rancho La Brea Tar Pits, California and dated to the Pleistocene (Miller 1929). Associated habitat at the time was probably coastal live oak (*Quercus agrifolia*).

Lewis's woodpecker is the fourth largest North American woodpecker and the largest member of the *Melanerpes* genus. Adults range in size from 26 to 27 centimeters (cm) long, with sing spans of 49 to 53 cm and weights of 88 to 116 grams (Tobalske 1997). Adult plumage is monomorphic and is characterized by glossy-green back, tail, and crown that often appear all dark; red belly and face; and pale gray/silver breast that extends around to the nape, giving it a collared appearance. Juvenile birds have similar "all dark" back and tail combined with brownish head, breast, and belly. Red on face and belly of juveniles is variable, becoming progressively more apparent as they mature post-fledging.

Lewis's woodpeckers differ from other picids in that they lack several anatomical adaptations that facilitate wood excavation (i.e., fused vertebrae, thickened skull; Goodge 1972). Perhaps due to the absence of these adaptations, they nest primarily in snags or soft-wooded trees and favor burned conifer and cottonwood riparian forests as breeding habitat (Tobalske 1997). These habitats provide trees that are more readily excavated and an abundance of aerial insects. Lewis's woodpeckers rarely, if ever, probe for wood-boring insects but instead employ the technique of fly catching. This feeding behavior is aided by an enlarged gape; relatively long, pointed wings; and distinctive flight, which is direct and slow with frequent glides, resembling that of a crow or jay more than other woodpeckers (Bock 1970, Goodge 1972, Tobalske 1996).

Distribution and abundance

Recognized distribution

Lewis's woodpecker distribution closely matches that of ponderosa pine in the western United States (Diem and Zeveloff 1980, Saab and Vierling 2001). This association forms the basis for its primary breeding habitat but not exclusively. Lewis's woodpecker is known to occur from southern British Columbia to northern Mexico. Its western limit is the Pacific Coast of California, Oregon, and Washington, and its range extends east to the eastern slopes of the Rocky Mountains, including portions of Montana, Wyoming, South Dakota, Colorado, and New Mexico (**Figure 1**). Rare sightings of transient individuals have occurred as far east as New England, as far south as Texas, and as far north as Alberta, Saskatchewan, and Manitoba. Throughout its range populations are patchily distributed in suitable habitats.

The breeding and non-breeding ranges of Lewis's woodpecker are fairly well delineated in western North America. The year-round range of resident populations

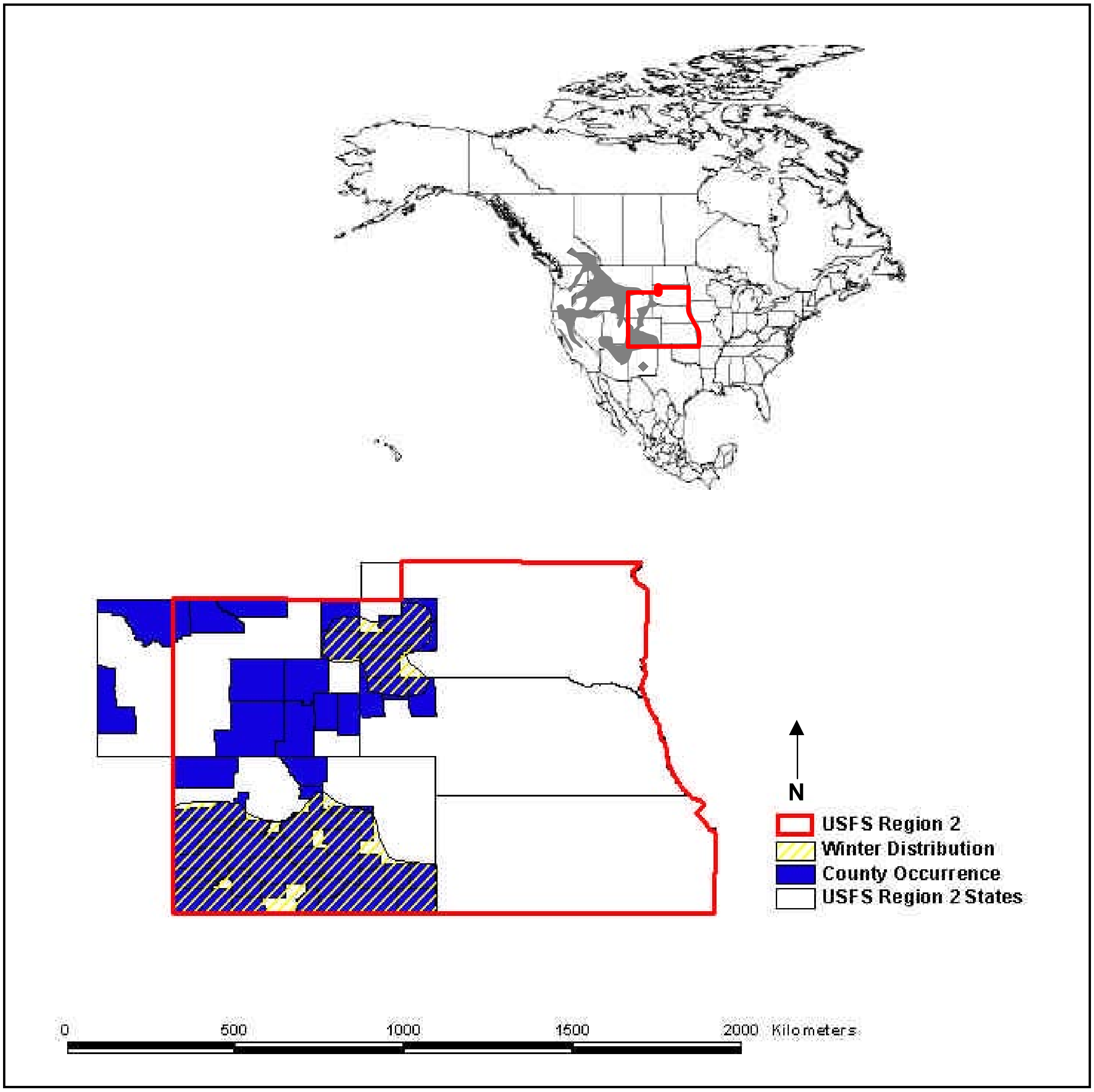

Figure 1. Relationship of Lewis's woodpecker distribution in the USDA Forest Service Rocky Mountain Region (R2) to the species' geographic range in North America based on county occurrence (breeding and wintering) records. In addition, Lewis's woodpecker winter range within R2 is depicted. Map of North America distribution derived from Tobalske (1997).

is also described but less well documented, with yearly and seasonal variations in movements and migrations thought to be influenced by local food availability. Breeding occurs most often in open forests or woodlands including park-like stands of ponderosa pine, riparian cottonwoods, and burned or logged conifer forest. Wintering sites include oak woodlands or commercial orchards where birds collect and store mast (see Broad habitat use patterns below).

Breeding range

In Canada, Lewis's woodpecker distribution is primarily limited to south-central British Columbia although they occasionally breed in the foothills of western Alberta. They are found breeding on both sides of the Cascade Mountains in Washington and Oregon, with populations having experienced more dramatic declines on the western side (Bock 1970, Siddle and Davidson

1991, Gilligan et al. 1994). In California, they breed throughout much of the state from the Oregon border south along both sides of the Sierra Nevada Mountains with range contractions having been reported for several southern counties (Bock 1970, Garrett and Dunn 1981, Small 1994). They commonly nest throughout Idaho and in isolated portions of northern Nevada (Alcorn 1988, Stephens and Sturts 1991, Gough et al. 1998), northern portions of Arizona, and eastern portions of Utah along the Colorado border, with precipitous local declines being experienced around Salt Lake City, Utah (Snow 1941, Sorensen 1986). They breed west of the Rocky Mountains in most of western Montana and in the southeast corner of the state in Powder River and Carter counties (Bergeron et al. 1992). They occur and breed across much of New Mexico including Bernalillo, Catron, Los Alamos, Otero, San Miguel, and Socorro counties (Hubbard 1978, Travis 1992). They have been documented nesting in Oklahoma, but are considered rare and irregular (Tyler 1979, Baumgartner and Baumgartner 1992).

In the Rocky Mountain Region of the USFS, birds breed throughout much of Wyoming east of the continental divide, with suitable habitat found most readily in the northeast and southeast portions of the state (**Figure 1**; Oakleaf 1992, Linder and Anderson 1998). In South Dakota, they breed in the southwest corner around the Black Hills (Peterson 1995); counties in which breeding has been confirmed include Fall River, Custer, Pennington, and Meade (**Table 1**). In Colorado they can be found breeding from the northeast limit of Larimer County south along the Front Range to Denver (Andrews and Righter 1992, Tashiro-Vierling 1994, Kuenning 1998). In southern Colorado birds are most strongly represented in the Arkansas River watershed, open pinyon pine and juniper habitat of Las Animas and Huerfano counties and the San Juan Basin, with significant numbers breeding north of the San Juan Mountains toward Grand Junction (Kuenning 1998). Significant breeding areas are also located in the Black Forest northeast of Colorado Springs. Apparent range expansion in southeastern Colorado plains along the Arkansas and Platte river drainages has been evident since 1910 but more pronounced since the 1950s (Hadow 1973, Andrews and Righter 1992, Tashiro-Vierling 1994). There have been fewer than 10 reported records for the state of Kansas (Kansas Ornithological Society 2003). In Nebraska, Lewis's woodpeckers were once considered rare but now very rare or possibly extirpated as a breeding species (Johnsgard 1979). They are a vagrant and possible summer resident near Pine Ridge in Sheridan County, Nebraska. During spring and fall migration they have been documented in the northwest portion of Nebraska and as far east as Brown, Buffalo, and Adams counties. Occasional sightings in Nebraska are probably migrants from the Black Hills area of South Dakota (Johnsgard 1979, DeSante and Pyle 1986).

Non-breeding range

In late summer or early fall, adult and juvenile Lewis's woodpeckers congregate into loose, nomadic flocks. During this period, birds make short altitudinal movements (Bock 1970). Eventually, birds move to wintering territories where they actively store and defend mast crops alone or in pairs. Mast, often in the form of acorns, leads this species to winter in oak woodlands, but they will also feed extensively on commercially grown crops including fruit, nuts, and corn. Although seasonal movements vary in magnitude and duration (see Movements below), wintering sites are generally located in the southern portion of their breeding range (extending south from approximately southern Oregon, central Utah, and central Colorado). Birds nesting in the southern portion of the breeding range often remain resident year-round or make short migrations to areas with abundant food. Winter range extends south of the breeding range to approximately San Quintin in Baja California Norte, Sonora, and northern Chihuahua, Mexico (Howell and Webb 1995, Tobalske 1997). However, occurrence of individuals during winter outside of the breeding range is sporadic, varying in magnitude yearly.

In British Columbia and Washington, small numbers of birds remain resident through the winter (Galen 1989, Campbell et al. 1990, Cooper et al. 1998). They are considered relatively common in portions of southern Oregon and throughout much of California although contractions in their range have been noted in the Willamette Valley, Oregon and several Southern California counties including Kern, Inyo, and San Bernardino (Gilligan et al. 1994, Small 1994, Garrett and Dunn 1981). In central Utah, birds winter in valley bottoms on the west side of the Wasatch Range around Salt Lake City, Utah and extending north and south to the borders of Idaho and Arizona (Snow 1941, Bock 1970). Evidence suggests wintering abundance in this region has declined (Sorensen 1986). Birds winter throughout much of Arizona, with a portion of these individuals remaining as year-round residents (Bock 1970, Monson and Phillips 1981). In New Mexico, they winter at lower elevations in the central portion of the state and extending southward toward the Mexican border, westward toward Arizona and northeast toward Colorado and Oklahoma (Hubbard 1978, Travis 1992). In Colorado, populations winter or remain partially resident in riparian and woodland habitat of the eastern plains, south-central, and west-central portions of the state including Baca, Las Animas, Prowers, Bent, Otero, Crowley, Pueblo, Custer, Morgan, Adams, Weld, Elbert, Larimer, La Plata, Archuleta, Montezuma, Dolores, Montrose, Delta, and Mesa counties (**Figure 1**; **Table 1**; Bock 1970, Hadow 1973, Andrews and Righter 1992, Tashiro-Vierling 1994, Vierling 1997, Kuenning 1998). Populations in the northern portion of the breeding range including northern Idaho, Montana, Wyoming, and South Dakota are almost exclusively migratory, but limited numbers of birds may reside throughout the winter (Bock 1970, Hadow 1973).

Estimates of local abundance and population trends

Quantifying total population size is a significant task in this species due to its spatially and temporally patchy distribution (DeSante and Pyle 1986). The only study of which we are aware that attempted to estimate population size was conducted in British Columbia, where the number of breeding pairs in the province was estimated to be between 350 and 600 (Cooper et al. 1998). Point estimates of nesting densities were four times greater in burned pine forest of Idaho than in cottonwood habitats of Colorado (0.4 vs. 0.1 nests per 10 hectares in Idaho and Colorado, respectively, although measures of precision were not calculated; Saab and Vierling 2001). Using a 200-meter wide belt transect, the number of nests per kilometer ranged from 0.94 to 1.2 in partially salvage logged burned forest of Idaho (Saab and Dudley 1998).

Populations are reported to be most abundant in northeastern Arizona, north-central New Mexico, south-central Colorado, northern California, Washington, Oregon, and Idaho during the breeding season (Toabalske 1997, Gough et al. 1998). During the winter, they appear most abundant in northern California near Red Bluff and Sacramento Valley extending south, east-central Arizona, northern New Mexico from Albuquerque north to the Colorado border, and southeastern Colorado (Root 1988, Gough et al.1998). Additional information on species abundance is difficult to discern.

Breeding Bird Surveys and Christmas Bird Counts represent the only long-term data to assess a broad scale trend in Lewis's woodpecker populations. As with many bird species, limitations of both methods for discerning population trends of Lewis's woodpeckers at various scales have been addressed (Sauer et al. 2001). For example, the year-to-year variation in abundance at any one locale may not indicate overall population decline but simply reflect a lack of detection on the part of the surveyor or an abandonment of one location for another on the part of the birds. Mindful of the limitations of the two methods, it appears that populations of Lewis's woodpeckers have declined during the past three or four decades. Examining range-wide trends, Tashiro-Vierling (1994) reported statistically significant declines of 56 percent between 1966 and 1991 ($p<0.05$) and 60 percent between 1960 and 1990 ($p<0.01$) using BBS and CBC data, respectively. At a finer scale, analysis of CBC data from Colorado revealed a significant negative trend of unspecified magnitude between 1960 and 1989 ($p<0.006$; Tashiro-Vierling 1994). Analysis of population trends in Colorado, the only state in Region 2 with sufficient BBS data, showed a slightly negative but insignificant trend ranging from -0.6 ($p=0.88$) to -2.1 ($p=0.77$) percent change in population abundance per year when using data from 1966 to 2000 and 1980 to 2000, respectively. Due to limited detections (number of birds) and small sample size (number of transects), the results are highly imprecise, enough so that a change of 5 percent per year would be difficult to detect. The results from BBS data do not represent evidence of a decline in Colorado (note the extreme p-values).

Local or state declines in numbers have also been reported in British Columbia (>50 percent), Oregon (58.9 percent), California (2.5 percent), Utah (unspecified), Lincoln County, Montana (unspecified), and Washington (unspecified) over the last 100 years, but declines were not statistically significant (Weydemeyer 1975, Tate 1981, Sorensen 1986, DeSante and George 1994, Tashiro-Vierling 1994, Cooper et al. 1998). Both Oregon and California showed negative state trends using BBS (years 1966 to 1991) and CBC (years 1960 to 1989) data, but these trends were not statistically significant (Tashiro-Vierling 1994).

Movements

Home range

No empirical data are available on home range size and use. Thomas et al. (1979) reported home range size of breeding birds ranging from 1 to 6 ha in the Blue Mountains of Washington and Oregon, but this estimate does not have documentation of sample size or methods. Several researchers have reported more than one pair nesting in a single snag (Currier 1928, Snow 1941), and although it may not be common, pairs nesting in snags only a short distance apart are often seen (Bock 1970). This semi-gregariousness is thought to facilitate nesting in locations with locally abundant food sources. During the breeding season, pairs defend the immediate area surrounding the nest tree (Bock 1970, Hadow 1973, Linder 1994, Tashiro-Vierling 1994). During the winter, previously mated males and females defend separate or shared mast storage sites (Bock 1970, Vierling 1997). Foraging ranges of territorial birds may overlap extensively in summer and winter (Bock 1970). For example, Bock (1970) reported four birds from two different nests making extended fly-catching flights over a single pond during an insect hatch. During the winter in southeastern Colorado, birds foraged and cached acorns in close proximity to one another, occasionally in the same tree (Tashiro-Vierling 1994). However, no evidence exists to suggest cooperative behavior among individuals. Instead, birds remain highly territorial but limit defensive behavior to the immediate area of the tree containing their cache.

Migration

Seasonal movements of Lewis's woodpeckers are not well understood, as no data are available on marked individuals. The variable nature of the birds' migration from their breeding habitat in open woodlands to winter habitat in oak woodlands or commercial orchards further complicates our understanding of their movements. Variation in routes, timing, and extent of migration probably revolve around the birds' foraging behavior, which takes advantage of temporarily abundant local food supplies (Bock 1970). Birds in breeding areas that provide ample winter food may remain year round or perhaps migrate only short distances. For example, in a study using non-marked individuals, approximately 50 percent of the study population breeding in southeastern Colorado reportedly moved to western Colorado for the winter, while the remainder made no movement (Hadow 1973). In general, birds breeding in the northern extent of their distribution are more likely to make "long" migrations, while birds nesting in the southern portion of their distribution may reside year round, make short altitudinal migrations, or migrate to the nearest areas providing sufficient mast (Bock 1970).

Although Lewis's woodpeckers are often thought to exhibit site fidelity, breeding habitats may be abandoned if prey abundance is limited (Bock 1970). Their foraging habits, which take advantage of superabundant local food supplies, suggest that nesting and wintering locations occur where insect prey and mast crops are readily available. Thus, migratory routes and timing may vary between years, and bird occurrence may vary year-to-year at any one location. Lewis's woodpeckers are often nomadic during late summer or early fall, prior to true fall migration (Snow 1941, Bock 1970). Nomadic movements tend to result in birds moving to higher elevations, but the extent and direction of these movements are not well understood (Gabrielson and Jewett 1940, Bock 1970). The extent of nomadic movements during the late summer may alter the duration of fall migration yearly and among populations.

Generally, Lewis's woodpeckers depart breeding grounds in late August to early September and arrive at wintering sites mid-September to mid-October (Tobalske 1997). They arrive on breeding grounds in late April to early May after departing from wintering sites in mid- to late April. Due to their nomadic movements during the fall, spring migration is presumed to be shorter in duration and more direct (Bock 1970).

In Wyoming, Idaho, and Montana fall migrants depart in mid-August through late October, peaking in mid-September, while spring migrants arrive on breeding grounds from late April through late May, peaking in early May (Bock 1970). In the Black Hills of South Dakota, birds depart their breeding areas in late August and return to breed in the last half of May (Pettingill and Whitney 1965). Migratory birds in Colorado leave their breeding areas in late September and return between late April and mid- May, with peak numbers arriving in early May. Some individuals are year-round residents in Colorado (Bock 1970, Hadow 1973).

While movements probably vary with annual variability in food, it appears fall movements may be toward the nearest suitable winter habitat (Bock 1970). Birds breeding in the Wasatch Front of Utah moved to higher elevations in the fall before returning to valley bottoms for the winter, with total movements ranging from 0.8 to 9.0 kilometers (km) (Snow 1941). Movements by birds on the Front Range of Colorado appeared to be short and local, focused around oak woodlands and commercial corn plantations (Bock 1970, Hadow 1973, Tashiro-Vierling 1994). Furthermore, portions of the population of birds breeding on the plains of Colorado were year-round residents (Bailey and Niedrach 1965, Hadow 1973). For example, eight of 18 pairs that nested within 100 m of cornfields remained throughout the winter (Hadow 1973). General movements of birds may be from higher elevation ponderosa pine habitat toward lower cottonwood riparian habitat. During mild winters in the Black Hills of South Dakota, some breeding birds did not migrate, but the habitat in which they were found during the winter was not reported (Pettingill and Whitney 1965).

In contrast to residents or short distance migrants, birds in the northern portion of their distribution (British

Columbia, Idaho, Wyoming, Montana) may travel from 100 to 1000 km to wintering grounds (Bock 1970, Tashiro-Vierling 1994, Tobalske 1997). Travel routes and distances for these populations are not known, but the birds are thought to move westward into Oregon and California, southeast toward Colorado, or south into Arizona and Utah. The migration pattern appears to be determined by several factors including the location of breeding grounds, habitat availability along migration routes, and annual food availability.

Data on migratory flight behavior are limited. Flights are typically diurnal, with speeds resembling that of normal flight (Bock 1970). Group size may range from two to 5000 individuals, in no apparent formation or cohesion (Adams 1941, Smith 1941, Bock 1970). Altitude of flight may vary from 3 to >150 m off the ground (Adams 1941, Smith 1941). Migratory flight behavior has been reported as direct as well as meandering, where birds flew in a circling pattern, occasionally stopping to perch (Adams 1941, Smith 1941, Hadow 1973).

Broad habitat use patterns

Breeding habitat

Breeding habitat for Lewis's woodpecker is characterized by an open canopy, brushy understory, available perch sites and abundant insects (**Figure 2**; Bock 1970, Sousa 1983, Tobalske 1997, Linder and Anderson 1998, Saab and Dudley 1998). Lewis's woodpeckers do not excavate for wood-boring insects, as do most North American woodpecker species. Instead during the breeding season these woodpeckers feed primarily on aerial arthropods captured through short direct flights to a specific prey item or through extended flycatching forays (see Food habits below; Bock 1970). Open forest appears to facilitate foraging and is consistently associated with breeding habitat (Bock 1970). While a certain number of trees are necessary for nesting and perching sites, a closed canopy forest is not suitable due to reduced visibility, limited room for aerial maneuvers, and retarded shrub development (Bock 1970, Saab and Dudley 1998). The HSI model for Lewis's woodpecker suggests that ideal breeding habitat would consist of no more than 30 percent tree canopy closure (Sousa 1983). In support of this model, similar findings for canopy closure were reported in burned pine forests in southeast Wyoming when comparing used versus random sites (**Table 2**; Linder and Anderson 1998).

Lewis's woodpeckers will use the shrub understory or the ground to glean terrestrial insects or fruits. A closed canopy forest limits the development of ground cover, which is important in maintaining certain insect populations. In burned habitats of Wyoming (Linder and Anderson 1998) and California (Block and Brennan 1987), the percentage of shrub cover at nest sites ranged from 13 percent to 16 percent. However, shrub crown cover at breeding sites did not differ significantly from randomly generated sites within the same habitat (**Table 2**).

Because Lewis's woodpeckers are equipped with weak excavation morphology compared with other woodpeckers (Spring 1965), they prefer to excavate nests in trees in advanced stages of decay, re-use pre-existing cavities, or usurp cavities from other woodpecker or secondary cavity-nesting species (**Table 2**; Bock 1970, Raphael and White 1984, Saab and Dudley 1998, Saab and Dudley unpublished data). Lewis's woodpeckers have not been observed excavating in live trees (Bock 1970, Sousa 1983, Linder and Anderson 1998). Burned conifer forests provide an abundance of suitable snags. However, suitability may vary with time since fire, pre-fire conditions, tree species, tree condition, weather conditions, and other unknown variables (Bock 1970). Once snags have reached the state at which their tops begin to break off and their wood begins to soften, conditions may develop that are more conducive to excavation. Riparian cottonwood also tends to provide suitable nest sites because of the soft nature of decaying cottonwood, frequent rot conditions in cottonwood trees, and the abundance of aerial insects associated with riparian habitats (Bock 1970).

Burned ponderosa pine stands probably represent high quality breeding habitat for Lewis's woodpecker based on nest-site selection and reproductive success (Bock 1970, Linder and Anderson 1998, Saab and Dudley 1998, Saab and Vierling 2001). Suitability of burned habitat, however, may vary with stand age prior to fire, time since fire, fire size, fire intensity, and geographic locale (Bock 1970, Raphael and White 1984, Block and Brennan 1987, Tobalske 1997, Linder and Anderson 1998, Saab and Dudley 1998). Preference for pine forest may be stronger at low to medium elevations and for riparian cottonwoods at low elevation (Bock 1970, Diem and Zeveloff 1980, Cooper et al. 1998, Linder and Anderson 1998). However, whether this is due to preference or availability has not been studied. Breeding birds have also been documented in landscapes dominated by oak woodlands, commercial nut and

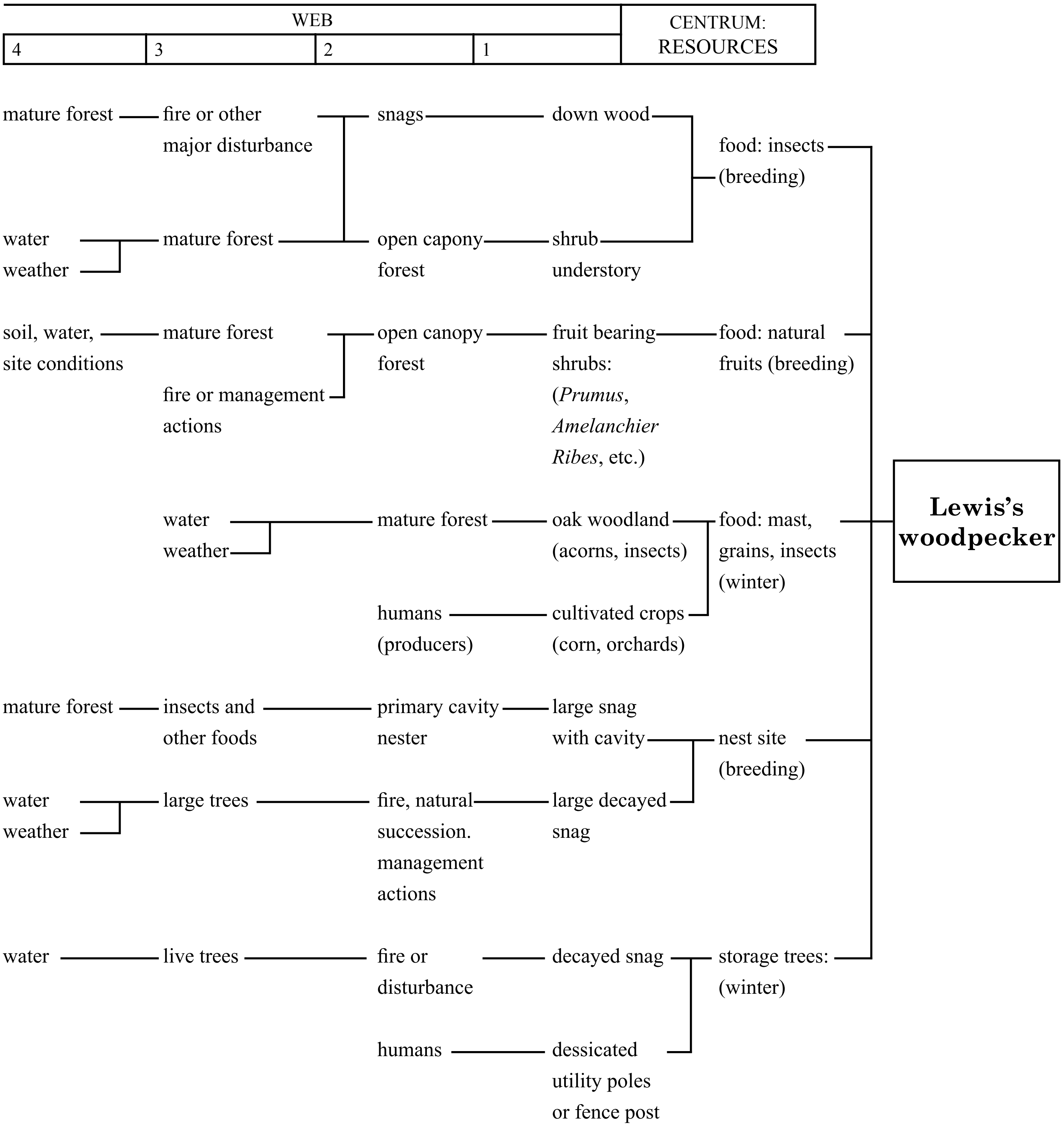

Figure 2. Envirogram representing the web of linkages between Lewis's woodpeckers in western North America and the dominant resources they use in forest ecosystems where they occur. This web depicts a series of hypotheses based on the ecology of Lewis's woodpecker as described throughout this assessment. For more information on the application of envirograms in conservation biology see Andrewartha and Birch (1984) and Van Horne and Wiens (1991).

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Table 2. Habitat characteristics of nest sites of Lewis's woodpeckers in western North America. Sample size (number of nests) reported in parentheses.

Feature	Idaho	Colorado	Wyoming	California
Cavity/nest tree				
Mean nest tree height (m)	14.9 ± 5.3 SD[1] (115)	20.4 ± 5.2 SD (47)	10.6 ± 3 SD (35)	11.4[1] (37) 8.3 ± 0.7 SE[3] (25)
Mean nest tree dbh (cm)	47.5 ± 1.1 SE[2] (354)	112.6 ± 39 SD (47)	48 ± 8.0 SD (35)	66.5[1] (37)
Snag decay/condition	Medium – heavy[2] (354)			Soft[1] (37)
Mean cavity height (m)	12.8 ± 4.8 SD[1] (115)	11.1 ± 3.4 SD (47)	7.5 ± 2.5 SD (35)	7.3[1] (37)
Mean cavity entrance diameter (cm)				6.2 ± 0.16 SE[1] (23) 6.7 ± 0.7 SD[2] (3)
Mean cavity depth (cm)				33.7 ± 1.4 SE[1] (23) 32.3 ± 4.9 SD[2] (3)
Surrounding vegetation				
Mean shrub cover (%)	35.1 ± 22.8 SD[1] (115)		16.1± 13.4 SD (35)	13.4 ± 3.2 SE[3] (25)
Mean canopy cover (%)	5.2 ± 5.6 SD[1] (115)		27.3 ± .13 SD (35)	
Mean litter (%)	53.1 ± 18.6 SD[1] (115)		18.7 ± 11 SD (35)	
Snags density /ha (>23 cm d.b.h.)	60 ± 6 SE[2a] (84) 63 ± 6 SE[2b] (118)			

Sources of information: Idaho, Abele (unpublished data)1, Saab and Dudley (1998)2, Saab et al. (2002)2; Colorado: Tashio-Vierling (1994), Vierling (1997); Wyoming: Linder (1994), Linder and Anderson (1998); California: Raphael and White (1984)[1], Bock (1970)[2], Block and Brennan (1987)[3].

[a] Standard salvage logging prescription

[b] Wildlife salvage logging prescription

fruit orchards, piñon pine-juniper (*Pinus cembroides* – *Juniperus* spp.) woodlands, fir forests (*Abies concolor*), and cottonwoods surrounded by agriculture (Bock 1970, Raphael and White 1984, Vierling 1997, Cooper et al. 1998, Linder and Anderson 1998, Saab and Vierling 2001). Preference for ponderosa pine is likely influenced by the depth and relative softness of sapwood compared to Douglas-fir, true firs (*Abies* spp.), and other pine species (*Pinus* spp.; Bull et al. 1997).

In southeast Wyoming, Lewis's woodpeckers selected burned ponderosa pine forests. Active nests occurred almost exclusively (98 percent) in burned stands, although only 41 percent and 21 percent of two study areas were burned (Linder and Anderson 1998). In three sites in California, birds were reported nesting in a burn 19 to 22 years post-fire but not in two other burns that were seven and 30 years post-burn (Bock 1970). The older burn was described as lacking suitable nest snags, and the younger was thought not to be good due to the dense nature of the stands and the lack of shrubs. In contrast, birds were observed in greater abundance in an 8-year old burn than in a 20-year old burn in southeast Wyoming, where the sizes of the fires were 1,590 ha and 1,295 ha, respectively (Linder and Anderson 1998). In a 24,000 ha high elevation, mixed conifer burn in northwestern Montana, birds were rare but present five years post-fire (Caton 1996). Lewis's woodpeckers were the most abundant cavity-nesting species in two large (100,000 and 30,000 hectares) burns characterized by low elevation ponderosa pine/Douglas-fir forest, within two to four years post-fire in western Idaho (Saab and Dudley 1998).

Research conducted in logged and unlogged burned forests in western Idaho identified several variables important in predicting nest occurrence (Saab et al. 2002). In unlogged areas (n=50 nests), nests were associated with larger patches of ponderosa pine with a pre-fire crown closure of 40 to 70 percent, while in logged forests (n=305 nests) nests were associated with smaller patches of ponderosa pine/Douglas-fir with a pre-fire crown closure of 40 to 70 percent.

Comparisons of nesting success between burned ponderosa pine forest (n=283 nests, nest success=78 percent) and cottonwood riparian woodlands (n=65 nests, nest success=46 percent) suggested that productivity differed because of differences between the two landscape matrices (Saab and Vierling 2001). Cottonwood forests were surrounded by an agricultural matrix where nest predators were likely very different than the predator assemblage occupying a large-scale burn in a relatively natural habitat matrix. Potential nest predators in cottonwood forests included human-commensal species such as raccoons (*Procyon lotor*), fox squirrels (*Sciurus niger*), and American magpies (*Pica hudsonia*), while in burned pine forests red squirrels (*Tamiasciurus hudsonicus*) and northern flying squirrels (*Glaucomys sabrinus*), gopher snakes (*Pituophis melanoleucus*), chipmunks (*Eutamias minimus*), and black bears (*Ursus americanus*) were present but usually in association with adjacent unburned forest.

Winter habitat

In the fall, Lewis's woodpeckers' primary food source shifts from arthropods to a variety of mast and grains (**Figure 2**). Lewis's woodpeckers primarily move to locations where mast and grain are readily available during winter, although they will continue to feed on aerial insects where available (Bock 1970). Primary wintering habitats in order of importance are oak woodlands, commercial orchards, riparian woodlands, and cornfields (Bock 1970). Caching behavior during winter requires an abundance of nuts and an availability of suitable storage trees. Occasionally telephone poles will substitute for caching trees if they are in a state of slight decay (Janos 1991). Bock (1970) suggested that some birds might winter without mast in portions of southern California and in Arizona where insects remain available.

Microhabitat

Nest sites

Several specific habitat characteristics appear to be important for nest-site selection (**Figure 2**; **Table 2**). In southeastern Wyoming, the amount and size of dead and down woody material, canopy cover, and ground cover differed among nest sites versus random sites (n=35 nests; Linder and Anderson 1998). Used plots had less small downed wood (<30 cm), more large downed wood (31 to 90 cm and >91 cm), more litter (18.7 percent vs. 9 percent), and a tendency toward less grass and forb cover than random sites. Lastly, canopy cover, which was composed mainly of dead, bare branches, was significantly greater at used sites (27 percent) than at random sites (4 percent). Linder and Anderson (1998) suggest that the size and amount of downed woody debris influenced insect production while greater canopy cover at nest sites indirectly indicated an increased availability of foraging and perching sites. Unfortunately this investigation did not look at the potential interactions among variables. Other variables that may be important to nest-site selection include the absence of human structures, the condition of surrounding agricultural fields (i.e., grazed, mowed, fallow, cultivated; Vierling 1997), and tree density (Saab et al. 2002). In western Idaho, Lewis's woodpeckers selected nest sites (n=208 nests) with higher densities of snags compared to random sites, suggesting a preference for snags distributed in clumps rather than those in uniform distributions (Saab et al. 2002). The mean number of snags per hectare surrounding nest trees was 62.1 ± 3.7 SE and 91.7 ± 26.4 SE on logged and unlogged study sites, respectively; snag densities at random sites were 36.4 ± 2.1 SE and 41.5 ± 5.5 SE on logged and unlogged study sites, respectively.

Nest tree and cavity characteristics

Lewis's woodpeckers are primary cavity excavators, but they most often nest in existing cavities and will reuse the same nest cavity for successive years (**Figure 2**; Bock 1970, Linder 1994, Tashiro-Vierling 1994, Vierling 1997, Saab and Dudley 1998, Saab et al. 2004). They often enlarge or use cavities excavated by other woodpecker species including pileated woodpecker (*Dryocopus pileatus*), hairy woodpecker (*Picoides villosus*), black-backed woodpecker (*Picoides* *arcticus*), and northern flicker (*Colaptes auratus*). Excavations of new cavities are almost exclusively in heavily decayed snags or dead portions of live trees (Bock 1970, Sousa 1983). In southeastern Wyoming, 91 percent of nests were in standing snags, and 9 percent were in dead portions of live trees (Linder and Anderson 1998). In burned pine forest of western Idaho, nearly 50 percent of 132 nest cavities originally occupied by Lewis's woodpeckers were reused by Lewis's woodpeckers in subsequent years (Saab et al. 2004). Furthermore, once a Lewis's woodpecker occupied a nest cavity, occupancy was maintained by this species for several years (up to seven years after fire).

Characteristics of nest trees and reported cavity dimensions vary among studies (**Table 2**). Nest height ranges considerably from 1 to 52 meters (Bock 1970, Campbell et al. 1990, Linder 1994, Tashiro-Vierling 1994, Linder and Anderson 1998). Based on literature review, Bock (1970) reported cavity depth ranged between 22.8 and 76.2 cm, and entrance diameter ranged between 5 and 7.5 cm (sample size not reported). From limited field measurements, cavities averaged 17.3 ± 3.8 cm internal diameter (range 13 to 20 cm), with an entrance diameter range of 6.3 to 7.5 cm (n=3; Bock 1970). In the Sierra Nevada Mountains of California, nest cavities (n=23) averaged 16.5 ± 0.6 cm horizontally with an average sill width of 3.3 ± 0.3 cm (Raphael and White 1984).

Lewis's woodpeckers will nest in a variety of tree species including ponderosa pine, Jeffrey pine (*Pinus jeffreyi*), white fir (*Abies concolor*), lodgepole pine (*Pinus contorta*), juniper, willow (*Salix* spp.), paper birch (*Betula papyrifera*), cottonwood, and aspen (*Populus tremuloides*; Tobalske 1997). In British Columbia, 47 percent of nests were in deciduous trees and 42 percent were in conifers (n=215; Campbell et al. 1990). The most frequently used species were ponderosa pine (35 percent) and black cottonwood (*Populus trichocarpa*; 33 percent), with nests occurring in both live trees and snags. In the Blue Mountains of Oregon and Washington, nest cavities (n=49) were located in cottonwoods (72 percent), ponderosa pine (12 percent), juniper (10 percent), willow (4 percent), and fir (2 percent; Thomas et al. 1979). In the Sierra Nevada Mountains of California, all nests occurred in soft snags with an average of 59 percent bark cover. Of 37 nests, 54 percent were in white fir, 43 percent in Jeffrey pine, 3 percent in lodgepole pine, and 2 percent in other (Raphael and White 1984). In Pueblo, Crowley, and Otero counties of Colorado, 100 percent of the nests occurred in dead or decaying cottonwoods (n=47 nests; Tashiro-Vierling 1994).

Storage sites

Little research has been conducted on Lewis's woodpecker food storage sites or their winter ecology. During winter, they feed extensively on nuts and fruit (**Figure 2**; Bock 1970, Hadow 1973, Vierling 1997). Trees used for mast storage in southeastern Colorado differed significantly from random trees (n=34 trees; Vierling 1997). Storage trees were predominately dead or decaying cottonwoods that were significantly taller and of greater diameter than random trees. Lewis's woodpeckers tend to use natural cavities and crevices in decayed snags or power poles for storage sites. The presence of deep furrows in cottonwoods and available crevices in decaying trees may facilitate the storage process (Vierling 1997). In the foothills of the Wet Mountains of Colorado, the mean percentage of oak trees around storage sites was dramatically greater than around random sites, suggesting a strong selection for wintering sites near good sources of acorns. Lewis's woodpeckers typically defend an individual storage tree (Bock 1970). Some birds share and defend only the section of a tree where their acorns were stored, suggesting that storage trees might be limiting in this part of Colorado (Vierling 1997). Along the Arkansas River Valley of Colorado, the mean percentage of grazed, fallow, and plowed fields was significantly greater around random sites compared to storage tree sites (Vierling 1997).

Roost sites

Little information is known about the importance of roost sites for Lewis's woodpeckers. During the breeding season, males are thought to incubate eggs and brood nestlings at night, while females roost in an alternative cavity (Tobalske 1997). This may suggest the need for an additional cavity in close proximity to the nest site. Similarly, during the winter, old nest cavities may be used for roosting (Cooper et al. 1998).

Foraging sites

There are no published accounts that have attempted to quantify habitat or vegetation characteristics surrounding foraging sites. However, based on Lewis's woodpeckers primary foraging method (see Foraging methods below) and research on nest-site selection, foraging locations are likely associated with open forest structure. During the breeding season in pine forest of California, foraging substrates consisted of 66 percent snag, 15 percent ground, 14 percent live trees, 3 percent bush, and 2 percent downed wood (n=88 foraging bouts; Raphael and White 1984). The use of snags and trees was presumably for gleaning or flycatching perch sites, but time spent performing each of these actions was not delineated. Because they feed on locally abundant food, individuals from neighboring territories often feed in the same location.

Food habits

Foraging methods

The Lewis's woodpecker has a broad diet ranging from hard and soft mast to an array of insects. Described as opportunistic (Bock 1970, Hadow 1973), it employs several methods to collect a variety of food resources (**Figure 2**). "One of the most aerial woodpeckers" (Bock 1970), they exhibit morphological characteristics that reflect their primary method of prey capture – flycatching. In California, birds spent between 53 and 66 percent of their time scanning for prey from a perch or actively flycatching (Bock 1970). Lewis's woodpeckers are not known to excavate for wood-boring insects like most picids, although they will glean tree boles and flake bark (Bock 1970).

Hawking flights originate from a perch, are focused on an individual aerial insect, and are highly visually oriented (Bock 1970). Birds spend time scanning from a prominent perch, often located at the distal tips of dead branches or treetops, before initiating a hawking flight that may extend 60 meters (Bock 1970). Perch location often affords high visibility and room for aerial maneuvers (Bock 1970, Saab and Dudley 1998). Lewis's woodpeckers use this method of scanning from a perch site to forage on the ground surface and shrub canopy.

Extended flycatching forays differ from hawking flights in that they are not oriented toward a specific prey item. Much like swallows and swifts, the birds range in altitude and duration during extended flights, usually returning with several insects. The duration of these flights may range from several minutes to a half hour or more, with the bird often returning to the nest or perch (Bent 1939, Bock 1970). Bock (1970) reported that approximately 12 percent of observed flights were of this type (n=677 observations). The time spent scanning is largely eliminated during these non-specific forays, suggesting that this type of foraging behavior may be more pronounced when the density of insects is high and the likelihood of a chance encounter is great.

Lewis's woodpeckers glean insects from trees in a manner similar to other woodpeckers. They move by "hitching" up the tree while using their tail as a prop. Their movements are slow while gleaning, and they often stop to chip and flake bark while visually searching cracks and fissures in the wood. Gleaning tree boles represented only 10 percent and 17 percent of the time spent foraging during the breeding season in California pine forest and oak woodlands, respectively, representing less time than flycatching or ground-shrub foraging (Bock 1970).

Harvest of acorns is accomplished in three steps: collecting, shelling, and caching (Bock 1970). Acorns are typically taken from the tree and not the ground. The bird collects, shells, and stores the acorn pieces in natural crevices. During collection, the bird plucks the acorn from its cup by grasping the acorn then twisting and pulling. The bird often grasps the acorn while standing upright on a stem in the distal portions of trees but will also hang upside down to reach desired nuts (Snow 1941, Bock 1970). After collection, the bird flies to a perch used for shelling. An individual bird often has a couple of shelling sites, which are used repeatedly. To remove the shell, the bird hammers the nut with direct blows that are usually vertical to gain maximum force and delivered in short bouts followed by a pause (Bock 1970). After a nut is extracted and broken into pieces, the bird consumes the meat or flies to a storage site for caching.

Diet

Principle prey items during the breeding season include ants, bees, and wasps (Hymenoptera); a variety of beetles (Carabidae, Coccinellidae, Scarabaeidae); grasshoppers (Orthoptera); and butterflies (Lepidoptera) (Beal 1911, Neff 1928, Snow, 1941). Vegetable foods include native and cultivated nuts (acorns, almonds), as well as a number of native and farmed fruits, including apples, cherries, peaches (*Prunus* spp.), serviceberry (*Amelanchier* spp.), hawthorn (*Crataegus* spp.), currant (*Ribes* spp.) dogwood (*Cornus* spp.), sumac (*Rhus* spp.), and elderberry (*Sambucus* spp.). They also gather corn but not other cultivated grains (Beal 1911, Neff 1928, Snow 1941, Bock 1970).

Stomach contents include large amounts of grit during the winter (50 to 98 percent) but much less during the summer (Snow 1941). Presumably the grit facilitates the breakdown of the mast consumed in the winter. Analyses of stomach contents collected throughout the year and in various locations suggest that the diet of Lewis's woodpecker is comprised of 8 to 38 percent animal foods and 44 to 63 percent vegetable food, with no evidence of wood-boring insect larvae (Beal 1911, Neff 1928, Snow 1941). No comparative studies have been conducted on differences in diet between adults and juveniles, and quantitative analyses of geographic variations in diet among populations are also lacking.

Morphology

Several morphological adaptations facilitate woodpeckers' unique form of foraging including the width of the first thoracic rib (Kirby 1980), the length of the pygostyle disk (Burt 1930), and several cranial adaptations that buffer against hard blows (Burt 1930, Spring 1965). Species specializing on excavating wood for food will display a wider first thoracic rib and a longer pygostyle disk, both of which allow for greater musculature attachment and, in turn, greater force per blow. The first thoracic rib of Lewis's woodpecker is relatively narrow, and the pygostyle disk is relatively short when compared to species in the genus *Picoides*. This may explain its limited use of excavation as a foraging method (Burt 1930, Kirby 1980). *Picoides* and *Dryocopus*, which feed primarily on bark beetle and wood-boring insect larvae, have broader skulls and an increased cranial kinesis compared to *Melanerpes* (Burt 1930). Similar to true flycatchers (Tyrannidae), Lewis's woodpecker has the broadest gape and the shortest legs among woodpeckers (Spring 1965, Bock 1970). Finally, Lewis's woodpeckers, compared to other woodpeckers, appear to have muscular (fiber type and arrangement) and wing (relatively long and pointed) characteristics suitable for a combination of sallying, frequent gliding, and longer-distance flying, including migration (Tobalske 1996).

Breeding biology

Phenology

Lewis's woodpeckers nest during the months of May through August (**Table 3**), with mean breeding dates earlier in southern regions and at lower elevations. Because Lewis's woodpeckers feed on free-living adult insects, the timing of breeding may depend on local precipitation and temperature conditions affecting insect availability rather than changes in photoperiod (Bock 1970). During a seven-year study in western Idaho, the average median date of courtship was prior to 30 May, with an average median date of fledging occurring after 20 July (n=323 nests; Dudley and Saab 2003). In Utah, Snow (1941) reported nest excavation in the first two weeks of April, and in the Bitterroot Valley, Montana birds were seen enlarging cavities on May 28 (Tobalske 1997).

Table 3. Nesting chronology of Lewis's woodpeckers in various geographic locations in western North America. Dates are reported as means or ranges, depending on available data. Length of nesting stage is reported in parentheses as days. Region 2 states are in bold.

Location	Courtship	Laying	Incubation	Nestling	Fledgling
California	Early May		7 June[1] 15 May[2] (13 – 14 d)	11 July[1] 5 June[2] (28 – 34 d)	22 June – 4 August
Colorado			**26 April – 9 May[1]** **6 May – 30 May[2]** **(13 – 14 d)**	**8 May – 22 May[1]** **18 May – 12 June[2]** **(28 d)**	**30 June – 21 July[1]** **17 June – 13 July[2]**
Idaho	**< 30 May**	**30 May** **(6.5 d)**	**5 June** **(13 – 14 d)**	**18 June** **(28 – 34 d)**	**>20 July** **(51 d)**
Montana Oregon South Dakota	Late May – Early June		1 June	29 June	
Utah Nevada	March – May		25 May (14 – 16 d)	24 June	
British Columbia			16 April – 27 June (15 d)		12 June – 6 July

Sources of information: California (Bock 1970), Colorado (Tashiro-Vierling 1994), Idaho (n=390 Laying, n=323 Fledgling; Dudley and Saab 2003), Montana, Oregon, South Dakota (n=10 Incubation, n=19 Nestlings; Bock 1970, Tobalske 1997), Utah, Nevada (n=14 Incubation, n=17 Nestling; Bock 1970), British Columbia (n=165; Campbell et. Al. 1990).

[1] California: Upland sites (n=10 Incubation, n=18 Nestling; pine forest, logged burned areas).

[2] California: Low-land sites (n=11 Incubation, n=16 Nestling; oak woodland, riparian cottonwood-sycamore).

[1] Colorado: Foothills of the Wet Mountains in southeastern Colorado (n=17).

[2] Colorado: Plains of the Front Range in southeastern Colorado (n=42).

Pair formation

Lewis's woodpeckers are assumed to be monogamous, forming long-term or multiple-season pair bonds, but no data are available on parentage (Bock 1970). Banding records of one pair of Lewis's woodpeckers suggest that pairs may bond permanently or at least display strong nest-site fidelity (Bock 1970). The pair nested together for three years, twice in the same cavity, and a third time within 200 meters of the original cavity. A nesting pair often uses existing cavities, with some cavities being used for three to four years in a row (Bock 1970, Saab et al. 2004). Furthermore, three pairs remained together year-round using the same acorn stores during the winter and the same breeding sites during the spring (Bock 1970). Differences in courtship intensity between paired and unpaired males suggest that pairing may be a lengthy process. For example, in California males arrived in early May, with mated males displaying little while unmated males were vigorous in their vocalizations and displays.

Courtship and copulation

Copulation usually occurs on the nest tree or in the immediate vicinity (Snow 1941, Bock 1970, Tobalske 1997). Peak period for copulation is during the later stages of nest initiation, prior to cavity completion, but it appears to continue throughout the laying stage of nesting (Snow 1941, Linder 1994). Extra-pair copulations have not been observed. Linder (1994) reported that copulation occurred primarily during pre-nesting, compared to incubation or nestling stages of the breeding cycle (n=11 nests). Copulation is often preceded by the male giving a wing-out display and chatter-call before mounting the female (Bock 1970). The wing-out display is also used in territorial displays toward an intruder. In monomorphic species, displays of courtship and threat are similar (Hinde 1966). Bock (1970) suggested that female Lewis's woodpeckers display a submissive posture for acceptance by the male. Males often fly in a circular pattern after copulation.

Coition occurs in a manner similar to that described for other species of woodpeckers; the male perches on the back of the female before dropping beside the female during copulation (Bock 1970, Tobalske 1997). Frequently before true copulation, the female briefly mounts the male. During this reverse mount, the female perches briefly on the male's back before they switch positions (Bock 1970). This behavior presumably indicates that the female is ready to copulate.

Clutch

Lewis's woodpeckers lay one clutch per year, which ranges in size from 5 to 11 eggs and averages between six and seven eggs (Bent 1939, Koenig 1987, Ehrlich 1988). This species appears to show a positive correlation (r=0.32) between clutch size and latitude (n=51 nests, latitude range 33 – 46°; Koenig 1986). The mean clutch size, adjusted for latitude, is 5.7 eggs and is suggested to correlate with body size in this genus (Koenig 1987). Geographic location, mean clutch size ± standard deviation, range, and sample size are listed in **Table 4**.

Clutch initiation, laying, and incubation

The complete nesting cycle of Lewis's woodpecker spans approximately 51 days, with only one brood per year (Dudley and Saab 2003). Re-nesting may occur if a nest fails early in the nesting cycle, but data are not available on marked birds (Saab and Vierling 2001). The onset of incubation ranges from mid-April in Utah to late June in British Columbia with peak activity occurring in May and June, respectively (**Table 3**; Snow 1941, Campbell et al. 1990). In western Idaho, nest initiation began in late May. The average median laying date (median calculated each year and averaged over six years, 1994 – 2000; n=390 nests) was 30 May, the average median date of incubation was 5 June, and the average median date of hatching was 18 June (Dudley and Saab 2003). In general, the average date of incubation in the northern portion of their range (Oregon, Idaho, Montana, South Dakota) is early June, and the average date of hatching is late June (Bock 1970). In the southern portion of their range (California, Nevada, Utah, Colorado), the average dates of incubation and hatching are 25 May and 24 June, respectively. The duration of incubation ranges from 13 to 16 days (**Table 3**).

Parental care and nestling development

Male and female Lewis's woodpeckers both develop brood patches. Males are thought to brood eggs during the night, while both parents are thought to participate equally during the day (Bock 1970). However, Bock (1970) reported for seven nests that males showed a greater proportion of attentive behavior during the day than females (69 percent attentive for males compared to 29 percent for females).

In California, at least one adult was in attendance of the nest during incubation 94 percent of the time (51

Table 4. Summary of reproductive capability for Lewis's woodpeckers from sites in western North America, with sample size (number of nests) in parentheses. Data were not available for all categories. Note estimates of nest success were calculated using Mayfield (M) or Traditional (T) methods. Region 2 states are in bold.

Location	Habitat	Mean clutch size ± SD	Clutch size range	Mean no. young/ successful nest	Nest Success ± SE
Colorado	**Foothills (cottonwood woodland)**			**2.0 ± 0 SE (19)**	**25% ± .06 (M)**
Colorado	**Arkansas River plains**			**1.6 ± .15 SE (46)**	**56% ± .07 (M)**
Wyoming	**Burned ponderosa pine**				**85% (T)**
Idaho	**Low elevation burned habitat (PIPO/PSME)**	**6.9 ±1.5 (21)**	**3 to 11**	**1.78 ± .05 SE (283)**	**78% ± .03 (M)**
California		5.4 ± 1.1 (45)	3 to 8		
Oregon		5.6 ± 1.8 (40)	2 to 9		
Nevada		6.3 ± .8 (6)	5 to 7		
Utah		5.0 ± 2.2 (4)	3 to 8		
Washington		5.8 ± .9 (11)	4 to 7		
British Columbia		4.8 ± 1.6 (30)	2 to 8	2.9 ± 1 SD (28)	

Sources of information: Colorado (Vierling 1994), Wyoming (Linder 1994), Idaho (Saab and Vierling 2001, Abele unpublished data), California, Oregon, Nevada, Utah, Washington (Tobalske 1997), British Columbia (Campbell et al. 1990).

hours observation; Bock 1970). The percentage of time actually spent incubating the eggs was 68 percent; the remainder of the time was spent perched on the cavity tree, usually in close proximity to the cavity entrance. Additionally, the actual time spent incubating varies daily and seasonally (Bock 1970, Tobalske 1997). Birds spent a greater proportion of time incubating in the morning presumably due to lower temperatures, although nest attentiveness remained fairly constant throughout the day (Bock 1970). During the first week of hatching, parents spent more time covering the young as compared with later in the nestling stage. During the last week of the nestling stage, males are thought to eliminate nightly brooding (Tobalske 1997).

Young are altricial and nidicolous at hatching (Bent 1939, Snow 1941). Shortly after hatching, the young emit a loud "hissing" vocalization, similar to other species of woodpeckers (Bent 1939). Feather tracts are visible after one week, and feathers begin to emerge from shafts after the second week, with red color being discernable on the belly (Snow 1941). Feather tracts are complete during weeks three and four. Adults enter cavities to feed nestlings during the first couple of weeks, but around week three the adults will feed from the cavity entrance by tipping into the cavity hole (Abele personal observation). Around week four, young are visible and will take food at the cavity entrance. The largest nestling obtains more food at the cavity entrance than the other siblings and is the first to leave the nest.

Nestlings emerge from the cavity at 28 to 34 days of age in California (n=7 nests; Bock 1970); at 28 days in Colorado (n=59 nests; Tashiro-Vierling 1994); and at 28 to 34 days in Idaho (**Table 3**; n=350 nests; Dudley and Saab 2003). The young will often re-enter the nest for various amounts of time after fledging (Abele personal observation). Asynchronous hatching results in variations in nestling development. The largest offspring fledges first, while other nestlings remain in the cavity for an additional two to three days (Snow 1941).

Adults feed nestlings directly from their beaks, but it is not known if the prey is ever regurgitated from the crop. Feeding rate may vary with food abundance, weather, and nestling stage of development (Tobalske

1997). During periods of abundant prey, adults may store insects in cracks on trees or the tops of broken snags for later use. In California, pairs averaged 15.1 feedings per hour ± 10.SD (range 2 to 62; n=110 hours of observation; Bock 1970). In cottonwood plains of Colorado, pairs averaged 15 feedings per hour ± 4.2 SD (range 7.7 to 22.3), and in the foothills of Colorado (cottonwood and oak-woodlands) pairs averaged 20 feedings per hour ± 4.4 SD (range 13.9 to 27.8; n=25 nests; Tashiro-Vierling 1994).

Adults feed juveniles for at least 10 days after fledging. Young often follow parents and give begging calls when adults arrive with food. In burned forests, adults occasionally move with juveniles from the nest site toward green trees, presumably for protection from predators (Abele personal observation). In the fall, loose flocks of adults and juveniles will form, but little is known about the composition of these flocks or the length of time juveniles remain with their parents.

Demography

Age of first reproduction

The age of first breeding is not known, as no birds banded as juveniles have been recaptured or seen breeding (Bock 1970; Saab, Dudley, and Abele unpublished data). The age of first reproduction in females is unknown, but likely one year (Tobalske 1997). The occurrence of unmated territorial males (Bock 1970) suggests that males may delay the onset of first breeding for >1 year. However, this may also result from an uneven sex ratio or greater survival among juvenile males. Mated birds are assumed to breed annually based on a single banded pair of birds in California (Bock 1970).

Annual fertility and lifetime reproductive success

Reproductive success, as measured by overall nest success (number of nests that fledge at least one offspring) and by number of offspring fledged per successful nest, appears to vary among habitats (**Table 4**). The number of young fledged from successful nests ranges from 1.6 in Colorado to 2.9 in British Columbia, while Mayfield estimates of overall nest success vary from 25 percent in cottonwood woodlands of Colorado to 78 percent in burned pine forests of Idaho (Campbell et al. 1990, Saab and Vierling 2001). In Utah, Snow (1941) noted that three nests from two trees produced 13 fledglings. In Wyoming, overall nest success was 85 percent (presumably using a traditional method); no other data were given (K. Linder in Tashiro-Vierling 1994).

Adult annual survival and life span

No data are available for adult survival rates of Lewis's woodpecker. Based on annual adult survival reported for other *Melanerpes*, estimates for Lewis's woodpeckers may range between 59 and 75 percent (Saab and Vierling 2001). The only study to quantify any aspect of Lewis's woodpecker survival restricted the estimate to over-winter survival (October to March); this estimate was reported as 87 percent and 81 percent for the foothills and plains of Colorado, respectively (n=44 birds; Tashiro-Vierling 1994). Birds were assumed to have survived the winter if they were still present on their winter territories in March. No other estimates are available. The maximum life span of Lewis's woodpeckers is not known, but longevity records for red-headed and red-bellied woodpeckers are approximately 10 and 12 years, respectively (Clapp et al. 1983).

First-year survival

Estimates of juvenile survival are not available. The acorn woodpecker is the only *Melanerpes* species for which we have data on juvenile survivorship; estimates range from 35 percent (Stacey and Taper 1992) to 57 percent (Koenig and Mumme 1987). Comparisons between Lewis's and acorn woodpeckers should be made with caution due to the differences in life history strategies. The acorn woodpecker is a cooperative breeding, permanently resident, and k-selected species, while the Lewis's woodpecker nests and raises its young in pairs, is r-selected, and is likely to have lower juvenile survivorship (Saab and Vierling 2001).

Non-breeders

The proportion of non-breeding individuals in a population has not been studied. Based on observations by Bock (1970), we know that in any one year some males are non-breeders.

Geometric rate of natural increase

Demographic modeling allows us to predict whether a population is increasing, declining, or remaining stable. However, due to our lack of information on juvenile survivorship, adult survivorship, and yearly population numbers, estimates of the finite rate of population increase (λ) for any Lewis's woodpecker population is difficult to calculate. One study evaluated the growth rate of Lewis's woodpecker populations based on survival rates from other melanerpine species (Saab and Vierling 2001). A range of values representing the minimum, maximum, and average values of adult and juvenile survival from acorn, red-headed, and red-bellied woodpeckers was used to evaluate the potential sink or source status of two populations of Lewis's woodpeckers. Based on this modeling effort, burned ponderosa pine forests consistently appeared as potential source habitat, whereas cottonwood riparian forests in an agricultural matrix were predicted most often to be sink habitat.

We developed a two-stage matrix population model to estimate λ and to evaluate the most sensitive demographic parameters (elasticity analysis; **Table 5**; Caswell 2001). This approach was used instead of an age-classified model (typically applied to avian species) due to our lack of information on age-specific fertility and survivorship. A stage-based approach assumes that adult fertility and survival are constant across adult age classes, and therefore effects such as breeding experience are omitted. Our stage-classified model was based on a 2x2 demographic matrix, which consisted of parameters reflecting adult fertility and juvenile and adult survival rates. Corresponding to our matrix model is a graphical representation in the form of a life cycle graph, an alternative way of depicting the matrix projection methods used to evaluate the current status of a population (**Figure 3**). Life cycle graphs are fairly straightforward to construct, but their complexity can increase rapidly depending on the ecology and life history characteristics of the organism being described. For a complete description of the construction of a life cycle graph and the stage-based population matrix modeling approach see Caswell (2001) and McDonald and Caswell (1983). This simple model still provides considerable insight into the demographics of Lewis's woodpecker.

Juvenile fertility is 0, as recently fledged birds will not reproduce until at least their first birthday (see Age of first reproduction above). Estimates of juvenile survival rates are probably the most problematic, and the only available data that appeared appropriate came from two studies on acorn woodpeckers. These studies reported juvenile survival rates of 35 percent and 57 percent (Koenig and Mumme 1987, Stacy and Taper 1992). Due to the difference in life history characteristics between Lewis's and acorn woodpeckers, these estimates are assumed to be high (see First year survival above). In light of this, we parameterized juvenile survival in two ways. First, we used a model that allowed us to incorporate three estimates of juvenile survival; 35 percent (low), 57 percent (high), and 46 percent (average of two reported survival estimates). Due to our assumption that these estimates may be high, we ran a second model holding juvenile survival at a constant 35 percent.

We parameterized adult fertility using the mean number of female fledglings per female and the upper and lower bounds of the 95 percent confidence interval reported by Saab and Vierling (2001). This was done for burned pine habitat in Idaho and for cottonwood woodland habitat in Colorado; these two locations were the only ones with sufficient data for this calculation. In Idaho, adult fertility was estimated at 69 percent with 59 percent and 78 percent being the lower and upper confidence intervals, respectively. Likewise in Colorado, adult fertility was estimated at 38 percent and ranged from 11 to 64 percent. The probability of

Table 5. Elasticity matrix results from four stage-classified matrix population models for Lewis's woodpecker. Values contained under categories of adult and juvenile survival and fertility represent the contribution of each stage to λ. All values, excluding λ, represent means ± one SE derived from 500 stochastic replicates. Matrix developed from survival and fertility data reported in Saab and Vierling (2001).

Location	Population growth (λ)	Juvenile fertility	Juvenile survival	Adult fertility	Adult survival
Colorado[1]	0.9035	0.0 ± .000	0.160 ± .002	0.160 ± .002	0.679 ± .004
Colorado[1]	0.8639	0.0 ± .000	0.139 ± .002	0.139 ± .002	0.722 ± .004
Idaho[1]	1.0209	0.0 ± .000	0.225 ± .001	0.225 ± .001	0.550 ± .002
Idaho[2]	0.9612	0.0 ± .000	0.199 ± .001	0.199 ± .001	0.601 ± .002

Notes: Colorado[1] – Juvenile survival estimates used in the model were 0.35, 0.46, and 0.57.

Colorado[2] – Juvenile survival estimate held at 0.35.

Idaho[1] – Juvenile survival estimates used in the model were 0.35, 0.46, and 0.57.

Idaho[2] – Juvenile survival estimate held at 0.35.

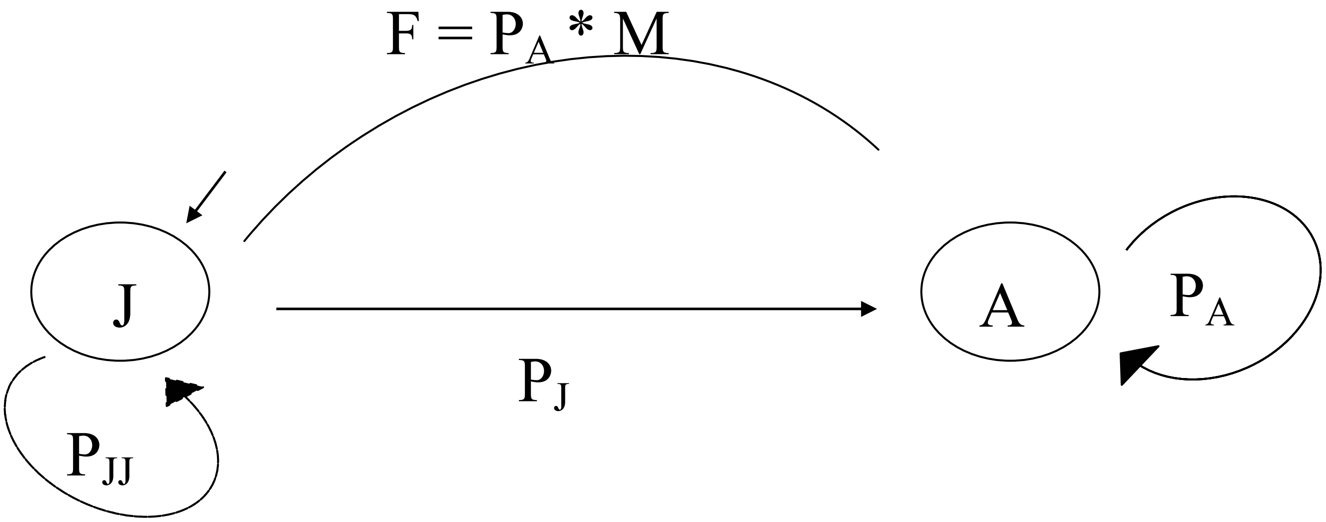

Figure 3. Two-stage life cycle graph for Lewis's woodpecker. The lettered circles (nodes) represent juvenile (J) and adult (A) stages of the life cycle graph. The arrows (arcs) connecting the nodes represent vital rates or transitions between stages (i.e., survival (P), fertility (F)). M represents the number of female offspring produced per female. Note that P_{jj} represents the probability of survival for juvenile birds that remain as juveniles for more than one year (age of first reproduction is not known). For a complete description of the use and construction of life cycle graphs see Caswell (2001).

an adult bird surviving was assumed equal for all age classes after its first birthday. Based on literature from red-headed woodpecker as well as the only available data on over-winter survival of Lewis's woodpecker, we used the highest (85 percent), lowest (62 percent), and average (71 percent) estimates to parameterize our models (Tashiro-Vierling 1994, Martin 1995).

Using ELASTIC6 (a DOS-based program developed by L. S. Mills), Colorado data resulted in a λ=0.9035 when juvenile survival, adult survival, and adult fecundity were 0.46, 0.71, and 0.38, respectively and a λ=0.8639 when juvenile survival was reduced to a more conservative level of 0.35 (**Table 5**). Idaho data resulted in a λ=1.0209, when juvenile survival, adult survival, and adult fecundity were 0.46, 0.71, and 0.69, respectively and a λ=0.9612 when juvenile survival was set at 0.35. Elasticity analysis indicated that λ is far more influenced by adult survival than by changes in other demographic parameters in all four models (**Table 5**). These results indicate that monitoring adult survival is more important for determining population viability than monitoring juvenile survival or adult fecundity. Our model assumed no differences between adult survival and fertility across age classes nor did it incorporate estimates of emigration and immigration, thus results may be flawed due to model structure (e.g., too simple). Certainly it would be possible or probable for nesting experience, age, genetics, or dispersal to affect these estimates. However, our results were consistent with the pattern reported by Saab and Vierling (2001).

Ecological influences on survival and reproduction

The primary cause of nest failure in Lewis's woodpecker is predation (Saab and Dudley 1998, Saab and Vierling 2001). Nest predation appears to differ among habitats, presumably from differences in predator assemblages and densities associated with different habitats (Saab and Vierling 2001). Possible causes include the habitat matrix surrounding nest sites and the degree to which certain predators are commensal with human habitation.

Causes of death

Very little is known about the ultimate cause of mortality in Lewis's woodpeckers. Documented cases of predation have been attributed to avian species, but data are limited (**Figure 4**). Pressure from avian predators, especially the American kestrel (*Falco sparverius*), may be greatest on recently fledged young, but targeting of adults by Cooper's hawks (*Accipiter cooperii*) and sharp-shinned hawks (*Accipiter striatus*) has also been reported (Snow 1941, Hadow 1973). Additionally, there is one report of feathers being found in the regurgitated pellet of a red-tailed hawk and another instance of presumed mortality due to a collision with an automobile (Fitch et al. 1946, Tobalske 1997). Nest predation has been documented for black bear and common raven (*Corvus corax*; Saab, Dudley, and Abele unpublished data). Depending on the nesting habitat, alternative nest predators include mustelids, corvids, northern flying squirrel, red squirrel, fox squirrels, chipmunks, raccoons, and gopher snakes (**Figure 4**; Saab and Vierling 2001).

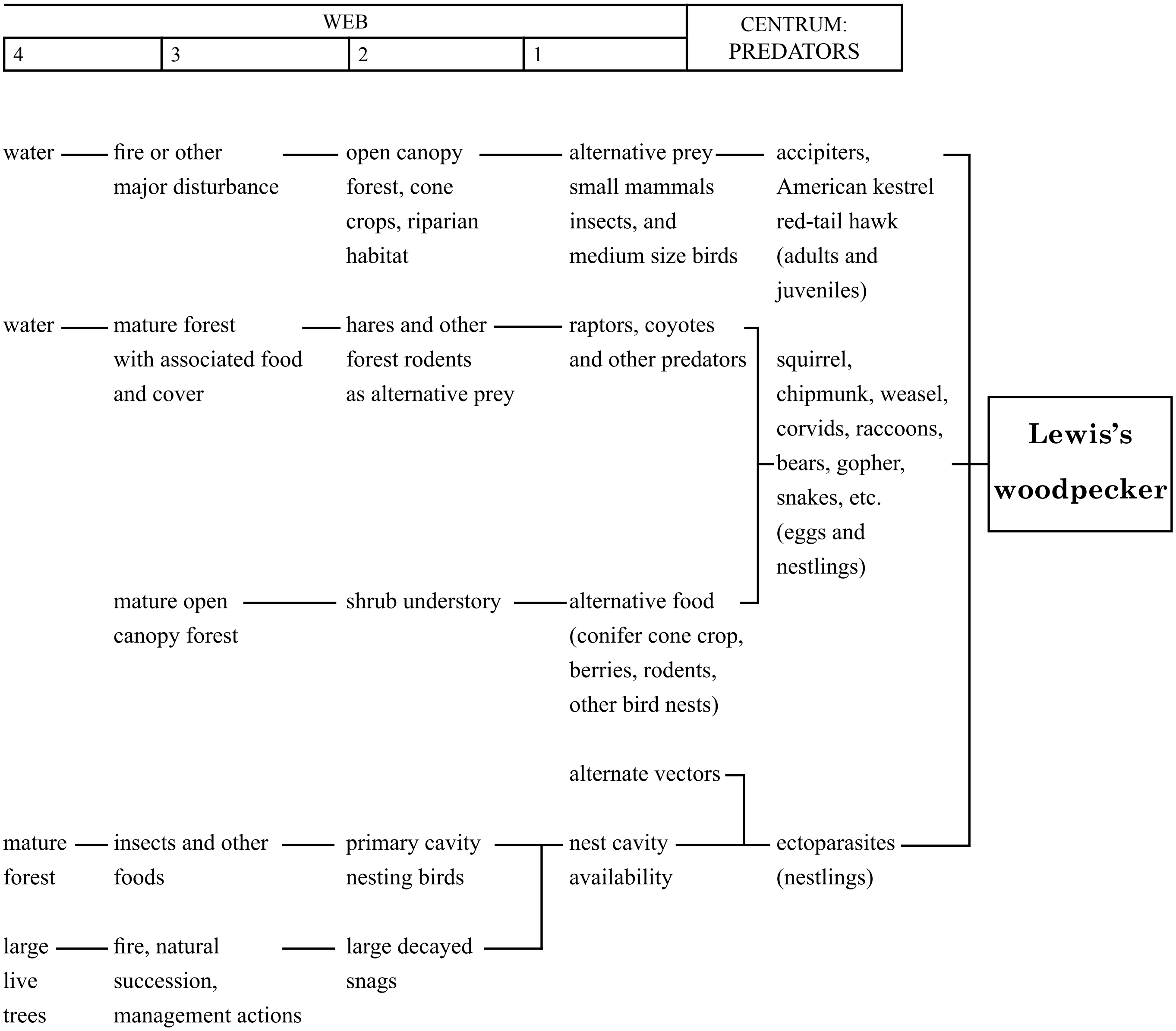

Figure 4. Envirogram representing the web of linkages between the Lewis's woodpecker and its predators in western North America and the forest ecosystems where they occur. This web should be viewed as a series of hypotheses based on the ecology of Lewis's woodpecker as described throughout this assessment. For more information on the application of envirograms in conservation biology see Andrewartha and Birch (1984) and Van Horne and Wiens (1991).

Limiting factors

Few studies have attempted to explicitly address potential limiting factors in Lewis's woodpecker. The species' restricted ability to excavate cavities may result in limited nest-site availability in some populations. The higher density of nesting birds found in burned pine forests compared to cottonwood woodlands may suggest a lack of suitable snags in the latter habitat (Saab and Vierling 2001). Based on the loss and degradation of riparian habitats over the last two centuries, this hypothesis is worth consideration (Johnson and Haight 1984, Nillson and Berggren 2000). However, low densities may not reflect the lack of nest sites, but a lack of food instead. Similarly, a lack of mast may limit over-winter survival. Again, there is little data to substantiate this hypothesis. Southeastern Colorado is the sole location where evidence for range expansion is strong (Hadow 1973). This expansion is thought to stem from the maturation of cottonwoods around ranch buildings as well as the cultivation of commercial corn crops. This suggests that competition for native mast may regulate wintering population numbers and the availability of corn may facilitate over-wintering in areas otherwise unsuitable. Over-winter survival of Lewis's woodpeckers on the southeastern plains and in the Wet Mountains of Colorado were reported at 81 percent and 87 percent, respectively (n=21 and 23 birds, respectively; Tashiro-Vierling 1994). The plains population fed almost exclusively on corn during the winter, while the Wet Mountains population fed almost exclusively on acorns. In both locations winter food appeared abundant and did not appear to influence survival of wintering birds. Although this study had only one year of data and a limited sample size of unmarked birds and researchers did not attempt to estimate bird densities, it did not appear that birds wintering in relationship to commercial cornfields fared better than birds feeding on natural mast crops. Thus, winter survival appears high, but competition for food resources may be influencing population numbers.

Human alterations to the environment may be working as proximate agents in population regulation. Fire suppression, post-fire management activities, and alterations to riverine systems are considered important proximal factors influencing population numbers of Lewis's woodpeckers (Saab and Dudley 1998, Wisdom et al. 2000, Saab and Vierling 2001, Saab et al. 2002). Burned ponderosa pine forests are suggested to be ephemeral source habitats critical for long-term persistence of Lewis's woodpecker, and the alteration of these systems may influence the availability of nesting and foraging locations (Saab and Vierling 2001). Similarly, induced changes to natural flow regimes along many western rivers and reductions in understory vegetation due to grazing have resulted in a loss and degradation of riparian woodlands (Saab et al. 1995, Rood et al. 2003). These alterations may affect nesting substrate and food supplies. In addition, researchers have suggested that competition from introduced European starlings (*Sturnus vulgaris*) for cavities may affect breeding birds (Sorensen 1986, Tashiro-Vierling 1994, Vierling 1997, Cooper et al. 1998). However, based on the majority of outcomes during Lewis's woodpecker - starling interactions, this hypothesis does not yet have strong empirical support (Vierling 1997). Similarly, in locations where distributions overlap with native conspecifics, competition for food or nest sites may limit population growth. Lewis's woodpecker appears to be a strong competitor, often displacing other foraging birds (Bock 1970, Bock et al. 1971, MacRoberts and MacRoberts 1976). Finally, pesticides in the environment and a declining prey base have both been suggested as potential factors affecting population growth (Sorensen 1986, Tashio-Vierling 1994).

As with all populations of Lewis's woodpeckers, those in Region 2 suffer from a lack of studies explicitly addressing potential limiting factors. Riparian cottonwood communities have a state designation by the Colorado Natural Heritage Program of S1 ("critically imperiled") to S4 ("apparently secure"), depending on the community association. However, few riparian cottonwood communities are designated as S4. The Wyoming Natural Diversity Database designates Fremont cottonwood (*Populus deltoides*) communities as S1 ("critically imperiled"). Ponderosa pine communities, similarly, are designated by the Colorado Natural Heritage Program as S1 to S4, depending on the understory shrub community association. Again, the majority of ponderosa pine communities rank between S1 and S3. Oak woodland communities, primarily Gambel's oak (*Quercus gambelii*), appear to be stable with a designation of S3/4. However, data are limited and numerous communities cannot be appropriately ranked.

Based on elasticity analysis (see Geometric rate of natural increase above), adult survival appears to be an important factor in population growth of Lewis's woodpecker. Although there is no information on acorn crop production in Colorado or on the amount of mast needed per Lewis's woodpecker during the winter, acorn mast availability does not appear to be limiting adult survival during the winter in southeastern Colorado (Tashiro-Vierling 1994). Alterations to breeding habitat may be influencing adult survival during the summer by affecting insect as well as predator abundances, but these alterations would likely affect reproductive success and not adult survival. Finally, nothing is known about survival during migration. This is often an energetically demanding time of year, and efforts to explore this portion of their life cycle would be welcomed.

Patterns of dispersal

Based on limited data, adult birds appear to display nest-site fidelity as long as habitat is suitable (Bock 1970). The possibility that the previous years' young were returning to breed in these sites was excluded by noting occasions where the nest failed to fledge young but the cavity was still reused the following year. No information is available on breeding adult dispersal or changes in nest sites at local or broad scales. In addition, Bock (1970) and Saab, Dudley, and Abele (unpublished data) banded nearly 100 nestlings, but in neither study were banded birds observed returning to their natal areas. Of course, this does not imply a low juvenile survival rate nor that juveniles make long-distance dispersals. It is more likely the case that dispersing juveniles move relatively short distances. However, this distance is probably long enough that individuals are not readily re-sighted (Shields 1982).

Metapopulation structure

Bock (1970) suggested that Lewis's woodpeckers breed and winter in an almost "semi-colonial" manner (Bock 1970). This hypothesis is supported by the findings of several birds nesting and storing mast in a single tree or in close proximity to one another. Although the cause for these groupings is more likely due to habitat heterogeneity than to social attraction or lack of dispersal ability, it does suggest the potential for a higher population structuring. Clusters of populations, separated by inhospitable habitat, imply a potential for a degree of separation that may result in metapopulation structure (Garton 2002). Because the dispersal ability of Lewis's woodpecker is likely great, undetected rescue events from source populations may already be occurring and preventing local extinctions in sink habitat (Saab and Vierling 2001). However, based on its presumed dispersal ability, which is supported by its strong flying ability and use of a variety of habitats, it is likely that this species displays a population structure more similar to a patchy population than that of a metapopulation. Differences in the timing of disturbance events that create burned forests and dynamic riparian habitats (preferred habitats of Lewis's woodpecker) also suggest a patchy population structure rather than a metapopulation structure. The underlying mechanisms responsible for population structure of Lewis's woodpecker have not been directly investigated and are not well understood.

Community ecology

Habitat change and vulnerability to predation

Ponderosa pine forests and riparian cottonwood woodlands have been dramatically altered by development, fire suppression, timber harvest, cattle grazing, and water management over the last 100 years (Rood and Heinze-Milne 1989, Agee 1993, Morgan 1994, Noss et al. 1995, Saab et al.1995, Arno 1996, Shinnenman and Baker 1997). Changes in the amount, composition, and structure of these preferred breeding habitats might affect the quantity and quality of breeding sites. Loss or fragmentation of habitat has been shown to influence nest success in a number of bird species due to changes in the amount and composition of nest predators (see review by Paton 1994). In a recently burned ponderosa pine forest, nest predation was not a limiting factor in population growth, whereas nest predation played a potentially limiting role in human-altered cottonwood forest (Saab and Vierling 2001). Human-commensal predators commonly detected in riparian habitat (e.g., raccoons, magpies, fox squirrels, and snakes) were rarely, if ever, detected in recently burned pine forests. Potential predators in the burned pine habitat included gopher snakes and tree squirrels, and although they were regularly seen in adjacent unburned forest, they were rarely observed within the burn. The differences in predation pressure between these two habitats may stem from several factors including landscape context, colonization by predators, and forest structure. In southeastern Colorado, the number of nest predation events was greater at sites that were predominately surrounded by forested landscape when compared to fragmented agriculture landscapes (Saab and Vierling 2001). While this finding is consistent with that reported for cottonwood forests in western Montana (Tewksbury et al. 1998), it contrasts with studies from the midwestern United States that suggest predation increases with increasing amounts of agriculture (Donovan et al. 1995, Robinson et al. 1995). In western Montana, the most abundant nest predator was the red squirrel and its population density declined with increasingly fragmented, agricultural landscapes (Tewksbury et al. 1998). Furthermore, re-colonization of predators into habitats affected by large-scale disturbances (i.e., wildfires) may take several years (Saab and Vierling 2001). Thus, predation pressure may be expected to be lower in recently burned forests. Nest predation in cavity-nesting species has not been well studied (Martin and Li 1992, Johnson and Kermott 1994), and the effect of habitat change on predation pressure is a complex question that needs additional research.

Competition and interactions

No studies have attempted to address interspecific or intraspecific competition for food resources during the breeding season. It appears reasonable that the foods used by Lewis's woodpeckers are similar to those used by numerous other avian species: American kestrels, western bluebirds (*Sialia mexicana*), mountain bluebirds (*Sialia currucoides*), several flycatchers (*Empidonax* spp. and *Tyrannus* spp.), swallows (Hirundinidae), swifts (Apodidae), goatsuckers (Caprimulgidae), white-breasted nuthatches (*Sitta carolinensis*), and other melanerpine species where their ranges overlap with Lewis's woodpeckers. However, no information on diet overlap is available (**Figure 5**). Interactions between Lewis's woodpeckers and other avian species appear to revolve around the nest tree and not specific foraging locations (except possibly in the case of Lewis's and red-headed Woodpecker interactions), thus competition for food resources may be minimal (Bock et al. 1971). Lewis's woodpeckers often nest semi-colonially and in association with abundant food supplies, thus exploitive competition for prey may be of limited importance. Similarly, Lewis's woodpeckers are often aggressive toward other avian species in proximity to nest sites (Saab et al. 2004), suggesting that interference competition may be strong but not a regulatory factor. While nest sites did not appear to be limiting in riparian woodlands of southeastern Colorado, understory shrub cover was virtually nonexistent. This likely decreased food availability by reducing substrate for arthropod prey and, in turn, limited population size (Saab and Vierling 2001). Finally, American crows (*Corvus brachyrhynchos*) and other Lewis's woodpeckers have been observed robbing cache sites for insects during the breeding season (Constantz 1974).

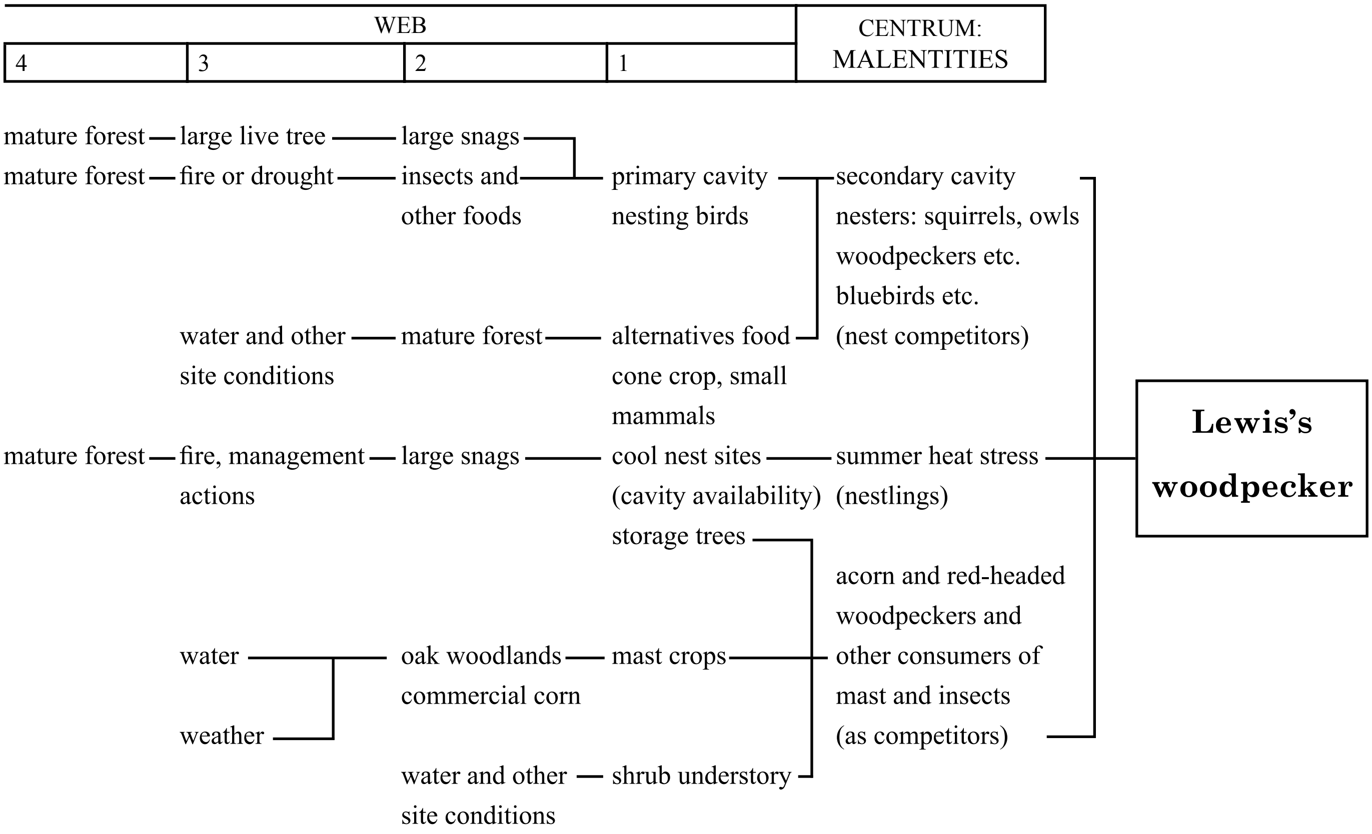

Figure 5. Envirogram representing the web of linkages between Lewis's woodpeckers and potential competitors and hazards in western North America and the forest ecosystems where they occur. This web should be viewed as a series of hypotheses based on the ecology of Lewis's woodpecker as described throughout this assessment. For more information on the application of envirograms in conservation biology see Andrewartha and Birch (1984) and Van Horne and Wiens (1991).

Nest-site competition may be more important than competition for food. Several cavity-nesting bird species often use similar cavities in similar habitats (**Figure 5**). Potential nest-site competitors include numerous primary and secondary cavity-nesting species. For example, apparent declines of Lewis's woodpecker populations around Salt Lake City, Utah have coincided with increases in abundance of European starlings, leading to speculation that displacement from nest sites by starlings has led to these declines (Sorensen 1986). However, in southeastern Colorado only one of 59 Lewis's woodpecker breeding pairs lost its cavity to European starlings (Tashiro-Vierling 1994). Furthermore, Lewis's woodpeckers dominated 94 percent of 70 Lewis's woodpecker -starling interactions, with over 90 percent of these interactions having been instigated by the woodpecker. Lewis's woodpeckers are known to usurp cavities from a number of primary and secondary cavity-nesting species (Saab and Dudley, unpublished report). Finally, cavity competitors include mammals, as well as birds. Lewis's woodpeckers may compete for cavities with small mammals that are known nest predators, including chipmunks, red squirrels, and northern flying squirrels.

Competition over mast and storage trees in the winter may also influence the distribution and abundance of Lewis's woodpeckers (**Figure 5**). Although Lewis's woodpeckers have been observed using and defending individual storage trees during winter (Bock 1970), sharing of storage trees in southeastern Colorado may be a consequence of storage site scarcity (Vierling 1997). Interactions between Lewis's woodpeckers and other avian species over mast stores suggest that this food resource is important (Bock 1970). In California, 15 species of birds elicited aggressive responses by Lewis's woodpeckers, with the largest number of interactions involving acorn woodpeckers, northern flickers, Nuttall's woodpeckers (*Picoides nuttallii*), scrub jays (*Aphelocoma coerulescens*), and plain titmouses (*Parus inornatus*) (Bock 1970). In southeastern Colorado, northern flickers, American magpies, American crows, and Steller's jays (*Cyanocitta stelleri*) elicited the greatest aggressive response by wintering Lewis's woodpeckers (Hadow 1973). In both of these studies, competition was defined as more intense if interactions were more numerous. Lewis's woodpeckers appear to do "well" during interactions with potential avian competitors. During the breeding season American kestrels fair equally well during interactions, and acorn woodpeckers are known to displace Lewis's woodpeckers during the winter.

Disease and ectoparasites

Snow (1941) reported body lice (Mallophaga and Anoplura) present on adults and nestlings during the nestling stage. Funk (1959) listed an inventory of insects found in the nest cavity. In southern Idaho, approximately 4 percent of nest failure resulted in dead nestlings remaining inside the cavity (n=117 nests; Abele unpublished data). Alternative explanations for this type of nest failure (e.g., adult mortality, temperature) could be responsible for dead nestlings in the nest cavity. Additional study is warranted because Lewis's woodpeckers commonly reuse existing cavities (**Figure 2** and **Figure 4**; Saab et al. 2004).

CONSERVATION

Introduction

In this section we evaluate the conservation status of Lewis's woodpecker by addressing several questions concerning perceived threats to its persistence, changes in its distribution and abundance, and how alterations to breeding and wintering habitats may be correlated with population numbers. Finally, we take a look at how specific management and recreational activities may influence the conservation of this species through direct and indirect alterations to the environment.

Are Lewis's woodpecker populations secure, or is this species in peril? Have their critical habitats been altered to such an extent that population numbers have been affected? Are there specific land management activities that influence the persistence of this species, and what are the tools and practices needed to assess and enhance its status? Finally, is there sufficient data to answer these questions? This section is based on the best available information, but we make assumptions in order to draw our conclusions. Conclusions are based on a "best guess" scenario. Since the arguments made are based on the literature used to compose the earlier sections of this assessment, we limit citations to only vital references.

Is the distribution and abundance of Lewis's woodpecker declining in all or part of its range?

Lewis's woodpecker populations have undergone both range expansions and contractions across its distribution in western North America. The abundance of local populations has fluctuated, but limited data are available to critically assess these regional trends.

Distribution

Available evidence has suggested both range contractions (e.g., Canada, Oregon, California) and range expansions (e.g., Colorado) in the distribution of Lewis's woodpecker in western North America. Certainly, fluctuations in distribution would be an expected natural result in a species that takes advantage of ephemeral habitats. Historic fire and flood events would create dynamic habitats that would vary temporally and spatially, thus creating a scenario where local population persistence would vary. In light of these expectations, however, the apparent relationship between range contractions and human-induced changes to the environment during the last several decades suggests that humans may indeed be influencing Lewis's woodpecker distribution. However, a direct cause and effect relationship is not forthcoming, so a definitive conclusion on the causes of apparent range fluctuations is not clear.

Abundance

Estimates of local, regional and, global abundances are limited by available data. No breeding or wintering population has the long-term monitoring necessary to truly assess trends; and even this may be misleading, given the species' ephemeral appearance in any one location. Long-term trend data, in the form of BBS and CBC routes, are insufficient to describe population numbers, except in limited locations. Tashiro-Vierling (1994) suggests that overall populations in the early 1990s may have declined by 50 percent since the 1950s. Given the fact that even BBS and CBC data are limited in time and the idea that populations of Lewis's woodpecker would be expected to fluctuate due to its natural history, it is difficult to assess the true population densities of this species.

What are the perceived threats to the conservation of Lewis's woodpecker?

The loss of breeding and wintering habitats in the form of burned pine forests, park-like ponderosa pine forests, riparian cottonwood stands, and oak woodlands is thought to be the primary threat to the long-term persistence of Lewis's woodpecker populations. Primary causes of habitat degradation are likely timber harvest, fire suppression, cattle grazing, water regulation, and human development. These activities may result in the loss of nest and storage substrates, a reduction in the understory shrub community, a decrease in prey availability, or an increase in forest stand density (making them unsuitable for breeding habitat) (Wisdom et al. 2000). Dense forest stands and grazing may reduce shrub and grass understories, which in turn may cause declines of associated insect prey (Morgan 1994). Timber harvest, firewood collection, and water regulation may impact the availability of large snags used for nesting and mast storage (Wisdom et al. 2000). Post-fire salvage logging and firewood collection influence the openness and distribution of snags suitable for nesting and perching sites. Alterations to water regimes have been shown to negatively impact cottonwood recruitment along many western streams and rivers (Johnson and Haight 1984). A decline in cottonwood seedling establishment may be creating future conditions unsuitable as Lewis's woodpecker breeding and wintering habitat. Finally, although mast limitation is poorly understood, loss of oak woodlands may be influencing survival and distribution, as was suggested for Vancouver Island, Canada (Campbell et al. 1990). Although human-induced changes to the environment often negatively affect important habitat characteristics, they can be beneficial. For example, post-fire salvage logging can actually enhance nesting habitat if large diameter snags are maintained in clumped distributions (Saab et al. 2002).

Natural disturbances (e.g., wildfires) and subsequent management activities (e.g., salvage logging) may have differential impacts on habitat quality and availability for Lewis's woodpecker. Wildfire in lower montane forests has the potential to enhance the quality of breeding habitats for Lewis's woodpecker, depending on pre-fire forest structure, burn severity and size, geographic area, and post-fire age (Saab et al. 2004). Burned ponderosa pine forest created by stand-replacing fires appears to be highly productive source habitat (Saab and Vierling 2001, Saab et al. 2004). Post-fire salvage logging influences the openness of the habitat and the distribution of suitable snags for nesting, perching, and foraging. In western Idaho, Lewis's woodpeckers nested primarily in salvage logged stands, presumably due to higher number of suitable nest trees, increased abundance of flying arthropods, and greater openness of habitat that provided greater opportunities for aerial foraging (Saab and Dudley 1998, Saab and Vierling 2001). However, depending on the snags retained and their distribution, this preferred habitat may vary in its suitability. Lewis's woodpeckers were found nesting in sites where snags were distributed in clumps, in appropriate stages of decay, and of suitable size based on the availability of such snags (Saab et al. 2002).

Efforts to suppress wildfire over the last century have been effective in some forest types. In ponderosa pine forests this has resulted in stands with increased stem densities (often of more shade tolerant species such as Douglas-fir and Grand fir), reduced shrub and grass understories, and an increased canopy closure (Morgan 1994). Resulting forest structure is apparently not suitable as a breeding habitat due to reductions in insect populations and limited space for foraging activity. Thinning of dense stands of small-diameter conifer trees (either through cutting or prescribed burning) could benefit Lewis's woodpeckers, based on the resulting canopy structure and long-term effects of increasing tree diameters. The use of managed stands would depend on the type of timber harvest prescription. Furthermore, depending on the type of timber harvest prescription in "green" forests, habitat quality may be affected either positively or negatively. In northern Idaho, Lewis's woodpeckers will nest in clearcuts, but their use of these areas depends, presumably, on the retention of snags following harvest (Abele personal observation). However, the reproductive success and productivity of Lewis's woodpeckers in these areas is not known. Presumably, the suppression of shrubs following harvest and perhaps the resulting changes in the predator community would influence nesting activity.

Water regulation, in the form of damming, dewatering, and imposing artificial instream flows, has significantly altered riparian woodlands in the western United States during the last two centuries (Johnson and Haight 1984). Changes in the hydrologic regime in the form of flood attenuation and insufficient flows have dramatically impacted cottonwood recruitment, either through seedlings or suckering (Mahoney and Rood 1998). Without recruitment to offset adult mortality, many cottonwood woodlands have disappeared and have subsequently been replaced by more drought tolerant upland species, or they are in a state of maturity that is tending toward collapse (Mahoney and Rood 1998, Nilsson and Berggren 2000). As a primary nesting habitat, the loss of riparian woodlands may be currently limiting populations of Lewis's woodpecker or creating the foundation for a future decline. Fortunately water flow management, and not simply the presence of dams, is one of the primary factors influencing cottonwood recruitment, and several river restoration research projects have met with considerable success (Molles et al. 2000, Richter and Richter 2000, Rood and Mahoney 2000, Rood et al. 2003). The approach taken during these programs was to restore a more natural instream flow pattern and in turn to allow for the natural recruitment of cottonwoods. This new approach has differed from traditional river restoration approaches that used artificial methods (i.e., vegetation replanting). Such methods have proven costly and have required continual effort. Along the Truckee River in California, preliminary surveys suggest that avian populations have approached historic numbers as a result of restoration efforts (Rood et al. 2003). Although Lewis's woodpeckers were not present in these surveys, the results are encouraging.

Lewis's woodpeckers forage on hard and soft mast crops, as well as insects during the winter. However, acorns and oak woodlands are considered critical for over-winter survival. The importance of oak woodlands as a limiting resource is not well understood. The apparent relationship between the onset of commercial corn production and Lewis's woodpecker appearance on the Colorado plains may offer support to the hypothesis of winter food limitation through an unintended food supplementation "experiment". Oak woodland habitat in the foothills of southeastern Colorado, however, did not appear saturated, and acorns appeared to be abundant. No studies have evaluated densities of wintering birds, the importance of acorns as a winter food source, or how commercial corn may be affecting population densities.

Cattle grazing in the West has had dramatic effects on ponderosa pine forests and riparian woodlands (Morgan 1994, Saab et al. 1995). Removing vegetation including fine fuels has altered historic fire regimes. This reduction in the amount of understory vegetation may influence the abundance and composition of insect prey. Increases in plant biomass and productivity have been followed by increases in insect abundance and diversity (Siemann 1998, Marques et al. 2000). However, a multitude of interacting factors can affect insect populations, including plant architecture, plant diversity, forage quality, dispersal ability, competition, and predation (Murdoch et al.1972, Lawton 1983, Andrewartha and Birch 1984, Siemann et al.1998). Furthermore, effects of livestock grazing may have differential impacts on insect populations. For example, in a ponderosa pine-grassland community of Arizona, a grazing-exclosure study reported no difference in insect species richness but a four- to ten-fold increase in insect abundance in ungrazed habitat (Rambo and Faeth 1999). Short-term (<5 years) cattle grazing in riparian habitats is reported to have little impact on cavity-nesting species, including Lewis's woodpeckers (Saab et al. 1995). The duration and timing of grazing practices plays an important role in the resulting quality of the habitat. Reduction or removal of grazing in degraded habitats and restricting fall grazing could allow for recovery of vegetation and maintenance of residual plant cover. While there are currently no published reports on the impacts of different grazing regimes on nesting Lewis's woodpeckers, studies are underway in central Idaho (Newlon and Saab unpublished data). However, grazing has degraded riparian forests in a similar, if not more deleterious, manner as altering stream flows (Ohmart 1994, Belsky et al. 1999). The effects of trampling and browsing have restricted cottonwood recruitment, creating even-aged riparian forest stands that lack structural complexity. Although the ramifications of this single cohort structure may not appear for many years, ultimately the overmature forest dies and falls creating unsuitable conditions.

Depending on firewood cutting restrictions and enforcement, road building and motorized recreation increase opportunities to cut and gather firewood (Wisdom et al. 2000). Downed wood collection and road traffic may not play critical roles in habitat quality, but cutting dead or dying trees does reduce the number of potential nest sites. Large snags are most attractive to both birds and humans. However, depending on the location of a burn (distance to urban environments) and road density (due to fire or logging activities), the cumulative impacts of firewood collection could be substantial. As with salvage logging, effects of firewood cutting on habitat quality could be either positive of negative. Through proper enforcement and management, habitat quality could be improved. Clumps of relatively large, decayed snags are favored for nesting habitat by Lewis's woodpeckers (Saab and Dudley 1998).

Non-motorized recreation or scientific investigation is unlikely to affect habitat quality and nesting activity of Lewis's woodpecker. Some researchers have warned against monitoring this species too intensively because individuals may abandon nests (Bock 1970, Tashiro-Vierling 1994, Tobalske 1997). Other researchers have not reported abandonment due to scientific investigation (Abele, Garton, and Saab unpublished data). We used an electronic cavity-viewer to view nest contents of 117 cavities over a two-year period, with no evidence of nest abandonment due to the researcher's presence. Although some nests (approximately 4 percent) failed with dead young in the cavity, adults often remained in the vicinity of the nest following failure. Regardless, all scientific investigation should be conducted in a responsible manner, and researchers should be aware of the potential for nest abandonment. We do not believe this species to be overly sensitive to human presence because they often nest in proximity to human development.

Pesticides, especially insecticides, have been implicated as threats to Lewis's woodpecker conservation, but limited data are available to directly support this hypothesis. Pesticides, including organochlorine and organophosphorus compounds, have been used extensively in the United States and may have direct (i.e., mortality) and indirect (i.e., aberrant behavior, decreased fertility, increased nestling mortality, decreased prey availability) negative effects on birds (Gard and Hooper 1995). Most organochlorine compounds (DDT, DDE, DDD) have been banned in the United States since 1972, following the evidence linking DDT with numerous adverse impacts on wildlife species. Since these bans, agricultural practices have increasingly relied on organophosphorus and carbamate insecticides (Szmedra 1991). Although these compounds are less persistent in the environment, they are potentially as hazardous to birds due to their greater acute toxicity (Gard and Hooper 1995). In general, insectivorous birds, birds in western North America, and birds migrating to Mexico and Central and South America are contaminated with higher levels of organochlorines (primarily DDE; DeWeese et al. 1986). Lewis's woodpeckers meet two of these criteria, suggesting that further research and monitoring is warranted. The U.S. Fish and Wildlife Service's Biomonitoring of Environmental Status and Trends Program and a nonlethal blood plasma method (Henny and Meeker 1981) may be useful in determining organochlorine burdens in populations. Diagnosing organophosphorus or carbamate pesticide exposure requires brain or plasma tissue. Analytical methods and procedures useful in this analysis were described by Ellman et al. (1961) and modified for easier field application by Hill and Fleming (1982) and Fairbrother et al. (1991).

Competition with European starlings and other cavity-nesting species for nest sites may threaten local populations, but data do not appear to support this idea (Vierling 1988). However, this hypothesis should not be entirely discounted. Elevated energetic costs and stress associated with higher rates of territorial encounters with European starlings which could reduce reproductive success, even if Lewis's woodpeckers dominate the majority of interactions (Siddle and Davidson 1991).

Do habitats vary in their capacity to support Lewis's woodpecker populations or to support principal food resources?

What are the important characteristics of high quality habitats?

Habitats do vary in their capacity to support populations and functional activities of Lewis's woodpeckers. Lewis's woodpeckers use several tree species and habitats for nesting and wintering. Their distribution suggests that certain habitat characteristics are essential, although many of these hypotheses are yet to be critically examined. Aspects of their winter ecology remain poorly understood, and investigations into the role of oak woodlands in limiting populations could help to focus conservation efforts. In addition, examinations of the thresholds at which known breeding habitat criteria such as canopy and shrub cover become unsuitable could facilitate our ability to predict species occurrence.

Globally, Lewis's woodpecker distribution corresponds with that of ponderosa pine (Saab and Vierling 2001). This association may be due in part to the birds' excavation ability and foraging ecology and in part to forest structure. Ponderosa pine is often used by cavity-nesting species because of the rapid decay in the thick layer of sapwood (Bull et al. 1997). This tree species is well suited to Lewis's woodpeckers because they have a relatively weak ability to excavate (Spring 1965). In addition to ponderosa pine, they frequently use other soft-wooded tree species, such as cottonwood and aspen. Historically, ponderosa pine forests in some regions were maintained by frequent fires that reduced stem densities. The resulting forest structure allowed for greater light penetration to the forest floor and subsequent development of understory vegetation. The understory development and associated insect community provided a needed food source and openings for aerial maneuvers. Habitats providing easily excavated trees, shrubs, and space for aerial maneuvers are consistently used by Lewis's woodpeckers, including riparian woodlands, aspen groves, pinyon-pine forests, and most notably stand-replacing burns.

Based on nest success and density of breeding pairs, Lewis's woodpecker favored partially salvage logged forests compared to unlogged forests, logged burned forests, or cottonwood woodlands (Saab and Dudley 1998, Saab et al. 2002, Saab et al. 2004). Openings in partially logged, recently burned forests likely provide greater opportunities for aerial foraging. Relatively few nests have been found in unburned forests (Saab and Vierling 2001, Saab et al. 2002), suggesting that they lack critical characteristics such as nest substrates, an open canopy, or suitable insect abundances. Lewis's woodpeckers are not known to excavate in live trees, thus the lack of snags in unburned forests could explain the lower densities found in this habitat, in addition to forests' closed canopies that reduce the birds' ability to capture prey. No empirical data are available to assess insect abundance as a limiting resource, but riparian cottonwood habitat in Colorado was noted for having limited understory vegetation, which may have influenced insect availability (Saab and Vierling 2001).

Typical picids feed primarily on wood-boring insect larvae and display limited seasonal movements because their food source is available year round. The diet of Lewis's woodpeckers, however, shifts in the winter from insects to a variety of hard and soft mast crops, although insects are taken when available. Consumption of mast crops by Lewis's woodpeckers may minimize excessively long and costly migrations. Altitudinal and latitudinal migratory behavior may be influenced more by availability of insects and fruits than by thermoregulatory necessity.

Oak woodlands not only provide mast but also may be suitable for flycatching, given appropriate temperatures. Similarly, wintering in proximity to commercial cornfields could provide an opportunity for both a mast crop and room for aerial foraging. Winter survival of Lewis's woodpeckers feeding on acorns was high (87 percent) in southeastern Colorado (Tahiro-Vierling 1994), as was adult winter survival in other melanerpine species (Koenig and Mumme 1987, Stacy and Taper 1992).

If Lewis's woodpecker or its prey relies on particular habitats, are these habitats declining or being stressed by current management?

Global climate change

Regional effects of climate change are not well understood but may be manifested in contrasting ways. Given conditions that are hotter and drier, the distribution of ponderosa pine forests would presumably move to higher elevations and be reduced in overall extent. Although the overall loss of forest is not known, suitable habitat would probably remain to support viable populations of Lewis's woodpecker. However, this drier climate scenario would presumably exert greater pressure on already taxed water resources and thus negatively affect riparian woodlands. If climates were to change toward a colder and wetter regional scenario (as suggested by some recent climate models), the extent and distribution of ponderosa pine would likely increase. This scenario would presumably provide a more suitable situation for Lewis's woodpeckers, given appropriate habitat conditions exist. The effect of the climate on the insect community would certainly be important in either of these situations. In the hotter scenario, insect populations may respond positively, while a colder climate may adversely affect insect populations. This may shift the distribution of birds to the south and restrict their current northern extent.

Current forest conditions

Although the negative impacts of fire suppression have been well documented, (i.e., denser stands, decreased perennial grass and shrub cover) unintended positive impacts may also be evident. Suppression of historically low intensity ground fires in ponderosa pine systems has inadvertently created conditions that result in more frequent and larger stand-replacing wildfires than occurred historically (Morgan 1994). These stand-replacing fires create habitat that is highly suitable to breeding Lewis's woodpeckers. For instance, recent wildfires (2000 to 2002) in ponderosa pine forests of Colorado and South Dakota may potentially benefit populations of Lewis's woodpecker in Region 2.

Alterations to riparian forests, through grazing practices and water management, have presumably affected both nesting substrate and insect abundance. The degree to which these have impacted populations of Lewis's woodpecker is not known, and data are somewhat contradictory. Although examples of range expansions are limited to southeastern Colorado, it presents an interesting anomaly. This expansion is likely due to artificial supplementation of winter food supplies in the form of commercial corn. Numerous individuals from this population were year-round residents, probably as a result of the artificial food supply. Such conditions could prove to be sink habitat.

Although population trends of Lewis's woodpecker over the last century are not known, it is evident that they have survived during a period of changing forest conditions. Fluctuations in population numbers would be expected, but whether human alterations to the environment have exacerbated these fluctuations is unclear.

Do the life history and ecology of Lewis's woodpecker suggest that populations are vulnerable to habitat change?

Details of the life history strategy of Lewis's woodpecker are incomplete, but available information offers a good understanding. This species takes advantage of abundant, ephemeral local food supplies; exhibits migratory behavior; breeds in a variety of habitats; and may respond quickly to newly created, suitable habitat. With this r-selected life history strategy, Lewis's woodpeckers are potentially less impacted by local habitat changes than k-selected species. Additionally, populations of Lewis's woodpeckers will be more resilient to habitat changes. For example, in the Okanagan Valley in British Columbia, substantial increases in breeding birds were noted following dramatic increases in grasshopper and cricket populations (Munro 1930).

Although nothing is known about adult or juvenile dispersal, individuals presumably move among locations that are suitable while crossing unsuitable habitat. Strong dispersal abilities may minimize issues confronting small populations. Small isolated populations are vulnerable to extinction from demographic stochasticity (e.g., a harsh winter that results in low survival) and loss of genetic variability due to isolation. However, the ephemeral nature of Lewis's woodpecker habitat suggests that local extinction is more likely a consequence of deterministic factors influencing habitat. Frequent movements among small populations help mitigate these concerns, and Lewis's woodpeckers appear capable of making these movements.

What are the appropriate monitoring methods for this species and its habitats, and what tools and practices should be employed?

Implications and potential conservation elements

Maintenance of open forest stands through natural fires, prescribed burns, selective timber harvest, and active management to promote cottonwood regeneration (e.g., restoration of native hydrographs) represents appropriate management to conserve this species. Forest restoration activities have not been tested to support this idea, although large-scale efforts are underway (see web page http://www.rmrs.nau.edu/lab/4251/birdsnburns/). Where applicable (i.e., designated wilderness areas, prescription permitting), wildfires will facilitate the creation of preferred breeding habitat through thinning dense forest stands or creating stand-replacement burns. Restoration of natural hydrologic regimes in areas of cottonwood riparian habitat may allow for the long-term maintenance of sites. Cottonwood seed dispersal generally occurs after annual peak river flows. A gradual receding of stream flows allows for seedling establishment and prevents desiccation of new cottonwood seedlings. Recent research into riparian forest restoration has modeled the conditions necessary to achieve seedling establishment (Mahoney and Rood 1998), and demonstrated the efficacy of these models through successful field application (Rood et al. 2003). In post-fire salvage logged sites, snag size, distribution, and decay class appear to influence habitat use. Retention of large diameter snags (>23 cm dbh) and relatively high densities of snags (60 per ha of >23 cm dbh), distributed in clumps, will be critical for creating suitable post-fire habitat (Saab et al. 2002). Monitoring and enforcing firewood harvest restrictions may facilitate the maintenance of snags.

Species inventory. Current broad-scale survey methods for small landbirds (BBS and CBC) are generally not effective to detect changes in Lewis's woodpecker populations. The number of detections is generally too small to assess population change. Both Breeding Bird Surveys and Christmas Bird Counts are most effective at discerning population trends at broad scales (population changes of 50 percent over a 25-year period with probability of 0.9; Peterjohn et al. 1995). The number of detections and routes needed to determine population trends at any scale (i.e., physiographic, regional, state, county) has been recommended to be one bird per route with 14 routes; trend estimates with less detections underestimate variance and produce positive bias (Barker and Sauer 1992). Furthermore, neither approach employs methods capable of estimating density. The most feasible method of improving statistical power (or the ability to detect a decline) is increasing the number of survey routes.

State Breeding Bird Atlases are currently a good resource for determining species' distributions. This method divides a state into thousands of atlas blocks and then randomly selects blocks in which to survey. Theoretically, this provides a statistically valid representation of all habitats in the state. However, there are limitations to these surveys. First, the task is daunting in its objectives, and limitations due to effort (i.e., time and money) and observer experience probably result in fewer reports for blocks that are difficult to access. Lewis's woodpecker is most easily detected and most strongly represented along riparian corridors and burned conifer forest. Because these habitats are patchily distributed and have limited spatial extent, they are often not surveyed adequately, which results in maps that display spotty occurrence. State Breeding Bird Atlases are a recent undertaking, so data do not illustrate temporal changes in distribution. However, until alternative methods are employed these surveys provide a valuable data source.

Currently the Colorado Bird Observatory, in cooperation with various agencies including Region 2 of the USFS, is monitoring Colorado bird populations. The program, Monitoring Colorado's Birds (MCB), was established in 1998 with the goal of establishing a regional habitat-based monitoring program to complement data generated by BBS (Leukering et al. 2000). MCB is a two-phase project. The first phase is the establishment of a monitoring program that ensures count-based data are obtained for all species that can be monitored effectively through a habitat-based approach, and that census programs are established for species requiring specialized approaches. Phase 2, currently incomplete, will involve demographic field studies investigating the possible reasons for known population declines. MCB's statistical target is to detect a population change of –3 percent per year over a 30-year period. Lewis's woodpeckers are monitored via a line transect approach, and all transects are established at randomly selected sites, avoiding biases associated with roads and trails. Additionally, MCB employs 30 samples (i.e., transects) per habitat, improving the ability to statistically detect population change. Although MCB is currently limited to the state of Colorado, the goal is to expand this program to the level of Bird Conservation Region, making it more cost effective by reducing duplicate efforts among states sharing similar habitats, and ultimately making it more biologically meaningful. For more information on the MCB program, see Colorado Bird Observatory's website (http://www.rmbo.org/conservation/mcb.html).

Habitat inventory. Based on the research reviewed for this assessment, it is apparent that certain habitat characteristics are important to Lewis's woodpecker: canopy cover, shrub understory cover, and snag availability. The collection of local-scale vegetation data may be critical to understanding current and future patterns of bird distributions. One difficulty in compiling habitat information from a number of studies is the diversity of methods used to collect and report similar data. Therefore, the method used to identify suitable habitats (i.e., traditional ground methods or satellite imagery) must be preceded by an understanding of which habitat characteristics are important and, there must be a full realization of the limitations of the chosen method to detect habitat change.

The use of satellite imagery for wildlife and forest management has increased dramatically in the last 10 years as costs have declined and available technology has improved. This technology is rapidly changing, and an increase in the level of detail is accompanied by a greater need for more computing power and effort. During preliminary study design, satellite imagery may prove useful in identifying potential suitable habitats such as stands of ponderosa pine, riparian cottonwood, and oak woodlands. In addition to this coarse evaluation, specific habitat characteristics that have been successfully identified by satellite imagery include the amount of canopy closure, and the size, distribution and number of snags per ha (Saab et al. 2002). Furthermore, this technology allows for the examination of how surrounding landscapes may affect breeding and wintering activities. Biologists have a critical eye for discerning limitations in field data such as sampling design and scope of inference, but maps generated from satellite imagery are often thought to be the absolute truth. Thus, understanding the error associated with these maps and the limitations of this data source should also be considered prior to accepting results generated from these sources.

Following the use of satellite imagery to coarsely identify potentially suitable habitat, traditional ground based methods may be used to ascertain the quality of these patches. Specifically, ground-based inventory methods could be used to examine percentage of shrub understory cover, the number of snags and their condition (i.e., decay class), the number of cavities present, and the amount and size of downed woody material. Additional work on insect abundance, through the use of sweep nets or Malaise traps, may be appropriate at this time.

Monitoring habitat change may be most appropriate at a Bird Conservation Region scale. Because Lewis's woodpeckers are nomadic and adapted to take advantage of ephemeral burned habitats, only broad-scale monitoring can examine population trends.

Population monitoring. Presence/absence surveys are an excellent and often cost-effective tool to detect changes in the distribution of a species, as well as monitor population trends. Often these data are interpreted informally (i.e., the species is absent from x % of the original census sites). However, simple statistical tests could be used to assess the significance of change in the number of occupied sites. Depending on the intent of the research, however, presence/absence surveys can have low statistical power (increased probability of Type II errors), especially if population declines are modest (<20 to 50 percent; Strayer 1999). Thus, if the researcher is interested in small declines (due to biological significance), presence/absence surveys may be ineffective. Furthermore, the effect of limited statistical power is compounded when the species being surveyed is not frequently detected (as is the case for Lewis's woodpecker), or if the species is undergoing moderate but widespread declines across its range as opposed to local extirpations. Researchers have several options to increase the power of presence/absence surveys: increasing effort per site, increasing the number of survey sites, and adjusting the a level to a more liberal level than 0.05. Of these, increasing the number of sites surveyed is likely the most easily controlled and acceptable to colleagues and critics. The Breeding Bird Survey recommends at least 14 surveys per unit of interest. However, more will be needed if the species is not detected at least once per survey. An alternative option to improve statistical power is to use a response variable based on local abundance instead of simply "1s" and "0s". Surveys based on abundance are more likely to detect modest changes in population numbers. In addition, abundance estimates can be used in conjunction with measures of habitat variables to assess the quality of habitats or to determine the impact of local management activities on populations.

Lewis's woodpeckers are readily detected when present. Therefore, using line transects as a detection method would likely prove feasible. In Idaho, 200-meter wide belt transects are used extensively and successfully in burned and unburned ponderosa pine habitat (Dudley and Saab 2003). Although these transects are used to completely census a designated study site and subsequently monitor demographics, they could easily be adapted to work as an abundance survey method. The use of a point sampling method, such as a fixed-radius point count or a variable circular plot, would likely be less effective than a line transect because woodpecker species are rare over most landscapes. The use of a variable circular plot method may provide a better data source than fixed-radius point-counts by providing more acute measures of abundance and density, although opinions differ due to the often-unmet assumptions (Hutto and Young 2002). With field surveys being preceded by a short training period, variable circular plots would require little extra effort, and data could always be adjusted to correspond with traditional fixed-radius point count data.

The spatial and temporal scales for conducting surveys depend on the intent of the research or monitoring. Local populations of Lewis's woodpecker are prone to change because the species takes advantage of ephemeral habitats. Monitoring of this species on larger regional or state scales may be most appropriate because of the ephemeral nature of local populations. At broader spatial scales, detected changes may more accurately represent fluctuations in overall population numbers and may not simply be a result of unsuitable local habitat conditions. Until a better understanding of what constitutes suitable breeding and wintering habitat is available, monitoring at broad spatial scales might be adequate to determine the persistence of local and regional populations. Monitoring population trends requires a long-term effort, but initiating this process is an important first step.

Lewis's woodpeckers are generally vocal during courtship and egg-laying, relatively quiet during incubation, and vocal again during the nestling stage. Thus early-season and late-season surveys will likely yield more data by aural cues. In addition, surveying during the breeding season offers insight on the quality of nesting habitat. Once nesting has been confirmed, a sub-sample of nests in this location could be monitored to determine reproductive success. In post-breeding surveys, ratios of adults to juveniles could be noted because plumage differs between adult and juvenile birds. Data gained from either pre-breeding or post-breeding censuses could be used to calculate important demographic parameters useful in modeling populations (Caswell 2001).

Abundance is potentially a misleading indicator of habitat quality (Van Horne 1983). Based on the natural history of Lewis's woodpecker, however, this is likely not the case for this species. Still, investigating the reproductive success of a sub-sample of censused birds would be valuable in evaluating the source/sink status of habitats as well as in providing survival data useful in population modeling efforts. Nest survival estimators, such as the Mayfield method, often use study sites as the primary experimental unit (Mayfield 1961, 1975). This method requires approximately 20 nests per site to gain accurate daily survival estimates. Johnson (1979) modified this method, correcting for biases attributed to unequal periods of nest observation and to include the standard error of the success estimator. Recent methods on determining nest survival allow for modeling survival as a function of several covariates (Dinsmore et al. 2002). Depending on the habitat (due to differences in apparent densities), the size of the study unit needed to capture an appropriate sample will vary. In burned and unburned ponderosa pine forests throughout the interior West (including national forests in Colorado and South Dakota), study units range in size from 250 to 400 hectares to gain an adequate sample and determine nesting survival (http://www.rmrs.nau.edu/lab/4251/birdsnburns/; Dudley and Saab 2003). A study site of this size requires one to three field biologists to conduct surveys and to monitor nesting birds, including most cavity-nesting species. Depending on the number of vegetation strata and the number of replicates within each, the size of field crews will vary. Estimates of adult and juvenile survival are lacking (see Information Needs below). Attempts to evaluate these demographic parameters would improve our ability to assess habitat suitability as well as potential limiting factors affecting populations.

Due to the apparent differences in densities of nesting birds and source/sink status of habitats (Saab and Vierling 2001), a stratified random sampling design may prove useful. For example, permanent transects or points could be established within each stratum (e.g., habitats), and estimates of abundance, presence/absence, or reproductive success could be obtained for each habitat. Since variation in these parameters is likely less within habitats, estimates will be better and more cost effective. Furthermore, population monitoring in riparian habitats would be the most appropriate method of gathering data on population trends because birds return annually to breed in these habitats, unlike ephemeral burned habitats where population responses are punctuated. Formulas are available to determine the sample size and the optimal allocation of effort to the strata (Scheaffer et al. 1986). The use of permanent stations (transects or points), however, is essential to ensure that variation in count data is due to variation in bird occupancy and not point location. The use of stations that vary on a yearly basis will increase variation in long-term monitoring data and decrease the power to detect trends in occurrence.

Management approaches

Specific management recommendations applied to the conservation of Lewis's woodpecker are limited, and tests of their effectiveness have not been undertaken (Cooper at al. 1998, Wisdom et al. 2000). Based on the available knowledge presented in this assessment, however, we can predict the consequences of certain environmental changes. The strong positive effect of recent fire in montane conifer forest is clear; the greatest density of nesting birds has been recorded in habitats created by stand-replacing wildfire. Maintenance of open canopy forests through active management will alleviate conditions that are not suitable for breeding populations, such as relatively high densities of small diameter (< 23 cm dbh) trees and lack of shrub understory. Developing measures for snag recruitment and retention (e.g., fuel wood management) will potentially provide more nesting opportunities. During post-fire salvage logging in ponderosa pine forest, retaining a clumped distribution of snags and restricting fuel wood harvest will facilitate development of quality Lewis's woodpecker habitat.

Information Needs

Introduction

Determining the current conservation status of a species requires a solid understanding of its habitat requirements and up-to-date information on its distribution and population trends. Managers, researchers, and the public are interested in obtaining the knowledge necessary to critically assess, manage, and potentially adjust current land use practices to meet society's conservation goals. Our intent in this section is to identify areas of research that would aid in understanding the ecology and conservation of Lewis's woodpecker. Although our discussion is not exhaustive, we highlight avenues of research that will assist in conservation including information on distribution, demography, habitat associations, limiting factors, and habitat characteristics that influence prey populations of Lewis's woodpeckers. Ideally our discussion will encourage research and enhance our understanding of Lewis's woodpeckers as well as improve conservation approaches.

Distribution

National and regional bird surveys, research projects, and the avocation of bird watching pursued by an ever-increasing number of people have provided a strong working knowledge of the distribution of Lewis's woodpecker. However, additional surveys targeting specific areas are justified to better delineate local breeding, wintering, and resident populations. In addition, incorporating methods that provide more accurate estimates of abundance into distribution surveys would greatly aid in determining population trends. Several aspects of Lewis's woodpecker distribution are unknown or poorly understood, including genetic variation, migration paths, and historic occurrence.

The distribution of genetic variation is completely unknown, and there are no recognized subspecies or races. A range-wide study of genetic variation might identify populations that are predisposed to the problems associated with small isolated populations. However, this is unexpected to be important for this woodpecker because of the ephemeral nature of historical populations.

Modern molecular or telemetry techniques might aid in the identification of important migratory paths. Migration is likely an energetically expensive endeavor that may influence annual survival. Knowledge of migratory pathways during seasonal movements is the first step toward conservation of needed habitats.

Response of Lewis's woodpecker to stand-level habitat change

The critical habitat associations of Lewis's woodpecker including stand structure, understory development, and snag availability are fairly well documented, but the limiting factors affecting this habitat specificity remain vague. Saab and Vierling (2001) demonstrated that nesting densities and nest success differed between habitats. However, it is not known if the high nest success documented in burned pine forests of Idaho would be found in all stand-replacing burned pine habitat. Similarly, the landscape matrix likely influenced the reproductive success witnessed in riparian cottonwood habitat of Colorado. Research examining a range of landscape matrix conditions would aid our understanding of the factors influencing reproductive success.

Understanding Lewis's woodpecker's response to stand-level habitat change can be broken into two main components. First we must determine which habitat elements are important to survival and reproductive success (e.g., mast availability, snag density, shrub cover) and how variation in these elements affects population size across a broad geographical range. Second, we must determine if forest management can lead to the habitat conditions needed for successful wintering and breeding. Investigations into nest success across broad geographical and temporal extents may facilitate our understanding of the critical thresholds at which habitat characteristics affect population dynamics. Furthermore, study of reproductive success as well as juvenile and adult survival in experimentally manipulated forest stands could examine the potential to develop important habitat characteristics such as stand structure, snag suitability, and understory shrub cover.

The role that forest structure and composition play in determining the availability of dietary items is unknown. Furthermore, the numeric and functional response of Lewis's woodpeckers to important insect prey populations is not understood. No studies have attempted to quantify insect abundance or diversity and relate these to Lewis's woodpecker population dynamics. Diet, in general, remains poorly understood. For example, Lewis's woodpeckers often forage on native fruits late in the breeding season, but it is not known if this dietary choice is based on a decrease in insect abundance, simply a result of plant phenology, or a way in which to supplement water intake. Understanding the relationship among factors influencing insect populations is critical to predicting the effects that stand management will have on Lewis's woodpecker population viability.

Influences of stand-level habitat change on predators and competitors are not well known. Nest predation appears to be a primary cause of nest failure in Lewis's woodpeckers, and predator communities are likely influenced by alterations to forest stands. Investigations into factors affecting both spatial and temporal arrangements of predator communities would aid our understanding of the role predation plays in population regulation. Similarly, mammalian nest predators may act as cavity competitors. Investigations into factors affecting the occurrences of these species would aid our assessment of possible limiting agents affecting Lewis's woodpecker populations.

Effects of broad-scale habitat changes on movement patterns

Daily movements during the breeding and winter seasons appear to be local and centered on small, defended territories. This suggests that alterations to forest stands are likely more influential than broad-scale habitat changes. However, natal dispersal patterns are not known, and changes to surrounding habitats may affect the survival and future reproductive success of dispersing juveniles by limiting the availability of suitable habitats. Furthermore, how broad-scale changes may influence predator assemblages is not well known. The landscape matrix likely influences the occurrence of nest-predators and in turn potentially affects reproductive success, but these impacts are poorly understood (Saab et al. 2004). Given the fact that Lewis's woodpeckers make seasonal movements, landscape-scale and regional-scale changes to habitats may have the greatest influence during migration. Broad-scale habitat changes may influence these movements and affect pre-migration condition. However, until a better understanding of the nature of Lewis's woodpecker migration is available, including migratory paths and the importance of specific habitats, we can only speculate on how broad-scale habitat changes would influence migrating birds.

Demography

Although nesting chronology, fecundity, and reproductive success of Lewis's woodpeckers are fairly well known, the foundation for this knowledge is limited to only a few habitats and geographic locations. Understanding adult and juvenile survival is critical to understanding the woodpecker's relationship to forest management. Adult survival appears to be the most influential demographic parameter affecting population growth rates (see Geometric rate of natural increase above). Research to determine annual adult survival would be beneficial; ideally, estimates of age-specific survival during breeding, wintering, and migration would help to focus conservation efforts. Estimates of juvenile survival would similarly aid evaluation of population persistence. Research on survival is difficult. Although traditional VHF telemetry methods could be used and would provide important insight into post-fledging survival, following juveniles during migration and onto the wintering grounds would be a challenge. Ideally, the use of GPS telemetry methods could be employed (animals are remotely sensed), alleviating the difficulties associated with locating migrating birds. However, this technology is currently not available for small animals because of weight limitations on the GPS transmitters. Alternatively, intensive banding efforts could be undertaken. Banding juveniles is a straightforward process, and in areas with a high density of birds, large numbers could be banded fairly rapidly. The difficulty of determining juvenile survival from banding projects is good band recovery. Although juvenile birds likely disperse fairly short distances, searching for returning birds would require considerable field time. Finally, estimates of juvenile dispersal are necessary to determine if the species exhibits metapopulation structure. Estimates of dispersal could be gathered from the same techniques used to determine survival, as well as modern genetic tools such as assignment tests. This information would greatly enhance population models.

An integrated research approach

Research needed to fill the information gaps for Lewis's woodpecker should involve a variety of scientific approaches and cooperation among agencies, regions, and researchers. Incorporating modeling efforts, quasi-experimental, and observational field studies will provide critical information needed to formulate a complete understanding of the biology, ecology, conservation status, and management of Lewis's woodpecker. The use of these research approaches should be coordinated and cover a broad geographical range to realize two primary research objectives, with the intent of achieving an overall conservation goal. The first objective is to develop a regional and range-wide monitoring protocol and to use observational and modeling studies to provide critical information concerning current distribution, population trends, and critical habitat associations. The second objective is to fill information gaps associated with Lewis's woodpecker biology and ecology.

Outline of suggested monitoring and research objectives:

- I. Monitoring
    - A. Establish permanent transects for annual survey in cottonwood/aspen riparian and < 15 year-old burned forests)
        - 1. Region-wide
            - a. Stratify by Bird Conservation Regions and habitat
        - 2. Habitat- based
            - a. Determine locations of important breeding and wintering habitats
            - b. Conduct quasi-experimental, model-based, and observational studies to assess local distributions, densities, and population trends in relation to land-use activities
- II. Genetic Analysis
    - A. Assess genetic variation throughout range by examining museum specimens and blood/feathers collected from adults and nestlings
    - B. Revise taxonomy
- III. Habitat Inventory
    - A. Evaluate habitat selection using observational, experimental, and modeling studies, including habitat manipulation of forest stands
        - 1. Determine contribution of forest structure, predator and prey abundances, and snag/cavity availability to preference for riparian and burned ponderosa pine forests
        - 2. Evaluate source/sink habitats using nest monitoring studies, and studies of adult and juvenile survival
    - B. Evaluate diet using observational and experimental approaches
        - 1. Conduct experimental feeding trials examining preference and energetic value of native and commercially cultivated mast
        - 2. Conduct experimental and observational studies of arthropod prey selection among habitats and the effects on bird density and reproductive success
    - C. Evaluate the effects of habitat fragmentation on nest predation
- IV. Population Viability
    - A. Determine survival estimates for winter, summer, and migration
        - 1. Use telemetry and mark-recapture studies to estimate adult and juvenile survival
        - 2. Conduct monitoring studies to determine nest survival across a broad
          geographic range and multiple habitats
    - B. Determine fertility estimates for age classes and habitats across a broad geographic range
    - C. Identify dispersal patterns of adults and juveniles through mark-recapture or molecular techniques
    - D. Examine interspecific relations, using marked individuals to examine Lewis's woodpecker's ability to usurp and occupy cavities
- V. Seasonal Movements
    - A. Spring/fall migration
        - 1. Identify migration paths through telemetry or mark-recapture studies
        - 2. Delineate resident and migratory populations or proportion of individuals undertaking seasonal movements among populations
    - B. Nomadic movements
        - 1. Conduct observational study of marked individuals to examine the importance of pre-migration fall movements

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