[badkitty] Autopsy results..

From: Paul Sieracki via badkitty list (badkitty@groups.electricembers.net)

To: badkitty@groups.electricembers.net

Date: Monday, December 14, 2020, 09:06 AM MST

"The laboratory results are very informative but did not identify a single definitive cause of mortality.

Starvation, unexpected weather to blame in mass migratory songbird mortality

SANTA FE –The U.S. Geological Survey National Wildlife Health Center has analyzed representative samples of the migratory songbirds collected, cataloged and sent for analyses by New Mexico Department of Game and Fish biologists, in early September. The lab report indicates that the single abnormality shared by nearly all birds was body condition ranging from poor to severely emaciated.

Kerry Mower, the Department's wildlife disease specialist, said, "The laboratory results are very informative but did not identify a single definitive cause of mortality. However, they did find that nearly all birds were severally emaciated."

The single abnormality shared by nearly all birds was body condition ranging from poor to severely emaciated. These observations are evidence of physical exertion without nourishment to support recovery, including:

- the large breast muscles controlling birds' wings were severely shrunken;
- kidney failure was apparent in many of the birds;
- stomachs and intestines were empty of foodstuffs;
- many intestines contained small amounts of blood, which is one of the effects of starvation;
- fat deposits, the stored energy for migration, were depleted; and
- lung tissues were irritated.

The USGS National Wildlife Health Center, located in Madison, Wis., is renowned for the thoroughness of the diagnostic tests for wildlife disease diagnosis and management. The center conducted numerous tests during analyses, ruling out contagious bacterial disease, contagious viral disease including avian influenza and Newcastle disease and parasites as cause of death, as well as finding no evidence of smoke poisoning or pesticide poisoning.

From the lab reports, Department biologists know that migrating birds entered New Mexico in poor body condition and some birds were already succumbing to starvation. The unusual winter storm exacerbated conditions, likely causing birds to become disoriented and fly into objects and buildings. Some were struck by vehicles and many landed on the ground where cold temperatures, ice, snow and predators killed them.

"The Department would like to thank many partners and the public who reported mortalities across New Mexico," said Erin Duvuvuei, the Department's avian biologist. "Hundreds of reports were received through email, phone calls and the iNaturalist app." Reports declined by late September.

The Department would also like to thank all of the partner organizations who were essential to this process. Partners include the: United States Fish and Wildlife Service, White Sands Missile Range, United States Forest Service, Bureau of Land Management, New Mexico Avian Conservation Partners, New Mexico State University, University of New Mexico, Audubon Southwest, Los Alamos National Laboratories and the New Mexico Wildlife Center.

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USDA

United States
Department of
Agriculture

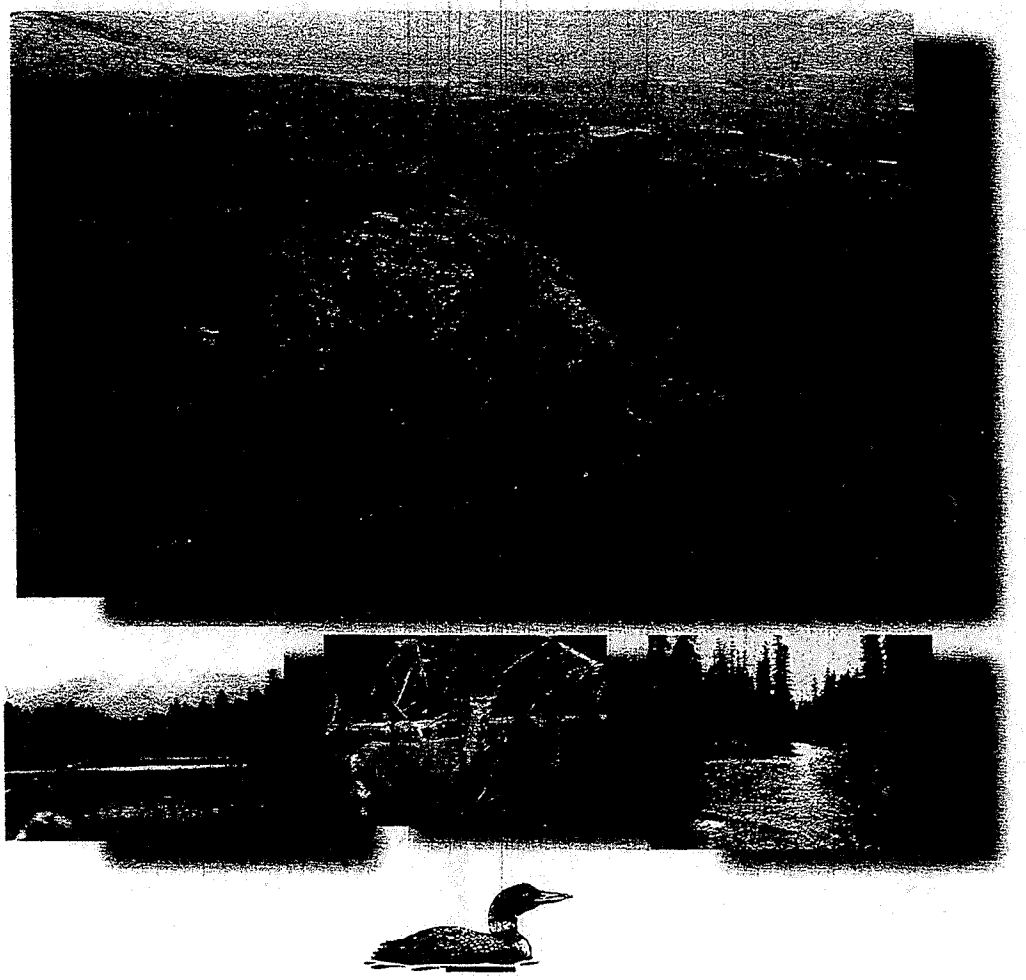
Forest Service

April 2018

Glacier Loon Fuels Reduction and Forest Health Project

Draft Decision Notice

Swan Lake Ranger District, Flathead National Forest
Missoula County, Montana



April 2018

OLD GROWTH ASSOCIATED WILDLIFE

INTRODUCTION

Old growth is defined in Amendment 21 of the Forest Plan as "a community of forest vegetation that has reached a late stage of plant succession." The generic description is as follows:

- The age of the dominant cohort of trees is significantly older than the average time interval between natural disturbances (interval will vary depending upon forest cover type and habitat type);
- Forest composition and structure are different from younger stands;
- Rates of change in composition and structure of the stand are slow relative to younger forests;
- There is a significant showing of decadence (wide range of defect and breakage in both live and dead trees).

In The Dictionary of Forestry (Helms 1998), old growth forests are described as having:

- Large trees for the species and site;
- Accumulations of large dead standing and fallen trees;
- Decay or breakage of tree tops, boles, or roots;
- Multiple canopy layers;
- A wide variation in tree size and spacing; and
- Canopy gaps and understory patchiness.

The characteristics of old growth forest described above provide habitat for many plant and animal species. Old growth forests are an important component of biological diversity. For the purpose of this discussion, old growth associated species includes any wildlife species that use the various attributes of old growth forests for some or all of their ecological needs. These needs could include nesting, denning, security, or foraging habitat. For some species, closed canopy old growth provides snow capture and reduces snow depths, insulates the animals from cold winds, and provides protection from predators. Some species, such as the fisher, are strongly tied to canopy cover and mature forest structure for the majority of their habitat needs. More open canopies, or open understories, provide foraging opportunities for prey and predator species alike. Wildlife may use interior old growth habitat as shelter from sun, heat, dryness, or wind and old growth cover may provide protection from predators. Some old growth associated wildlife species need only a portion of their home range to be in old growth; examples include the Canada lynx, northern goshawk, and American marten. Other species such as southern red-backed voles, chestnut-backed chickadee, Swainson's thrush, and northern flying squirrels, have relatively small home range sizes (less than 100 acres), with the necessary proportion of this home range being in old growth unknown.

The following table displays 31 old growth associated species that may be found in the Swan Valley, along with their associations with various old growth habitat characteristics (USDA 1999b).

TABLE 3- 87 HABITAT REQUIREMENTS OF OLD GROWTH ASSOCIATED WILDLIFE SPECIES. (BASED ON WARREN 1998 AND LRMP AMENDMENT 21 FEIS).

SPECIES	COVER TYPE IN AFFECTED AREA	CANOPY	EDGE	LARGER PATCHES	SNAG	DOWN LOG	OCCURRENCE
American Marten	Mixed mesic, lodgepole, spruce/fir forests	Closed	-	+	X	X	Known current
Bald Eagle (S)	Mixed mesic forests, near large lake or river	Open		+	X		Known current
Black-backed Woodpecker (S)	Lower Montane & Montane; post-fire or insect-epidemic forests	Open			X		Known current
Boreal Owl	Mixed mesic and spruce/fir forest mosaic	Closed			X	X	Known current
Brown Creeper	Mixed mesic, lodgepole, and spruce/fir forests	Closed	-		X		Known current
Canada Lynx (T1)	Mixed mesic, lodgepole, and spruce/fir forests; gentle terrain		+2	+	X3	X	Known current
Chestnut-Backed Chickadee	Mixed mesic and spruce/fir forests, especially cedar-hemlock	Closed	-4		X		Known current
Fisher (S5)	Mixed mesic and lodgepole forests	Closed				X	Known current
Flammulated Owl (S, F[6])	Lower Montane and Montane, single-story.	Open			X		Known current
Golden-crowned Kinglet	Mixed mesic, lodgepole, and spruce/fir forests	Closed		+	X		Known current
Hairy Woodpecker	Mixed mesic, lodgepole, and spruce/fir forests	Open			X	X	Known current
Hammond's Flycatcher (F)	Mixed mesic and spruce/fir forests	Closed					Known current
Harlequin Duck (S)	Swift mountain streams, riparian old growth (weak association)	Open				X	Known current
Hermit Thrush	Dry mixed mesic and spruce/fir forests	Open		+			Known current
Lewis' Woodpecker	Lower Montane ponderosa pine and old burns	Open			X		Known current
Northern Flying Squirrel	Mixed mesic and lodgepole forests			+	X	X	Known current
Northern Goshawk	Single or multistory old growth; clear forest floor	Closed		+	X		Known current
Pileated Woodpecker	Mixed mesic forests	Closed		+	X	X	Known current
Pine Grosbeak	Mixed mesic, lodgepole, and spruce/fir forests						Known current
Pygmy Nuthatch	Large single-story ponderosa pine and mixed mesic forests	Open			X		Known current
Red-Breasted Nuthatch	Mixed mesic, lodgepole, and spruce/fir; relatively dry	Open		+	X		Known current
Silver-haired Bat	Mixed mesic and lodgepole forests; caves and snags				X		Suspected
Southern Red-backed Vole	Mixed mesic, lodgepole, and spruce-fir forest				X	X	Known current
Swainson's Thrush (F)	Mixed mesic and lodgepole forest with shrub understory			+			Known current
Tailed Frog	Cold, high gradient headwater streams					X	Known current

TABLE 3- 87 HABITAT REQUIREMENTS OF OLD GROWTH ASSOCIATED WILDLIFE SPECIES. (BASED ON WARREN 1998 AND LRMP AMENDMENT 21 FEIS).

SPECIES	COVER TYPE IN AFFECTED AREA	CANOPY	EDGE	LARGER PATCHES	SNAG	DOWN LOG	OCCURRENCE
Three-toed Woodpecker	Mixed mesic, lodgepole, and spruce/fir forests; post-fire				X		Known current
Townsend's Warbler	Mixed mesic and lodgepole forest; dense understory	Closed	-	+			Known current
Varied Thrush	Mixed mesic and spruce/fir forests, especially cedar-hemlock	Closed		+			Known current
Vaux's Swift (F)	Mixed mesic and spruce/fir forests; large hollow snags				X		Known current
White-breasted Nuthatch	Large single-story ponderosa pine	Open			X		Known current
Winter Wren	Mixed mesic and spruce/fir forests, especially cedar-hemlock		-	+	X		Known current

[1] T = Threatened
[2] + = Positive correlation (where known)
[3] X = Important Habitat Component
[4] - = Negative correlation (where known)
[5] S = Sensitive
[6] F = Forest-dwelling Neotropical migrant with apparently declining populations

ANALYSIS AREA

SPATIAL BOUNDS

The effects analysis area for direct, indirect, and cumulative effects to old growth associated wildlife species is the Glacier Loon Project Area (37,320 acres). This area is large enough to include the home ranges of old growth associated species, and is representative of the effects of fire, natural tree mortality, timber harvest, and road management across the landscape. At the same time, this analysis area is small enough to not obscure the effects of the alternatives. A multi-scale assessment has also been conducted to address habitat diversity concerns.

TEMPORAL BOUNDS

The length of time for effects from the proposed fuels reduction and forest health treatments is approximately 1 to 5 years. This is based on the probable contract length for the proposed project, and the timeframes for related activities.

DATA SOURCES, METHODS, AND ASSUMPTIONS USED

Data used included stand exams, field surveys of snags and down woody logs, old growth surveys, project area field visits, research literature, and GIS and dataset information for features, such as general forest attributes, habitat type, and forest type.

MEASUREMENT INDICATORS

The effects analysis will focus on:

1. Effects to old growth habitat, and
2. Potential effects to old growth associated wildlife species.

April 2018

SNAG AND DOWN WOODY ASSOCIATED SPECIES

INTRODUCTION

Snags, broken-topped live trees, down logs, and other woody material are required by a wide variety of species for nesting, denning, roosting, perching, feeding, and cover (Bull et al. 1997). Snags and down, dead, material are also used for communication purposes:

- Singing, (songbirds),
- Drumming (grouse and woodpeckers),
- Calling (squirrels, jays, birds of prey), and
- Sight recognition posts.

Small mammals and birds use standing and down dead material for food storage and for hunting. Down logs and stumps are important for travel, both below the snow in the winter, and as travel cover throughout the year. It is estimated that about one third of the bird and one third of the mammal species that live in the forests of the Rocky Mountains use snags for nesting or denning, foraging, roosting, cover, communication, or perching. On the Flathead National Forest, at least 42 species of birds and 10 species of mammals are dependent on dead wood habitat for nesting, feeding, or shelter (USDA 1999b). The more mobile species that depend on dead wood habitat include black bears, Canada lynx, wolverines, marten, fisher, bats, woodpeckers, and small owls. Less mobile species that depend on dead wood include snowshoe hares (the primary prey of Canada lynx), red-backed voles (the primary prey of marten, fisher, boreal owl, and several other species), shrews, bryophytes, lichen, fungi, and protozoa. As down woody material further decays, it plays an important role in nutrient cycling, soil fertility, and erosion control.

Snags and their management have become a major conservation issue in managed forests across the western United States. Biologists have recognized for a long time that snags and down woody material provide important wildlife habitat, but only in the last decade or so have managers begun to understand that not only is tree decay an important ecological process that affects wildlife habitat (Bull et al. 1997), but snags and dead wood are an essential, important part of the larger ecosystem. The number, species, size, and distribution of available snags strongly affect snag-dependent wildlife. An insufficient number of suitable snags may limit or eliminate populations of cavity-using species (Saab et al. 1998; Thomas et al. 1979).

Although various sizes of snags and down woody are used, larger birds and mammals require larger dead trees. The larger-diameter down trees provide stable and lasting structure and offer better protection from weather extremes (Bull 2002). Longer down woody pieces provide better runways, shelter, and under-snow access.

Several wildlife species that use snag and down woody habitats on the Flathead National Forest are USFS Region One Sensitive Species, including the bald eagle, black-backed woodpecker, fisher, flammulated owl, Townsend's big-eared bat, and wolverine. One of the TES Species on the Flathead National Forest, the Canada lynx, has a strong habitat association with down woody material (denning).

Snags are essential habitat for at least 42 species of birds and 10 species of mammals in Montana. Table 3- 88 displays specific habitat relationships and Montana NHP rankings for wildlife species in Montana associated with snag, "defective" live tree, or down woody habitat.

TABLE 3- 89 SPECIES THAT USE SNAGS, "DEFECTIVE" LIVE TREES, AND/OR DOWNED LOGS.

SPECIES	GLOBAL & STATE RANKS (MTNHP 2009) *	SNAG DBH (INCHES)	SNAG HEIGHT (FEET)	DOWNED LOGS?	OCCURRENCE
American Kestrel (N)	G5, S5B	17	20		Known current
Bald Eagle (S)	G5, S3, SOC	25	40		Known current
Barred Owl (former MIS)	G5, S4	25	30		Known current
Barrow's Goldeneye	G5, S4, potential SOC	25	10		Known current
Big Brown Bat	G5, S4	17	20		Known current
Black-backed Woodpecker (S)	G5,S3 (SOC)	17	10		Known current
Black-capped Chickadee	G5, S5	9	10		Known current
Bobcat	G5, S5	-	-	yes	Known current
Boreal Chickadee	G5,S3 (SOC)	9	10		Known current
Boreal Owl (former S)	G5, S4	17	10		Known current
Brown Creeper	G5, S3, SOC	15	20		Known current
Bufflehead	G5, S5B	17	10		Known current
Canada lynx (T)	G5, S3, SOC	-	-	yes	Known current
Chestnut-backed Chickadee	G5, S4	9	10		Known current
Common Goldeneye	G5, S5	25	10		Known current
Common Merganser	G5, S5B	17	10		Known current
Dark-eyed junco	G5, S5B	-	-	yes	Known current
Downy Woodpecker	G5, S5	11	10		Known current
Fisher (S)	G5, S3, SOC	25	30	yes	Known current
Flammulated Owl (S, N)	G4, S3B, SOC	17	10		Known current
Great Horned Owl	G5, S5	25	30		Known current
Hairy Woodpecker	G5, S5	17	20		Known current
Harlequin Duck (S)	G4, S2B, SOC	-	-	yes	Known current
Hooded Merganser	G5, S4, potential SOC	17	10		Known current
House Finch	G5, S5	15	10		Known current
House Sparrow	G5, undesired species	15	20		Known current
House Wren (N)	G5, S5B	15	10		Known current
Lewis' Woodpecker	G4, S2B (SOC)	17	30		Known current
Little Brown Myotis	G5, S4	17	10		Known current
Long-eared Myotis	G5, S4	17	10		Known current
Long-legged Myotis	G5, S4	17	10		Known current
Long-tailed Weasel	G5, S5	-	-	yes	Known current
Marten (former MIS)	G5, S4	17	20	yes	Known current
Mountain Bluebird	G5, S5B	15	10		Known current
Mountain Chickadee	G5, S5	9	10	yes	Known current
Northern Alligator Lizard	G5,S3 (SOC)	-	-	yes	Known current
Northern Flicker	G5, S5	17	10		Known current
Northern Flying Squirrel	G5, S4	17	20		Known current
Northern Goshawk (former S)	G5,S3 (SOC)	-	-	yes	Known current
Northern Hawk Owl	G5, S4, potential SOC	25	10		Known current
Northern River Otter	G5, S4	-	-	yes	Known current
Northern Waterthrush (N)	G5, S5B	-	-	yes	Known current
Osprey	G5, S5B	17	40		Known current

TABLE 3- 89 SPECIES THAT USE SNAGS, "DEFECTIVE" LIVE TREES, AND/OR DOWNED LOGS.

SPECIES	GLOBAL & STATE RANKS (MTNHP 2009) *	SNAG DBH (INCHES)	SNAG HEIGHT (FEET)	DOWNED LOGS?	OCCURRENCE
Painted Turtle	G5, S4	-	-	yes	Known current
Pileated Woodpecker (former MIS)	G5,S3 (SOC)	25	60		Known current
Pygmy Nuthatch	G5, S4	17	30		Known current
Pygmy Owl	G5, S4	17	30		Known current
Raccoon	G5, S5	25	10		Known current
Red-breasted Nuthatch	G5, S5	17	20		Known current
Red-naped Sapsucker (N)	G5, S4B	17	20		Known current
Rubber Boa	G5, S4	-	-	yes	Known current
Ruffed Grouse	G5, S4	-	-	yes	Known current
Saw-whet Owl	G5, S4	17	20		Known current
Silver-haired Bat	G5, S4, potential SOC	17	20		Known current
Southern Red-backed Vole	G5, S4	-	-	yes	Known current
Spruce Grouse	G5, S4	-	-	yes	Known current
Striped Skunk	G5, S5	-	-	yes	Known current
Swainson's Thrush (N)	G5, S5B	-	-	yes	Known current
Tailed Frog	G5, S4	-	-	yes	Known current
Three-toed Woodpecker	G5, S4	17	20		Known current
Tree Swallow (N)	G5, S5B	15	20		Known current
Vaux's Swift (N)	G5, S4B	25	40		Known current
Violet-Green Swallow	G5, S5B	15	20		Known current
Western Bluebird	G5, S4B	15	10		Known current
Western Jumping Mouse	G5, S4	-	-	yes	Known current
Western Screech Owl	G5, S3, potential SOC	17	20		Known current
Western (Townsend's) Big-eared Bat (S)	G4, S2 (SOC)	?	?		Known current
White-breasted Nuthatch	G5, S4	17	20		Known current
Williamson's Sapsucker (N)	G5, S4B	17	20		Known current
Wilson's Warbler (N)	G5, S5B	-	-	yes	Known current
Wolverine (S)	G4, S3 (SOC)	-	-	yes	Known current
Wood Duck	G5, S5B	25	10		Known current
Yuma Myotis	G5, S3, potential SOC	17	10		Known current

T=Threatened; S=Sensitive Species; N-Neotropical migratory bird; Natural Heritage Program Rank: G=species range-wide (global); S=state wide; 2=At risk because of very limited and/or declining numbers, range, and/or habitat, making it vulnerable to global extinction or extirpation in the state. 3=Potentially at risk because of limited and/or declining numbers, range, and/or habitat, even though it may be abundant in some areas. 4=Uncommon but not rare (although it may be rare in parts of its range), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern. 5=Common, widespread, and abundant (although it may be rare in parts of its range). Not vulnerable in most of its range. B=State rank modifier indicating breeding for a migratory species. SOC=Montana Species of Concern.

48 feet

ANALYSIS AREA

SPATIAL BOUNDS

The Glacier Loon Project Area was considered for the evaluation of direct and indirect effects on snag and down woody associated species. This approximately 37,320-acre area is large enough to include the home ranges of several individuals or pairs of a species, and is representative of the effects of fire, natural tree mortality, timber harvest, and road management across the landscape. The actions proposed in the alternatives that could directly or indirectly affect snag or down woody associated wildlife species are contained within this area. The Upper Swan Valley was considered in the cumulative effects analysis. A multi-scale assessment was also conducted to address habitat diversity concerns for dead tree dependent species (USDA 2006).

TEMPORAL BOUNDS

The length of time for effects from the proposed fuels and forest health treatments is approximately 1 to 5 years. This is based on the probable contract length for the proposed project, and the timeframes for related activities.

DATA SOURCES, METHODS, AND ASSUMPTIONS USED

Data used included project area field visits, research literature, and GIS and dataset information for features, such as general forest attributes, habitat type, and forest type.

MEASUREMENT INDICATORS

The effects analysis will focus on:

1. Effects to snag and down woody habitat, and
2. Potential effects to snag/down woody associated wildlife species.

AFFECTED ENVIRONMENT

HISTORICAL CONDITION

Forest ecosystems in the western United States have adapted in response to disturbances such as wildfire, insects, disease, and windstorms. Snags and down woody material have always occurred on the landscape, a direct result of these disturbance factors, either on a large scale, or on a very small scale, as individual trees grow old and die. Ritter and others have described snag populations as occurring in either "pulses" of snags following a large disturbance event, or as "continuous" populations of scattered individuals (Ritter et al. 2000).

Historically, in the Swan Valley, snag habitat and down woody material, though always present in varying amounts, experienced greater "pulses" across the landscape and in localized areas as a result of natural disturbances. Warmer and drier areas historically underwent more frequent, lower-intensity fires, and typically supported fewer snags and large down logs than cooler and moister environments, where the stands reached climax conditions before experiencing stand-replacing fire.

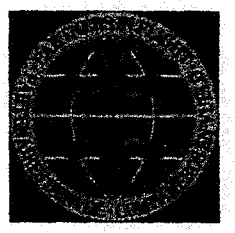
EXISTING CONDITION

The Northern Region of the Forest Service estimated snag densities for Western Montana Forests by

Conservation Strategy for the Pinyon Jay (*Gymnorhinus cyanocephalus*)

Photo by Scott Somershoe

Version 1, February 2020



Chapter 2. Pinyon Jay Distribution, Natural History and Habitat

Distribution Patterns and Natural History

The Pinyon Jay is most abundant in the southern Great Basin and the southwestern U.S. (Figure 4), where it is usually associated with the piñon pines (e.g., *Pinus edulis*, *P. monophylla*) for which it is named (Figure 6). Pinyon Jays are found in lower densities outside the range of piñon pines, in South Dakota, Nebraska, California, Oregon, Wyoming, and Montana, where they occur in habitat types dominated by ponderosa pine (*P. ponderosa*), Jeffrey pine (*P. jeffreyi*), and limber pine (*P. flexilis*) (Burleigh 1972, Grenfell and Laudenslayer 1983, Balda 2002, Faulkner 2010, Marks et al. 2016, Drilling et al. 2018, Silcock and Jorgensen 2018). Pinyon Jays are associated with juniper (in the absence of piñon pine) in southern Idaho (Brody 1992) and may also use juniper-dominated areas in Montana (J. Marks, pers. comm.), New Mexico (Johnson et al. 2014) and other areas.

Pinyon Jays are highly social throughout the year. They occur in flocks of up to a few hundred individuals and nest colonially, sometimes cooperatively, often using the same general nesting colony site annually (Marzluff and Balda 1992). Home ranges are large, typically 8,645 acres (3,500 hectares) to 15,800 acres (6,400 hectares) (Marzluff and Balda 1992; Balda 2002; Johnson et al. 2016, 2017a). Unlike traditionally territorial species, their nests are spatially clumped in nesting colonies that can cover 141 acres (57.4 hectares) or more (Figure 7, Johnson et al. 2014, 2015, 2018a).

Across their geographic range, Pinyon Jays inhabit varying elevations and latitudes with diverse woodland structures, dominant tree species, and landscape characteristics, and thus home range attributes may vary substantially from region to region. Additionally, local home ranges may shift seasonally, and jays may occasionally make large-scale movements (up to hundreds of miles) out of their normal home range when food resources are limited in fall and winter (Balda 2002). Pinyon Jays may also adjust daily and annual habitat use within home ranges as habitat conditions and resources vary over space and time. As a result, well-established occupancy patterns can change with seasons and with habitat conditions in unanticipated ways.

Pinyon Jays have a mutualistic relationship with piñon pines where they co-occur (Ligon 1978, Lanner 1996). Piñon pines are a masting species, producing highly nutritional nuts in large crops that historically occurred within local stands or regions at irregular intervals, from one to three crops every 10 years for *P. edulis* (Forcella 1981) and one crop every one to three years for *P. monophylla* (Sutton 1984). These intermittently abundant nuts sustain Pinyon Jays throughout the winter, support successful nesting, and significantly influence population viability (Marzluff and Balda 1992). Pinyon Jay nesting success and productivity are higher following mast years than non-mast years (Ligon 1978, Marzluff and Balda 1992), and adult survivorship is highest after moderate cone crops (Marzluff and Balda 1992). In turn, Pinyon Jays serve as the

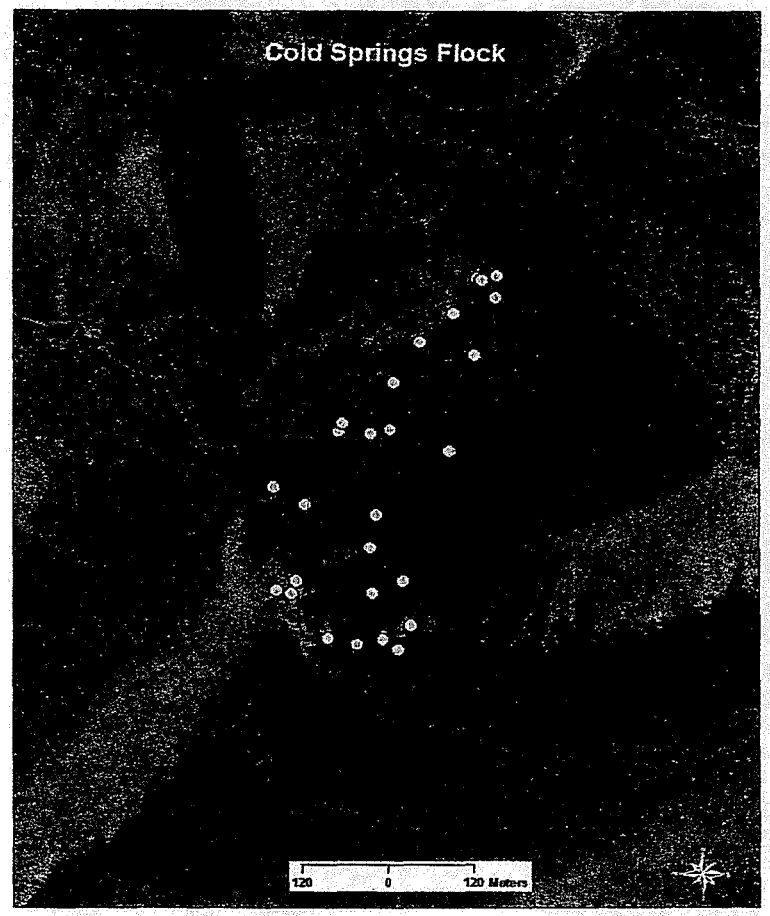
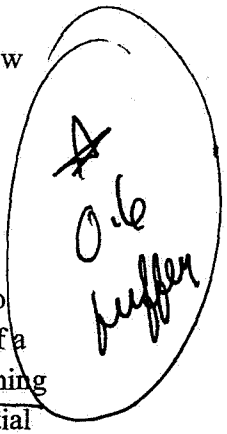


Figure 7. Spatial extent of a typical nesting colony in Nevada, with known nest sites as yellow points (J. Boone and E. Ammon, unpublished data).

Two other classification systems for piñon-juniper vegetation provide useful additional perspectives (Table 2, Figures 8–20). First, Romme et al. (2009) define three main piñon-juniper vegetation types based on historical disturbance regimes (Table 2) that vary in geography, site condition, and tree species. A second scheme (Miller et al. 2008 and references therein) classifies piñon-juniper vegetation in the Great Basin in terms of "phases". This system has become widely referenced in areas where Greater Sage-Grouse (*Centrocercus urophasianus*) are a management focus. The descriptions shown in Table 2 refer to the early (Phase I), middle (Phase II), and late (Phase III) successional phases of woodland development (Miller et al. 2008).

primary objectives, but simultaneously investigate Pinyon Jay responses. This could include designing treatments with different levels of retained woodland cover (e.g., canopy cover) to assess jay response and determine critical thresholds to minimize negative impacts to jays. **Current knowledge:** Pinyon Jay response to management has been assessed in one study in central Colorado (BCR 16) (Magee et al. 2019) and at a single nesting site in New Mexico (BCR 16) (Johnson et al. 2018b).

d. Investigate Pinyon Jay responses to disturbances. Very little is known about how sensitive Pinyon Jays are to physical disturbances associated with management and multiple-use activities, such as infrastructure development, infrastructure operation, recreation, and noise. Clarifying these issues, especially with regard to nest colony disturbances that might affect nest success, is important. This will facilitate the development of clear and regionally-specific guidelines (including non-disturbance buffers) for management and other activities to minimize or avoid negative impacts to Pinyon Jays. **Current knowledge**: The limited guidance recommends maintenance of a 0.6 mile (1 kilometer) undisturbed buffer around Pinyon Jay nest colonies when planning energy develop projects, OHV trails, or road building, especially when there is potential for significant noise disturbance or vehicular traffic associated with developments (Wiggins 2005, Johnson et al. 2013, Kleist et al. 2018).



Pinyon Jay Nesting Biology

With the exception of studies by R. Balda and students in the 1980s in Flagstaff, Arizona, little information exists about nest success, productivity, adult and juvenile survival, and other associated demographic parameters across most of the range. More importantly, few studies have related habitat covariates to reproductive success and current information may not be applicable to a broader geographic region, specifically regions and/or BCRs.

Specific research needs are:

a. Conduct research on Pinyon Jay nesting biology, productivity, and other demographic parameters. Studies to assess nesting success, productivity, and site fidelity are needed, as basic nesting demographics are largely unknown. Additional largely unstudied population parameters critical to understanding declines include adult and post-fledging juvenile survival, and causes of predation. The degree to which Pinyon Jays have a strict or approximate fidelity to nesting colony sites over multiple years is also unknown (see item d., below). **Current knowledge:** Nesting demographic data are largely limited to New Mexico (BCR 16) (Johnson et al. references in literature cited) and Flagstaff, Arizona (BCR 34) (Balda 2002). Survivorship has only been assessed in Flagstaff, Arizona (BCR 34) (Balda 2002).

developed models for the Colorado portion of the Colorado Plateau (BCR 16). Several climate projection models exist for the Southwest.

Effects of Piñon-Juniper Woodland Management

Although current paradigms for "best woodland management practices" and "forest health" could translate into benefits for Pinyon Jays, this conjecture has not been explicitly studied and evaluated. Determining how current vegetation management practices and goals relate to Pinyon Jay conservation needs, including health and productivity of piñon pines, is a high priority, and a prerequisite to inform future management designed to benefit or minimize negative impacts to Pinyon Jays.

Specific research needs are:

a. Investigate the effects of woodland thinning on tree health and survival. Woodland thinning treatments using mechanical approaches and herbicide application occur mostly, but not exclusively, in the Southwest region of the Pinyon Jay range. However, the effects of these management practices on mast production and health of remaining trees are largely unexplored. **Current knowledge**: Instead of improving tree health or survival within the stand by reducing intraspecific competition, limited information suggests under some circumstances, thinning can be detrimental due to increased evapotranspiration (Greenwood and Weisberg 2007, Clifford et al. 2008, Morillas et al. 2017). There is also anecdotal evidence that piñon pine trees retained after woodland thinning may be highly vulnerable to drought-related bark beetle mortality (Coop and Magee 2016). Limited research suggests the survival of remaining trees after thinning may depend upon the type of piñon-juniper woodland; wooded shrublands, and perhaps piñon-juniper savannas, may respond positively to thinning, while persistent piñon-juniper woodlands may respond negatively (Roundy et al. 2014, Morillas et al. 2017, Flake and Weisberg 2018). Further, effects of thinning could vary with pre-treatment tree density and age, soil type, and final tree density (e.g., canopy cover, basal area). Thinned piñon pines may be more vulnerable to drought conditions than undisturbed stands in central New Mexico (BCR 16) (Morillas et al. (2017).

b. Examine the comparative effects of different vegetation management techniques and designs on Pinyon Jays, tree health, and pine nut productivity. In some cases, vegetation management goals can be accomplished through multiple methods. For instance, woodland stands can be removed by prescribed fire, mastication, or lop-and-scatter cutting. A comparative assessment of impacts on tree health, productivity and habitat quality, along with Pinyon Jay response, could be used to identify the best management option for a given situation. In order to quantify habitat and jay response, monitoring should be conducted in association with management projects. **Current**

knowledge: Lop-and-scatter may be preferable to other slash management methods by reducing erosion, protecting the health of the remaining trees, and promoting healthy invertebrate populations (Stoddard et al. 2008). Prescribed surface fire is not recommended as a follow-up to thinning within persistent piñon-juniper woodlands and wooded shrublands because these ecosystems did not evolve with frequent, low-intensity surface fires (Baker and Shinneman 2004, Romme et al. 2009). Targeting thinning in areas of natural die-offs (from drought, beetle kill, or other factors) may promote or retain a diverse woodland mosaic that better mimics how historical fire would have affected the landscape in these woodland types (Romme et al. 2009).

c. Incorporate expanding knowledge about Pinyon Jays and habitat use into existing guidelines for vegetation management. As the new information outlined in this chapter is obtained, it will be advantageous to actively look for opportunities to integrate these insights into existing vegetation management guidelines. This will ensure that appropriate knowledge is considered with designing and implementing vegetation management for a variety of compatible goals.

Chapter 6. Management Considerations

Overview

Currently, our understanding of how land and vegetation management may affect Pinyon Jay populations is not sufficient to support comprehensive recommendations for Pinyon Jay conservation. However, the limited data that are available provide a basis for the management considerations outlined in this section. In presenting these considerations, we recognize there is a wide variety of objectives and priorities that managers must balance in designing and implementing their woodland treatment projects in areas used by Pinyon Jays. Most often, these are either: a) thinning or herbicide treatments in the Southwest for fuels management or wildlife habitat, or b) sagebrush restoration treatments in the Great Basin to create or improve habitat for priority species such as Greater Sage-Grouse and other sagebrush obligate species. The information presented below is a resource for managers who wish to adopt measures that reduce the likelihood of negative impacts to Pinyon Jays. We do not have sufficient knowledge to describe and quantify management actions that would actively improve habitat for Pinyon Jays at this time; rather we focus on minimizing adverse effects when woodland treatments are conducted for other purposes. As new research becomes available, the Working Group plans to update this document with more detailed conservation actions and recommendations that encompass a wider variety of objectives, including Pinyon Jay population recovery and forest health, with improved regional specificity.

Considerations for the Location of Woodland Treatment Projects

Clearance surveys

Pinyon Jay use of the landscape within a flock's home range is likely to vary across a daily cycle, a seasonal cycle, and possibly across years. Although it is important to model Pinyon Jay habitat and occupancy at multiple scales (Johnson et al. 2014, 2015, 2016, 2017), standardized, site-specific assessments to determine whether Pinyon Jays are present in a proposed treatment area and how they are using the habitat may be especially useful in informing management at the treatment scale. These assessments can include surveys to locate nests during the breeding season (e.g., "clearance surveys", as typically used for Migratory Bird Treaty Act [MBTA] compliance) or other surveys to identify whether Pinyon Jays use the area for other activities, such as caching or foraging.

Vegetation thinning within a traditional nesting colony site can cause the birds to abandon treated areas (Johnson et al. 2018b) or alter the suitability of the habitat (Johnson et al. 2019), and complete removal of the colony site removes nesting substrate altogether. Therefore, avoiding treatment of nest colony sites is recommended. Pinyon Jays often use the same general area each year for nesting, with colony site shifts of up to 550 yards (~500 meters) between years (Marzluff and Balda 1992, Johnson et al. 2017c, J. Boone and E. Ammon, pers. comm.). Thus, a buffer of undisturbed habitat of 550 yards (~500 meters) around a known breeding colony is

1635' .3 mi

treatment areas. If juniper is the target species, avoiding treating areas that contain piñon trees avoids compromising piñon nut production.

d. As piñon nut production is critical to Pinyon Jays, mast-producing trees are particularly valuable. Therefore, thinning may be particularly detrimental in known productive piñon woodlands containing old or very old trees, likely of prime piñon nut producing age, and trees of moderate age to support future nut production (Parmenter et al. 2018, Crist et al. 2019). Parmenter et al. (2018) identified age and size of *P. edulis* as an indicator of probable nut productivity: little to no productivity (<3.5 inches or <9 centimeter diameter at breast height [dbh]); medium productivity (3.5–5.9 inches or 9–15 centimeter dbh); and high productivity (>6.3 inches or >16 centimeter dbh) (Zlotin and Parmenter 2008). Old and very old trees likely produce more mast due to their large size and larger number of fruiting branches (Parmenter et al. 2018).

e. South- and west-facing slopes, as opposed to north- and east-facing slopes, may be more suitable for treatments avoiding impacts to Pinyon Jays because north- and east-facing slopes are projected to better survive future climate change scenarios (Rondeau et al. 2017). Sites with lower heat load (north-facing) are also favored for Pinyon Jay colony sites (Johnson et al. 2017b).

thermal!

f. Large and densely crowned trees are particularly valuable for Pinyon Jay nesting, particularly when they occur within areas of higher tree density (Wiggins 2005, Johnson et al. 2014, 2015, Johnson and Sadoti 2019).

g. Retaining and promoting native grasses, forbs, and shrubs in the understory may increase available invertebrate prey for Pinyon Jays (Bombaci and Pejchar 2016).

h. If cheatgrass and other invasive annual plants are in the vicinity of a planned treatment area, aggressive invasive species control in post-treatment management plans decreases fire risk and fire intensity (Chambers et al. 2017), thus lowering the risk to stands important to Pinyon Jays. A minimum of 20% perennial native herbaceous cover in a treatment area is recommended for preventing a large increase in cheatgrass and other annual invasive plants post-treatment (Chambers et al. 2017).

Cheat

Considerations for Region Wide Fuels Reduction and Fire Management Projects
Reduction of fuels and fire risk is a common reason for woodland thinning or prescribed fire treatments in some regions. For the purposes of this document, we assume that treatments that successfully reproduce the woodland conditions associated with historical natural fire patterns may help minimize negative impacts for Pinyon Jays, but considerable research is still needed to confirm this assumption.

The historical role of fire in piñon-juniper woodlands is not fully understood, but Romme et al. (2009) provide a comprehensive assessment of the frequency and significance of fire in each of the three piñon-juniper vegetation types. In persistent piñon-juniper woodlands and wooded shrublands, low-intensity, frequent surface fire generally did not occur due to the limited ground fuels; instead, these habitats typically experienced stand-replacing crown fires at approximately 300–400 year intervals (Baker and Shinneman 2004, Romme et al. 2009, Friggens et al. 2018, Miller et al. 2019). As a result, management actions designed to replicate the effects of frequent, low-intensity fires, such as thinning and prescribed burning may not achieve ecological restoration goals. Fire disturbance regimes are not well understood in piñon-juniper savannas. Although the higher grass component in savannas would suggest these habitats supported low-severity fires, there is little empirical information to support this supposition (Romme et al. 2009). Because of these complexities and information gaps, there are no one-size-fits-all recommendations for fuels reduction and fire management treatments. If fuels treatments are planned, the following guidance may help to minimize negative impacts to Pinyon Jays:

a. If thinning in persistent piñon-juniper woodlands or wooded shrublands, creating a patchy-clumpy mosaic of suitable nesting habitat within the treated area, as opposed to evenly spaced thinning, allows for shifting colony locations. Further, thin and/or retain Phase I and/or II woodlands rather than closed canopy woodlands (Phase III) to provide woodland conditions preferred by Pinyon Jays. This treatment pattern also better mimics how fire would have impacted the landscape in persistent piñon-juniper woodlands and wooded shrublands (Romme et al. 2009). Provided that sufficient suitable habitat is retained throughout the treatment area, retaining as many larger trees as possible within areas of higher tree density and/or higher canopy cover will likely conserve more Pinyon Jay nesting habitat than thinning all size/age classes to a uniform density. For example, a guideline is to retain trees within the 25–75% quartiles of these measures at the target site or similar sites (Johnson and Sadoti 2019).

b. As piñon nut production is critical to Pinyon Jays, mast-producing trees are particularly valuable. Therefore, thinning may be particularly detrimental in known productive piñon woodlands containing old or very old trees, likely of prime piñon nut producing age, and trees of moderate age to support future nut production (Parmenter et al. 2018, Crist et al. 2019). Parmenter et al. (2018) identified age and size of *P. edulis* as an indicator of

Pine Seeds

Amer. Zool., 19:1065-1083 (1979).

Competition Among Insects, Birds and Mammals for Conifer Seeds

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1979

SYNOPSIS. Species of at least 5 orders of insects, 6 families of birds, and 2 orders of mammals, in various combinations, can exploit the cones and seeds of most species of conifers. Lodgepole pine is the exception to this pattern of broad taxonomic diversity of seed predators in that only pine squirrels and coreid bugs attack its serotinous cones. The contrast between lodgepole pine and other conifers demonstrates that large intrinsic variation in the abundance of a resource fosters the evolution of a broad range of taxonomic groups to exploit the resource. The diverse groups are limited by different predators and alternate resources when conifer seeds independently decrease in abundance.

INTRODUCTION

Because conifers are such an important source of lumber, a great amount of effort has been put into the study of their biology (Fowells, 1965), their seeds (USDA, 1974), and the predators of their seeds (Keen, 1958). People concerned with the lumber industry are interested in how many seeds escape predation to allow reforestation of logged or burned areas. Questions of general biological interest that do not relate directly to reforestation may go unasked even though pertinent information is available. In this paper, we use the extensive literature on conifer seeds and their predators to outline the nature of these seeds as a food resource and the manner in which the various seed predators use this resource. The information can then be used as a basis for answering three questions: 1) Why are there many different distantly related taxa of animals exploiting a distinctive and easily delimited resource? 2) How do the various taxa interact in using the resource? 3) How do the different taxa avoid competitive exclusion? Our personal experience is mainly limited to the conifers of western North America and our discussion will be concentrated on those, although some of the patterns probably apply generally to conifers in the Northern Hemisphere (Bock and Lepthien, 1976).

We wish to thank Jim Reichman for stimulating us to think about competition between distantly related taxa. Gary Bateman and Gilbert Schubert made helpful comments in reviewing the manuscript. Anne Slobodchikoff was very helpful in editing and typing the manuscript.

THE RESOURCE

As a food resource, single viable conifer seeds are highly uniform as to size (weight of female gametophyte and embryo) and quality (caloric value of female gametophyte and embryo) within an individual cone, tree or species population (Table 1). The total number of viable seeds in single cones within a single annual crop for one tree or a species population is more variable than seed size or quality, especially in lodgepole pine (*Pinus contorta* Dougl.) (Table 1). The sizes of annual cone crops for single trees or species populations are by far the most variable feature of conifer seeds in all western North American species, except lodgepole pine (Table 1).

The variation in caloric value of seeds given in Table 1 is probably an underestimation because 5 to 10 seed kernels were burned to derive each value thus masking the variation between individual seeds. The similar variations between samples from the same cone, cones from the same tree,

TABLE 1. *The source of variation in conifer seeds as a food resource.*

Species	Source of units	Number	Range	Mean	Coefficient of variation
	Caloric value of female gametophyte and embryo (Cal/g dry weight):				
Lodgepole pine	groups of 6 to 10 seeds from one cone	5	6.55–6.91	6.74	2.0%
Lodgepole pine	groups of 6 to 10 seeds from one tree	6	6.63–7.04	6.79	2.3%
Lodgepole pine	groups of 5 to 10 seeds from one population	7	6.54–6.96	6.83	2.2%
	Weight of female gametophyte and embryo (mg/seed):				
Engelmann spruce	seeds from one cone	40	1.6–2.0	1.91	7.5%
Lodgepole pine	seeds from one cone	25	1.7–2.3	1.88	9.5%
Lodgepole pine	10 means of seeds from 10 cones from one tree	10	2.01–3.27	2.49	14.8%
Lodgepole pine	6 means of seeds from 6 cones from different trees	6	1.88–3.63	2.53	24.0%
	Filled seed content of cones (filled seeds/cone):				
Lodgepole pine	cones from one tree	5	9–23	15.8	40.4%
Lodgepole pine	10 means of cones from 10 trees	10	4.4–18.8	11.6	39.5%
Ponderosa pine	cones from one tree	5	53–89	70.4	22.9%
Ponderosa pine	7 means of cones from 7 trees	7	39.0–70.4	53.5	20.6%
	Annual cone crops (cones/tree or cones/acre):				
Douglas-fir	11 annual means for several trees (cones/tree)	11	0–14,244	4219	124.6%
Ponderosa pine	10 annual crops (cones/acre)	10	316–7521	2437	93.1%
	Ratios of successive cone crops (%):				
Douglas-fir	smaller crop/larger crop × 100 for 10 pairs of successive years	10	0.0–67.2	6.9	
Ponderosa pine	smaller crop/larger crop × 100 for 9 pairs of successive years	9	4.2–94.4	40.2	
Lodgepole pine	smaller crop/larger crop × 100 for 4 pairs of successive years	4	50.8–73.5	62.4	

Family: Sittidae			
White-breasted Nuthatch	*Pinus*	uses and makes cache of seeds and finds seeds on ground	alternate foods
Red-breasted Nuthatch	*Abies*, *Picea*, *Pinus*, *Pseudotsuga*, *Tsuga*	seeds from open cones cached and eaten by adults	alternate foods, emigration
Pygmy Nuthatch	*Abies*, *Picea*, *Pseudotsuga*, *Pinus*	seeds from open cones cached and eaten by adults	alternate foods
genus: *Sitta*			
Family: Fringillidae			
crossbills	*Abies*, *Larix*, *Picea*, *Pinus*, *Pseudotsuga*, *Tsuga*	seeds from closed and open cones fed to young and adults	nomadic nesters, emigrate to alternate foods
genus: *Loxia*			
Pine Siskins	*Abies*, *Larix*, *Picea*, *Pinus*, *Pseudotsuga*, *Tsuga*	seeds from open cones and the ground fed to young and adults	emigration, alternate foods
genus: *Carduelis*			
MAMMALS:			
Order: Rodentia			
pine squirrels	*Abies*, *Larix*, *Picea*, *Pinus*, *Pseudotsuga*, *Tsuga*	cache and feed from whole closed cones	territoriality, emigration, alternate foods
genus: *Tamiasciurus*			
tree squirrels	*Pinus*	seeds from closed cones	alternate foods
genus: *Sciurus*			
chipmunks	*Abies*, *Larix*, *Picea*, *Pinus*, *Pseudotsuga*, *Tsuga*	cache and eat seeds from closed or open cones	alternate foods
genus: *Eutamias*			
golden-mantled ground squirrel	*Pinus*	forage for single seeds	alternate foods
Spermophilus lateralis			
deer mice	*Larix*, *Picea*, *Pinus*, *Pseudotsuga*, *Tsuga*	forage for single seeds and cache seeds	alternate foods
genus: *Peromyscus*			
red-backed voles	*Larix*, *Picea*, *Pinus*, *Pseudotsuga*, *Tsuga*	forage for single seeds and cache seeds	alternate foods
genus: *Clethrionomys*			
Order: Insectivora			
shrews	*Larix*, *Picea*, *Pinus*, *Pseudotsuga*, *Tsuga*	forage for single seeds	alternate foods
genus: *Sorex*			

TABLE 3. *continued*

Taxonomic group of seed predators	Genera of trees exploited	Method of conifer exploitation	Method of escaping starvation during cone crop failure
BIRDS:			
Family: Psittacidae			
parrots	*Pinus*	extracted seeds from closed and open cones	emigration, nomadic
genus: *Rhynchopsitta*			
Family: Picidae			
Hairy Woodpecker	*Pinus*	extracted seeds from closed and open cones eaten by adults and juveniles	alternate foods
White-headed Woodpecker			
genus: *Picoides*			
Family: Corvidae			
Pinon Jay	*Pinus*	cache seeds extracted from closed and open cones to feed young and adults	alternate foods, emigration
genus: *Gymnorhinus*			
Clark's Nutcracker	*Pinus*	cache seeds extracted from open and closed cones to feed young and adults	alternate foods, emigration
genus: *Nucifraga*			
Gray Jay	*Abies*, *Picea*	may extract seeds from open cones or retrieve from ground to eat and store as boli	alternate foods, territorial
genus: *Perisoreus*			
Steller's Jay	*Pinus*	cache seeds from open cones to feed adults	alternate foods, territorial, emigration
genus: *Cyanocitta*			
Scrub Jay	*Pinus*	cache seeds from open cones and ground to feed adults	alternate foods, territorial
Mexican Jay			
genus: *Aphelocoma*			
Black-billed Magpie	*Pinus*	cache seeds from open cones and ground to feed adults	alternate foods, territorial
genus: *Pica*			
Family: Paridae			
Mountain Chickadee	*Abies*, *Picea*, *Pseudotsuga*, *Pinus*	cache seeds from open cones and ground to feed adults	alternate foods
Boreal Chickadee	*Abies*, *Picea*, *Pseudotsuga*	cache seeds from open cones and ground to feed adults	alternate foods
Plain Titmouse	*Pinus*	cache seeds from open cones and ground to feed adults	alternate foods, territorial
genus: *Parus*			

The Influence of Mammals and Birds in Retarding Artificial and Natural Reseeding of Coniferous Forests in the United States

Clarence F. Smith and Shaler E. Aldous[1]

FORESTERS have long been searching for an economical method of re-establishing trees on deforested lands. Three methods have been used, namely: the planting of nursery-raised stock and natural seedlings, direct seeding, and the encouragement of natural reproduction. To date the planting program has been given the most attention but the other two methods are older and considerable hope for their satisfactory use is always being expressed. Chief among the factors that have pushed reproduction by seeding into the background is the depredation of seed-eating rodents and birds.

This does not mean, however, that animals are the chief factors in preventing reforestation. Among the many other important factors are: availability of seed source, soil type and condition, prevalence of destructive insects and diseases, moisture supply, temperature, slope, and many others. So it should not be inferred that if rodent and bird pressures could be removed reforestation would always be successful. The role of mammals and birds in aiding reforestation is not discussed in this paper. Although actual consumption of coniferous seeds implies destruction, it must be recalled that in the process of feeding, mammals through caching, and birds by transportation and dropping of seeds may function as seed distributors.

The first known effort at direct seeding on a national forest in the United States was in 1901 (*11*) on the San Bernardino National Forest, California. This and several other trials (*12, 38*) failed due to a combination of factors, one of which was the activity of seed-eating animals. Periodic attempts at direct seeding were continued with little or no success through about 1912 (*6, 20, 27, 39, 59, 62*). In the early twenties an interest was again shown in this work (*30, 41, 42, 50*), but still one of the main obstacles to success was the animal factor. During the late thirties and up until the present time, a renewed interest has again been extended to this method of reforestation (*1, 2, 8, 10, 16, 25, 26, 32, 33, 34, 35, 36, 37, 40, 45, 46, 47, 48, 49, 58, 61, 63*).

It has been during this latter period that the authors and other workers in the Fish and Wildlife Service have been making extensive investigations of the relation of animals to the forest. Reproduction by seed and the animal pressure thereon has received considerable attention. It is the purpose of this paper to point out the degree and type of pressure exerted by birds and mammals on forest seeds, the tree species affected, and to describe methods of reducing or eliminating these losses.

Many Animal and Bird Seed Eaters

A large number of different mammals and birds feed on the seeds of coniferous trees, both when supplied naturally and when provided by planting procedures. From the literature and the authors' studies, a total of 44 mammals and 37 birds have been found to eat coniferous seeds (Table 1). This list could be materially lengthened if the data from unpublished stomach analyses in the files of the Fish and Wildlife Service were assembled. Van Dersal (*64*) lists the animals that feed on all species of conifers in the United States, but from his descriptions it is impossible to separate seed eaters from vegetative feeders.

Although the list of seed eaters is long, only a few species are of significance in forest regeneration. The tree squirrels, chipmunks, white-footed mice, and a few species of seed-eating fringillid birds are responsible for the greater part of all trouble caused by mammals and birds in regenerating forests by seeding. Habitat is the governing factor which determines which species of animal might be present to consume the seeds.

Tree squirrels (*Sciurus*) are not commonly found very far from trees with the result that their depredations are usually on the cones or on the seed dropping from them. On denuded areas that are being artificially reseeded, these squirrels are of minor importance except around the tree-fringed borders. On the other hand, they

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TABLE 1.—LIST OF BIRDS AND MAMMALS KNOWN TO EAT THE SEEDS OF CONIFEROUS TREES (AND THE AUTHORITY REFERENCE)[1]

Common name	Scientific name	Reference
Birds		
Blue grouse	*Dendragapus obscurus*	4
Sierra grouse	*Dendragapus fuliginosus sierrae*	52
Ruffed grouse	*Bonasa umbellus*	52
Bobwhite	*Colinus virginianus*	8
California quail	*Lophortyx californica*	52
Band-tailed pigeon	*Columba fasciata*	52
Eastern mourning dove	*Zenaidura macroura carolinensis*	8, 58, 60
Red-shafted flicker	*Colaptes cafer collaris*	57
Lewis woodpecker	*Asyndesmus lewis*	52
Canada jay	*Perisoreus canadensis*	59
Blue jay	*Cyanocitta cristata*	59
Steller's jay	*Cyanocitta stelleri*	52, 57
Crow	*Corvus brachyrhynchos*	52
Clark's nutcracker	*Nucifraga columbiana*	52
Winter wren	*Nannus hiemalis*	36
Robin	*Turdus migratorius*	15, 59
English sparrow	*Passer domesticus*	59
Southern meadowlark	*Sturnella magna argutula*	8
Red-wing blackbird	*Agelaius phoeniceus*	8
Rusty blackbird	*Euphagus carolinus*	8
Brewer's blackbird	*Euphagus cyanocephalus*	8
Blackbirds	No species named	15, 59
Cowbird	*Molothrus ater*	8
Bronzed grackle	*Quiscalus quiscalus aeneus*	15
Blue grosbeak	*Guiraca caerulea*	59
Evening grosbeak	*Hesperiphona vespertina*	52
California purple finch	*Carpodacus purpureus californicus*	36
Pine grosbeak	*Pinicola enucleator*	52
Redpoll	*Acanthis linaria*	59
Goldfinch	*Spinus tristis*	Text
Red crossbill	*Loxia curvirostra*	52
Towhee	*Pipilo maculatus*	36
Slate-colored junco	*Junco hyemalis hyemalis*	Text
Carolina junco	*Junco hyemalis connectens*	13
Oregon junco	*Junco oreganus*	36
Red-backed junco	*Junco phoeonotus dorsalis*	39, 52
Chipping sparrow	*Spizella passerina*	2
Song sparrow	*Melospiza melodia*	36
Mammals		
Cinereous shrew	*Sorex cinereus*	Text
Trowbridge shrew	*Sorex Trowbridgii*	37
Wandering shrew	*Sorex vagrans*	37
Baird's dusky shrew	*Sorex obscurus bairdi*	37
Yaquina shrew	*Sorex yaquinae*	37
Gibbs shrew-mole	*Neurotrichus gibbsii*	37
Columbia ground squirrel	*Citellus beecheyi*	23
Rock squirrel	*Citellus variegatus*	24
California ground squirrel	*Citellus beecheyi*	23
Fisher ground squirrel	*Citellus beecheyi fisheri*	52
White-tailed antelope squirrel	*Citellus leucurus*	24
Mantled ground squirrel	*Citellus lateralis*	24, 59
	Citellus lateralis arizonensis	57
	Citellus lateralis chrysodeirus	52
Western chipmunk	*Eutamias minimus*	52
	Eutamias minimus jacksoni	Text
	Eutamias amoenus	52
	Eutamias quadrivittatus	52
	Eutamias quadrivittatus speciosus	52
	Eutamias cinereicollis	52, 57
	Eutamias townsendii	26, 52
	Eutamias quadrimaculatus	52
	Eutamias sp.	12, 30, 49, 58, 61
Eastern chipmunk	*Tamias striatus striatus*	53
	Tamias striatus griseus	Text

are probably the heaviest consumers of coniferous seeds under natural conditions. Heavy cutting of sugar pine cones (even before they are mature) by the California gray squirrel was reported by Berry (*6*) and Jotter (*27*). As much as 70 to 75 percent of the seed crop was reported taken by these squirrels and as many as 702 ponderosa pine cones were found under one tree.

Voracious Rodents Are Heavy Seed Consumers

The appetite for pine seeds by squirrels was shown by Hatt (*18*) when he reported one pair of captive red squirrels ate the seeds from 422 cones of eastern white pine in one week's time. Mollenhauer (*35*) found red squirrels clipped from 50 to 100 percent of the cone-bearing limbs of the table mountain pine. It was the opinion of Pulling (*41*) that red squirrels took all the white pine seed produced during a poor year in one area in New York State. An examination of three red squirrel stomachs from a jack pine slash area in Minnesota showed that they had consumed 1,178 jack pine seeds or an average of 392 seeds per squirrel. In this latter case, the squirrels were collected at the edge of the cutting area. None was observed in the main body of the clearing. This localization was further illustrated by Smith (*53*) when he wrote, "The greatest rodent damage occurred on the fully-timbered area where red squirrels invaded the quadrats several times searching for ungerminated seeds."

Ground squirrels (*Citellus*) are not commonly pests on sites requiring reforestation. These animals occur only in the western states in open types of habitat where reforestation is not likely to be practiced. However, these animals are known to retard forest regeneration at times, as Tinsley (*58*) reported the Columbian ground squirrel in Idaho to have consumed practically all the seeds (pondersosa and western white pine) sown.

One associated quite closely with the forest is the mantled squirrel. Throughout the ponderosa pine belt, this group is common and believed to be an important ponderosa pine seed consumer by Wahlenberg (*60*) and Taylor and Gorsuch (*57*).

Chipmunks play an important role in preventing the reseeding of forests. The western chipmunk (*Eutamias*) has been a greater factor in this respect than the eastern form (*Tamias*). Most seeding studies have been made in the West and in the Lake States where the western form is much more abundant. In the Lake States, both chipmunks occupy the same range, but *Eutamias* is found more in the logged or burned areas and is much more numerous over the whole area.

In northern Minnesota, chipmunks were found to be pronounced pine seed destroyers. The examination of stomachs from 88 chipmunks col-

Table 1—(*Continued*)

Common name	Scientific name	Reference
Red squirrel	*Tamiasciurus hudsonicus*	*5, 9, 15, 26, 29, 41, 43, 49, 53, 56*
	Tamiasciurus hudsonicus baileyi	*41, 43, 49, 53, 56, 18*
	Tamiasciurus hudsonicus loquax	*65*
	Tamiasciurus hudsonicus ventorum	*21*
	Tamiasciurus hudsonicus richardsoni	*36, 54*
	Tamiasciurus douglasii	*36, 52*
	Tamiasciurus douglasii albolimbatus	*17*
	Tamiasciurus fremonti fremonti	*19*
Western gray squirrel	*Sciurus griseus*	*36, 52*
Flying squirrel	*Glaucomys sabrinus latipes*	*3*
Pocket mouse	*Perognathus fasciatus*	Text
	Perognathus parvus mollipilosus	*51*
Kangaroo rat	*Dipodomys heermanni*	*52*
White-footed mouse	*Peromyscus maniculatus*	*52*
	Peromyscus maniculatus gracilis	Text
	Peromyscus leucopus noveboracensis	*53*
	Peromyscus sp.	*55, 62*
Woodrat	*Neotoma fuscipes*	*14*
Red-backed mouse	*Clethrionomys gapperi*	Text
Meadow mouse	*Microtus montanus*	*58*
House mouse	*Mus musculus*	*53*

[1] This list does not include species eating Juniper and Taxis, and includes references only from published articles and findings from the author's field work.

lected in a jack pine slash area revealed that 72 percent contained the remains of jack pine seeds. They averaged 31 seeds per stomach, but one chipmunk had eaten 796 and another had 204 in its stomach and 168 in its cheek pouches. The 88 animals had disposed of a total of 2,749 jack pine seeds. Although chipmunks formed only 39.5 percent of the rodent population, they consumed 61 percent of the jack pine seeds removed by rodents on this area.

Coniferous seed destruction by chipmunks has been reported by Dearborn (*12*) from the Black Hills, Tinsley (*58*) in the Northern Rocky Mountains, Korstian and Baker (*30*) in the intermountain region of Utah, Taylor and Gorsuch (*57*) in the Southwest, Willis (*62*) and Moore (*36*) in the Pacific Northwest, L. Smith (*53*) for the New England area, and Horn, in an unpublished (1932) report from California.

Mice as a group, because of their wide habitat and geographic distribution, are perhaps the greatest animal factor in retarding forest regeneration by seeds. A great many of the authors reviewed, mentioned mice as one of the chief offenders.

White-footed mice (*Peromyscus*) have been found by the authors to be the most widely distributed and the most influential species in their studies. Where other authors have specified species, the white-footed group are usually mentioned. According to Silver (*50*), white-footed mice damaged from 10 to 90 percent of the seed spots on a planting program in the Ocala National Forest, Florida, Willis (*62*) attributed 98 percent failure of seed spots of Douglas-fir on the Columbia National Forest to the work of mice, and cage tests showed that a mouse could consume 300 seeds of this species daily. In the Lake States white-footed mice were found to be second only to chipmunks in numbers and in the consumption of jack pine seeds. The examination of 30 stomachs revealed that 70 percent had eaten jack pine seeds and the whole lot averaged 19 seeds per stomach. The greatest number eaten by a single animal was 156.

Other mice known to feed on coniferous seeds are red-backed mice (*Clethrionmys*), meadow mice (*Microtus*), jumping mice (*Zapus*), pocket mice (*Perognathus*), and house mice (*Mus musculus*).

The red-backed mice are perhaps the most characteristic forest species, but their food preferences run more to succulent vegetation than to seeds. After a logging operation where most of the timber is cut, these mice are rapidly replaced by the white-footed species. That they can be a minor factor in seed consumption, however, is shown by the analysis of 59 stomachs of mice trapped on a jack pine slash area. Only 14 percent of them had eaten jack pine seed, the greatest number per individual being 25, and the average .6.

Birds Also Take Much Seed

Birds are more of an influence in seed consumption than is generally believed. Many workers have referred to seed destruction by birds and rodents but few have specified which birds are involved. As early as 1916, Toumey (*59*) listed mourning doves, redpoll, Canada jay, blue jay, English sparrow, robin, blackbird, finch, junco, and blue grosbeak as forest seed eaters. In the longleaf pine area of Mississippi, Burleigh (*8*) found heavy consumption of seeds by mourning doves, bobwhites, meadow larks, Brewer's rusty, and red-winged blackbirds, and cowbirds. He found that damage by these birds was most severe during years of heavy seed production and relatively light during scanty seed years, the explanation being that the seed crop when abundant attracted and held larger bird populations. Pearson (*39*) and Krauch in a 1937 report for the southwest named the junco as a cause of failure of seeding experiments.

In the northwest, Moore (*36*) found Douglas-fir seeds attractive to winter wrens, purple finches, song sparrows, towhees, and juncos.

Four juncos, eight chipping sparrows, eight goldfinches, and one Brewer's blackbird were collected on a jack pine slash area in northern Minnesota. Of these 21 birds only three (chipping sparrows) had failed to feed on jack pine seeds. Most of these birds were present in fair-sized flocks, which could have been responsible for the consumption of a large part of the seed crop.

It is rather surprising to find such insectivorous mammals as shrews consuming coniferous seeds, but Moore (*37*) states, "They play a definite and deleterious part in natural reforestation." He lists five species of shrews that were found to eat Douglas-fir seeds. Jack pine seeds were found in the stomach of one long-tailed shrew in Minnesota.

Many workers have deplored serious losses of seed by rodents and birds without specifying the identity of the animals concerned. In fact, the writers have found it impossible to attribute

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Decline of the North American avifauna

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Species extinctions have defined the global biodiversity crisis, but extinction begins with loss in abundance of individuals that can result in compositional and functional changes of ecosystems. Using multiple and independent monitoring networks, we report population losses across much of the North American avifauna over 48 years, including once common species and from most biomes. Integration of range-wide population trajectories and size estimates indicates a net loss approaching 3 billion birds, or 29% of 1970 abundance. A continent-wide weather radar network also reveals a similarly steep decline in biomass passage of migrating birds over a recent 10-year period. This loss of bird abundance signals an urgent need to address threats to avert future avifaunal collapse and associated loss of ecosystem integrity, function and services.

Slowing the loss of biodiversity is one of the defining environmental challenges of the 21st century (*1–5*). Habitat loss, climate change, unregulated harvest, and other forms of human-caused mortality (*6, 7*) have contributed to a thousand-fold increase in global extinctions in the Anthropocene compared to the presumed prehuman background rate, with profound effects on ecosystem functioning and services (*8*). The overwhelming focus on species extinctions, however, has underestimated the extent and consequences of biotic change, by ignoring the loss of abundance within still-common species and in aggregate across large species assemblages (*2, 9*). Declines in abundance can degrade ecosystem integrity, reducing vital ecological, evolutionary, economic, and social services that organisms provide to their environment (*8, 10–15*). Given the current pace of global environmental change, quantifying change in species abundances is essential to assess ecosystem impacts. Evaluating the magnitude of declines requires effective long-term monitoring of population sizes and trends, data which are rarely available for most taxa.

Birds are excellent indicators of environmental health and ecosystem integrity (*16, 17*), and our ability to monitor many species over vast spatial scales far exceeds that of any other animal group. We evaluated population change for 529 species of birds in the continental United States and Canada (76% of breeding species), drawing from multiple standardized bird-monitoring datasets, some of which provide close to fifty years of population data. We integrated range-wide estimates of population size and 48-year population trajectories, along with their associated uncertainty, to quantify net change in numbers of birds across the avifauna over recent decades (*18*). We also used a network 143 weather radars (NEXRAD) across the contiguous U.S. to estimate long-term changes in nocturnal migratory passage of avian biomass through the airspace in spring from 2007 to 2017. The continuous operation and broad coverage of NEXRAD provide an automated and standardised monitoring tool with unrivaled temporal and spatial extent (*19*). Radar measures cumulative passage across all nocturnally migrating species, many of which breed in areas north of the contiguous U.S. that are poorly monitored by avian surveys. Radar thus expands the area and the proportion of the migratory avifauna that is sampled relative to ground surveys.

Results from long-term surveys, accounting for both increasing and declining species, reveal a net loss in total abundance of 2.9 billion (95% CI = 2.7-3.1 billion) birds across almost all biomes, a reduction of 29% (95% CI = 27-30%) since 1970 (Fig. 1 and Table 1). Analysis of NEXRAD data indicate a similarly steep decline in nocturnal passage of migratory biomass, a reduction of 13.6 ± 9.1% since 2007 (Fig. 2A). Reduction in biomass passage occurred across the eastern U.S. (Fig. 2, C and D), where migration is dominated by large numbers of temperate- and boreal-breeding songbirds; we observed no consistent trend in the Central or Pacific flyway regions (Fig. 2, B to D, and table S5). Two completely different and independent monitoring techniques thus signal major population loss across the continental avifauna.

Species exhibiting declines (57%, 303/529) based on long-

term survey data span diverse ecological and taxonomic groups. Across breeding biomes, grassland birds showed the largest magnitude of total population loss since 1970—more than 700 million breeding individuals across 31 species— and the largest proportional loss (53%); 74% of grassland species are declining. (Fig. 1 and Table 1). All forest biomes experienced large avian loss, with a cumulative reduction of more than 1 billion birds. Wetland birds represent the only biome to show an overall net gain in numbers (13%), led by a 56% increase in waterfowl populations (Fig. 3 and Table 1). Surprisingly, we also found a large net loss (63%) across 10 introduced species (Fig. 3, D and E, and Table 1).

A total of 419 native migratory species experienced a net loss of 2.5 billion individuals, whereas 100 native resident species showed a small net increase (26 million). Species overwintering in temperate regions experienced the largest net reduction in abundance (1.4 billion), but proportional loss was greatest among species overwintering in coastal regions (42%), southwestern aridlands (42%), and South America (40%) (Table 1 and fig. S1). Shorebirds, most of which migrate long distances to winter along coasts throughout the hemisphere, are experiencing consistent, steep population loss (37%).

More than 90% of the total cumulative loss can be attributed to 12 bird families (Fig. 3A), including sparrows, warblers, blackbirds, and finches. Of 67 bird families surveyed, 38 showed a net loss in total abundance, whereas 29 showed gains (Fig. 3B), indicating recent changes in avifaunal composition (table S2). While not optimized for species-level analysis, our model indicates 19 widespread and abundant landbirds (including 2 introduced species) each experienced population reductions of >50 million birds (data S1). Abundant species also contribute strongly to the migratory passage detected by radar (*19*), and radar-derived trends provide a fully independent estimate of widespread declines of migratory birds.

Our study documents a long-developing but overlooked biodiversity crisis in North America—the cumulative loss of nearly 3 billion birds across the avifauna. Population loss is not restricted to rare and threatened species, but includes many widespread and common species that may be disproportionately influential components of food webs and ecosystem function. Furthermore, losses among habitat generalists and even introduced species indicate that declining species are not replaced by species that fare well in human-altered landscapes. Increases among waterfowl and a few other groups (e.g., raptors recovering after the banning of DDT) are insufficient to offset large losses among abundant species (Fig. 3). Importantly, our population loss estimates are conservative since we estimated loss only in breeding populations. The total loss and impact on communities and ecosystems could be even higher outside the breeding season if we consider the amplifying effect of "missing" reproductive output from these lost breeders.

Extinction of the Passenger Pigeon (*Ectopistes migratorius*), once likely the most numerous bird on the planet, provides a poignant reminder that even abundant species can go extinct rapidly. Systematic monitoring and attention paid to population declines could have alerted society to its pending extinction (*20*). Today, monitoring data suggest that avian declines will likely continue without targeted conservation action, triggering additional endangered species listings at tremendous financial and social cost. Moreover, because birds provide numerous benefits to ecosystems (e.g., seed dispersal, pollination, pest control) and economies (47 million people spend 9.3 billion U.S. dollars per year through bird-related activities in the U.S. (*21*)), their population reductions and possible extinctions will have severe direct and indirect consequences (*10, 22*). Population declines can be reversed, as evidenced by the remarkable recovery of waterfowl populations under adaptive harvest management (*23*) and the associated allocation of billions of dollars devoted to wetland protection and restoration, providing a model for proactive conservation in other widespread native habitats such as grasslands.

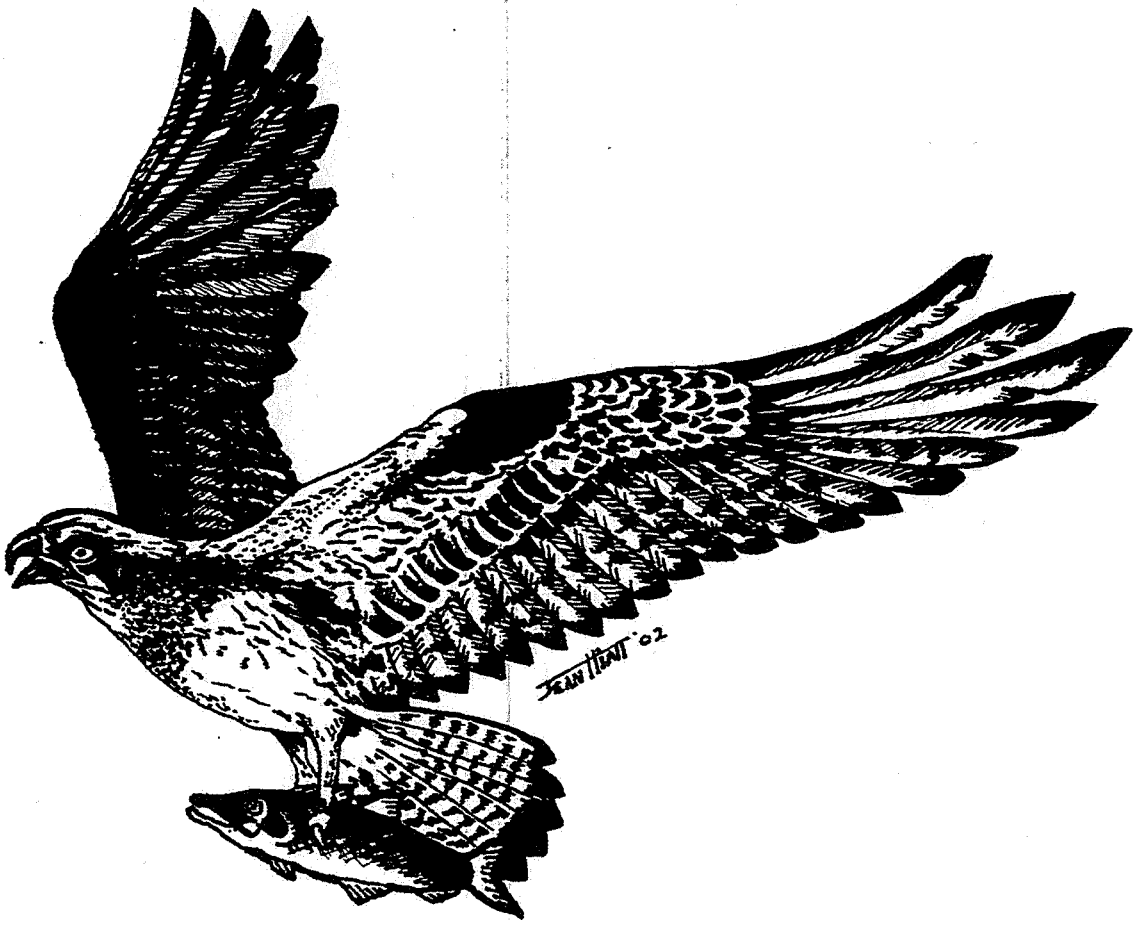
Steep declines in North American birds parallel patterns of avian declines emerging globally (*14, 15, 22, 24*). In particular, depletion of native grassland bird populations in North America, driven by habitat loss and more toxic pesticide use in both breeding and wintering areas (*25*), mirrors loss of farmland birds throughout Europe and elsewhere (*15*). Even declines among introduced species match similar declines within these same species' native ranges (*26*). Agricultural intensification and urbanization have been similarly linked to declines in insect diversity and biomass (*27*), with cascading impacts on birds and other consumers (*24, 28, 29*). Given that birds are one of the best monitored animal groups, birds may also represent the tip of the iceberg, indicating similar or greater losses in other taxonomic groups (*28, 30*).

Pervasiveness of avian loss across biomes and bird families suggests multiple and interacting threats. Isolating spatio-temporal limiting factors for individual species and populations will require additional study, however, since migratory species with complex life histories are in contact with many threats throughout their annual cycles. A focus on breeding season biology hampers our ability to understand how seasonal interactions drive population change (*31*), although recent continent-wide analyses affirm the importance of events during the non-breeding season (*19, 32*). Targeted research to identify limiting factors must be coupled with effective policies and societal change that emphasize reducing threats to breeding and non-breeding habitats and minimizing avoidable anthropogenic mortality year-round. Endangered species legislation and international treaties, such as

Table 1. Net change in abundance across the North American avifauna, 1970-2017. Species are grouped into native and introduced species, management groups (landbirds, shorebirds, waterbirds, waterfowl), major breeding biomes, and nonbreeding biomes (see data S1 in (*18*) for assignments and definitions of groups and biomes). Net change in abundance is expressed in millions of breeding individuals, with upper and lower 95% credible intervals (CI) shown. Percentage of species in each group with negative trend trajectories are also noted. Values in bold indicate declines and loss; those in italics indicate gains.

Species Group	Number of Species	Net Abundance Change (Millions) & 95% CI			Percent Change & 95% CIs			Proportion Species in Decline
		Change	LC95	UC95	Change	LC95	UC95	
Species Summary								
All N. Am. Species	529	**-2,911.9**	-3,097.5	-2,732.9	**-28.8%**	-30.2%	-27.3%	57.3%
All Native Species	519	**-2,521.0**	-2,698.5	-2,347.6	**-26.5%**	-28.0%	-24.9%	57.4%
Introduced Species	10	**-391.6**	-442.3	-336.6	**-62.9%**	-66.5%	-56.4%	50.0%
Native Migratory Species	419	**-2,547.7**	-2,723.7	-2,374.5	**-28.3%**	-29.8%	-26.7%	58.2%
Native Resident Species	100	*26.3*	7.3	46.9	*5.3%*	1.4%	9.6%	54.0%
Landbirds	357	**-2,516.5**	-2,692.2	-2,346.0	**-27.1%**	-28.6%	-25.5%	58.8%
Shorebirds	44	**-17.1**	-21.8	-12.6	**-37.4%**	-45.0%	-28.8%	68.2%
Waterbirds	77	**-22.5**	-37.8	-6.3	**-21.5%**	-33.1%	-6.2%	51.9%
Waterfowl	41	*34.8*	24.5	48.3	*56.0%*	37.9%	79.4%	43.9%
Aerial Insectivores	26	**-156.8**	-183.8	-127.0	**-31.8%**	-36.4%	-26.1%	73.1%
Breeding Biome								
Grassland	31	**-717.5**	-763.9	-673.3	**-53.3%**	-55.1%	-51.5%	74.2%
Boreal forest	34	**-500.7**	-627.1	-381.0	**-33.1%**	-38.9%	-26.9%	50.0%
Forest Generalist	40	**-482.2**	-552.5	-413.4	**-18.1%**	-20.4%	-15.8%	40.0%
Habitat Generalist	38	**-417.3**	-462.1	-371.3	**-23.1%**	-25.4%	-20.7%	60.5%
Eastern Forest	63	**-166.7**	-185.8	-147.7	**-17.4%**	-19.2%	-15.6%	63.5%
Western forest	67	**-139.7**	-163.8	-116.1	**-29.5%**	-32.8%	-26.0%	64.2%
Arctic Tundra	51	**-79.9**	-131.2	-0.7	**-23.4%**	-37.5%	-0.2%	56.5%
Aridlands	62	**-35.6**	-49.7	-17.0	**-17.0%**	-23.0%	-8.1%	56.5%
Coasts	38	-6.1	-18.9	8.5	-15.0%	-39.4%	21.9%	50.0%
Wetlands	95	*20.6*	8.3	35.3	*13.0%*	5.1%	23.0%	47.4%
Nonbreeding Biome								
Temperate North America	192	**-1,413.0**	-1,521.5	-1,292.3	**-27.4%**	-29.3%	-25.3%	55.2%
South America	41	**-537.4**	-651.1	-432.6	**-40.1%**	-45.2%	-34.6%	75.6%
Southwestern Aridlands	50	**-238.1**	-261.2	-215.6	**-41.9%**	-44.5%	-39.2%	74.0%
Mexico-Central America	76	**-155.3**	-187.8	-122.0	**-15.5%**	-18.3%	-12.6%	52.6%
Widespread Neotropical	22	**-126.0**	-171.2	-86.1	**-26.8%**	-33.4%	-19.3%	45.5%
Widespread	60	-31.6	-63.1	1.6	-3.7%	-7.4%	0.2%	43.3%
Marine	26	**-16.3**	-29.7	-1.2	**-30.8%**	-49.1%	-2.5%	61.5%
Coastal	44	**-11.0**	-14.9	-6.7	**-42.0%**	-51.8%	-26.7%	68.2%
Caribbean	8	-6.0	1.4	-15.7	12.1%	-2.8%	31.7%	25.0%

UTAH FIELD OFFICE GUIDELINES FOR RAPTOR PROTECTION FROM HUMAN AND LAND USE DISTURBANCES



U.S. Fish and Wildlife Service, Utah Field Office
Salt Lake City
January 2002 update

Prepared by Laura A. Romin and James A. Muck

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SUMMARY

Proponents of land-use activities are responsible for determining potential impacts to raptors of those activities. Appropriate management strategies for conservation and restoration of raptor populations and their habitats associated with the proposed actions should be devised. The following steps should become routine during initial project planning:

1. Coordinate with appropriate U.S. Fish and Wildlife Service (Service), Utah Division of Wildlife Resources (UDWR), and/or land management agency wildlife biologists at the onset of project planning.

2. Identify species and distribution of raptors occurring within the project area by evaluating existing data and/or conducting on-site surveys.

3. Determine location and distribution of important raptor habitat, raptor nests, and available prey base associated with proposed developments and activities.

4. Ascertain the type, extent, timing, and duration of development or human activities proposed to occur.

5. Consider cumulative effects to raptors of proposed projects when added to past, present, and reasonably foreseeable actions.

6. Minimize, to the extent feasible, loss of raptor habitats and avoid long-term habitat degradation. Mitigate for unavoidable losses of high-valued raptor habitats, including (but not limited to) nesting, winter roosting, and foraging areas.

7. Plan and schedule short-term and long-term project disturbances and human-related activities to avoid raptor nesting and roosting areas, particularly during crucial breeding and wintering periods.

8. Post-project and post-mitigation monitoring are necessary to document stability of raptor populations and their prey base, and to evaluate success of mitigation efforts.

PREFACE

The following raptor protection guidelines were prepared by the Service in coordination with various federal, state, tribal, and private entities with an interest in raptor protection. These guidelines are intended to provide an advisory framework for consistent raptor management approaches statewide.

to minimize disturbance to raptors and raptor nest sites.

STEP 3

Apply the information attained in Steps 1 and 2 to the following guidelines for occupied and unoccupied nest sites to avoid or minimize effects of proposed land use activities to nesting raptors:

- Occupied raptor nests: Activities should not occur within the spatial/seasonal buffer of any nest (occupied or unoccupied) when raptors are in the process of courtship and nest site selection. Egg laying, incubation, fledging, brooding, and post-fledging dependency periods are protected by varying seasonal and spatial buffers (Tables 2 and 3).

  Short term land use and human use activities should only proceed within the spatial buffer of an occupied nest outside the seasonal buffer, after coordination with appropriate Service, UDWR, and/or land management agency biologists. Mitigation for habitat loss or degradation should be planned. Long term land use activities and human use activities should not occur within the species-specific spatial buffer zone of occupied nests.

- Unoccupied raptor nests: If a nest site within a territory is deemed unoccupied after sufficient time has elapsed in a specified breeding season and prior to the beginning of the next year's breeding season, human activity could be allowed within the nesting area. This period varies dependent on raptor species. However, as a general rule, even renesting will usually not occur later than May 30 (C. White, BYU, 1998, pers. comm.).

  Short term land use and human activities may progress near a nest or nest territory designated as unoccupied. For long term land use activities, unoccupied nests should be protected for 7 years, or the period a known preferred prey species fluctuates from population highs to lows. At the end of the 7-year period, each nest should be evaluated by a qualified wildlife biologist as to its potential future use. Criteria could include the raptor species current population trend in the local area, the corresponding prey species population levels and trends, as well as past, current, and future impacts of the proposed action. Nests could also be considered permanently abandoned if the nest has been physically damaged past the point of repair by raptors.

  Long-term land use activities and human use activities should not occur proximally to unoccupied nests unless it is determined that mitigation is appropriate and can be accomplished prior to initiation of the long-term disturbance. Coordination with Service, UDWR, and/or land management agency

Monitoring and documentation of results is recommended following any of the aforementioned techniques to maximize success of efforts. Publishing data and results should also be considered to widely circulate information regarding success of raptor mitigation techniques.

CONCLUSION

It has been the intent of these guidelines to provide land use planners with the tools to develop successful raptor management and mitigation strategies proximal to disturbances from land use activities. Raptor survey information attained through implementation of these guidelines will also provide a means to track raptor population trends and document population responses to human use of their environments.

The guidelines have presented recommendations for protection of raptor life stages (i.e., nesting and wintering) as well as raptor habitats. The recommendations are hardly exhaustive of available protective strategies, nor are all recommendations intended to be incorporated on every proposed project. Coordination with appropriate Service, UDWR, and/or land management agency biologists is important during the analysis of project impacts and selection of protective measures.

Project proponents should seek first to avoid or minimize impacts. Where there are inevitable losses or degradations of habitat or disturbance to individual birds, mitigation can be incorporated to lessen the impact. Overall, these guidelines have been designed to maintain viable raptor populations amid continued human use of the environment.

Table 2. Nesting periods and recommended buffers for raptors in Utah						
Species	**Spatial Buffer (miles)**	**Seasonal Buffer**	**Incubation, # Days**	**Brooding, # Days Post-Hatch**	**Fledging, # Days Post-Hatch**	**Post-fledge Dependency to Nest, # Days[1]**
Bald eagle	1.0	1/1-8/31	34-36	21-28	70-80	14-20
Golden eagle	0.5	1/1-8/31	43-45	30-40	66-75	14-20
N. Goshawk	0.5	3/1-8/15	36-38	20-22	34-41	20-22
N. Harrier	0.5	4/1-8/15	32-38	21-28	42	7
Cooper's hawk	0.5	3/15-8/31	32-36	14	27-34	10
Ferruginous hawk	0.5	3/1-8/1	32-33	21	38-48	7-10
Red-tailed hawk	0.5	3/15-8/15	30-35	35	45-46	14-18
Sharp-shinned hawk	0.5	3/15-8/31	32-35	15	24-27	12-16
Swainson's hawk	0.5	3/1-8/31	33-36	20	36-40	14
Turkey vulture	0.5	5/1-8/15	38-41	14	63-88	10-12
California condor	1.0	NN yet	56-58	5-8 weeks	5-6 months	2 months
Peregrine falcon	1.0	2/1-8/31	33-35	14-21	35-49	21
Prairie falcon	0.25	4/1-8/31	29-33	28	35-42	7-14
Merlin	0.5	4/1-8/31	28-32	7	30-35	7-19
American kestrel	NN[2]	4/1-8/15	26-32	8-10	27-30	12
Osprey	0.5	4/1-8/31	37-38	30-35	48-59	45-50
Boreal owl	0.25	2/1-7/31	25-32	20-24	28-36	12-14
Burrowing owl	0.25	3/1-8/31	27-30	20-22	40-45	21-28
Flammulated owl	0.25	4/1-9/30	21-22	12	22-25	7-14
Great horned owl	0.25	12/1-9/31	30-35	21-28	40-50	7-14
Long-eared owl	0.25	2/1-8/15	26-28	20-26	30-40	7-14
N. saw-whet owl	0.25	3/1-8/31	26-28	20-22	27-34	7-14
Short-eared owl	0.25	3/1-8/1	24-29	12-18	24-27	7-14
Mex. Spotted owl	0.5	3/1-8/31	28-32	14-21	34-36	10-12
N. Pygmy owl	0.25	4/1-8/1	27-31	10-14	28-30	7-14
W. Screech owl	0.25	3/1-8/15	21-30	10-14	30-32	7-14
Common Barn-owl	NN[2]	2/1-9/15	30-34	20-22	56-62	7-14

[1] Length of post-fledge dependency period to parents is longer than reported in this table. Reported dependency periods reflect the amount of time the young are still dependent on the nest site; i.e. they return to the nest for feeding.

[2] Due to apparent high population densities and ability to adapt to human activity, a spatial buffer is not currently considered necessary for maintenance of American kestrel or Common barn-owl populations. Actions resulting in direct mortality of individual birds or take of known nest sites is unlawful.

Table 3. Recommended proportion (None, Half, or Full) of the species-specific spatial buffer zones for level and duration of activities during raptor nesting				
NESTING PHENOLOGY (Risk Level)				
	Courtship and Nesting (High)	**Incubation, and Brooding (High)**	**Post-Brooding Nestling Period (Moderate)**	**Post Fledging Dependency (Moderate)**
In-Vehicle, Recreational[a] Activity: Any recreational vehicle driving off-road, or on dirt roads, and not part of a routinely used transportation corridor.				
less than 1 hour[b]	NONE	NONE	NONE	NONE
less than 1 hour[c]	HALF	HALF	NONE	NONE
greater than 1 hour	FULL	FULL	HALF	HALF
Out-of-Vehicle, Recreational Activity: including, but not limited to hiking, dispersed camping, rock climbing, birdwatching, fishing, hunting, biological surveys.				
less than 1 hour[b]	HALF	HALF	NONE	NONE
less than 1 hour[c]	FULL	FULL	HALF	HALF
greater than 1 hour	FULL	FULL	FULL	FULL
Developed Recreation: including, but not limited to ski resorts, snowmobile and off-road vehicle courses, developed campground sites, and group tour operations.				
	FULL	FULL	FULL	FULL
Industrial, Municipal, and Transportation Disturbance: including, but not limited to urbanization; mining; oil and gas development; logging; power line construction; road construction & maintenance; use of explosives; agricultural operations; fixed wing and helicopter overflights.				
less than 1 hour[b]	FULL	FULL	HALF	HALF
less than 1 hour[c]	FULL	FULL	FULL	HALF
greater than 1 hour	FULL	FULL	FULL	FULL

[a] Recreational activities are defined as those providing outdoor recreation, entertainment, or adventure.

[b] No more than 1 repetition in a 24 hour period for a duration of less than 1 hour is allowable.

[c] More than one repetition per 24 hours, spaced no less than 2 hours apart, occurs during daylight hours. Full buffer zone is required for any activities occurring during nighttime hours

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Old-Growth Concepts from Habitat Type Data in the Southwest[1]

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Abstract:–Tree data collected from plant association field plots was viewed to develop an old-growth data base to help determine an inventory definition for old-growth in the Southwestern Region. The plant association field plots were helpful in establishing the minimum criteria for the live tree, dead tree, and basal area structural attributes used to identify potential old-growth.

INTRODUCTION

There has been an effort to determine an inventory definition for old-growth in the Southwest. An old-growth core team was established in 1989 to develop definitions for the pinyon-juniper, ponderosa pine, mixed-species group (includes Douglas-fir, white fir, blue spruce, bristlecone pine, and limber pine) and Engelmann spruce-subalpine fir forest cover types the Southwestern Region.

Seven structural attributes were identified to inventory candidate old-growth stands. The attributes are shown in table 1. The first five attribut were designated as National required standards for all Regions; the remaining two were additional attributes considered important for the Southwest.

Table 1. The minimum criteria for the structural attributes used to determine old-growth.

Forest Cover Type, Name	Pinyon-Juniper		Interior Ponderosa Pine		Mixed-Species Group		Engelmann Spruce-Subalpine Fir	
Forest Cover Type, SAF Code	239		237		209,210,211,216,219		206	
Site Capability Potential					50 Douglas-Fir		50 Engelmann Spruc	
Break Between Low and High Site			55 Minor		Edminster & Jump		Alexander	
Site	Low	High	Low	High	Low	High	Low	High
1. LIVE TREES IN MAIN CANOPY								
TREES/ACRE	12	30	20 12 @ or @	20 14 @ or @	12	16	20 15 @ or @	30 25 @ or @
DBH/DRC	9"	12"	14" 18"	20" 24"	18"	20"	10" 12"	14" 16"
AGE (YEARS)	150	200	180	180	150	150	140*/170**	140*/170**
2. VARIATION IN TREE DIAMETERS (YES OR NO)	ND	ND	ND	ND	ND	ND	ND	ND
3. DEAD TREES								
STANDING								
TREES/ACRE	0.5*	1	1	1	2.5	2.5	3	4
SIZE, DBH/DRC	9"	10"	14"	14"	14"	16"	12"	16"
HEIGHT (FEET)	8'	10'	15'	25'	20'	25'	20'	30'
DOWN								
PIECES/ACRE	2	2**	2	2	4	4	5	5
SIZE (DIAMETER)	9"	10"	12"	12"	12"	12"	12"	12"
LENGTH (FEET)	8'	10'	15'	15'	16'	16'	16'	16'
4. TREE DECADENCE TREES/ACRE	ND	ND	ND	ND	ND	ND	ND	ND
5. NUMBER OF TREE CANOPIES	SS/MS	SS/MS	SS/MS	SS/MS	SS/MS	SS/MS	SS/MS	SS/MS
6. TOTAL BA, SQUARE FEET/ACRE	5	23	70	90	80	100	120	140
7. TOTAL CANOPY COVER, PERCENT	20	35	40	50	50	60	60	70

PINYON-PINE * Dead limbs help make up dead material deficit. ** Unless removed for firewood or fire burning activities.
SPRUCE-FIR * In mixed corkbark fir and Engelmann spruce stands where Engelmann spruce is less than 50 percent composition in the stand.
** In mixed corkbark fir and Engelmann spruce stands where Engelmann spruce is 50 or more percent composition in the stand.
ND is not determined; SS is single-storied; MS is multi-storied

[1]*Paper presented at the conference on Old-Growth Forests in the Rocky Mountains and Southwest, Portal, AZ, March 9-13, 1992.*
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The purpose of this study was to develop an old-growth data base that would help establish the minimum criteria for the structural attributes used to inventory old-growth (table 1). Tree data from over 2,000 forest and woodland habitat type (plant association) field plots was viewed and 1,585 plots had complete, usable data that could be used to develop the old-growth data base. A simple comparison procedure was then used to help establish the minimum live trees, dead trees, and basal area per acre minimum old-growth structural attributes.

METHODS

Data Collection

Several researchers, contractors and others collected plant species information during the late 1970s and early 1980s to develop forest habitat type (plant association) classifications for the southwestern United States (Arizona, New Mexico, and southern Colorado). The information was collected from temporary sample plots that were purposely located in undisturbed, forest climax communities. This biased sampling method provided the greatest amount of information for a selected habitat type with the least number of plots. Since old-growth forests are ecosystems distinguished by old trees and related structural features that are in the later stages of stand development, the habitat type classification data could be used to establish an old-growth inventory data base.

The original plant association field plot data and a computerized comprehensive habitat type data base developed by Muldvin *et al.*, were archived at the Forestry Sciences Laboratory, Rocky Mountain Forest and Range Experiment Station, Albuquerque, New Mexico (Muldvin *et al.*, 1990). The archived, noncomputerized, field plot data included information on stand structure, site productivity, soil analysis, plus descriptive materials such as photographs and maps. The computerized habitat type data base included information about floristic diversity, environmental characteristics, stand productivity, and other descriptive information on the forest communities.

Data Analysis

Although there were 2009 plant association plots, a total of 1585 plots were used for the new old-growth data base. Many of the original field plots were not useable because there was no tree data recorded, the data was lumped in the field, or because of questionable plot sizes which would yield unreliable results when expanded. There were also a number of plots with the field data cards missing.

The tree data from the 1585 useable plots were organized in the new old-growth data base that was compatible with the VARGEN stand data processing program. The data base included the species, diameter of each tree, and site tree data, when available. The VARGEN program was able to determine forest cover type and site productivity (site index) as well as generate two-inch diameter class stand tables by each species and a summary for all species on a plot.

The next step was to combine the VARGEN stand table information into three tables for comparison purposes. Tables were generated for the mean number of live trees per acre, mean number of dead standing trees per acre and mean square foot basal area per acre.

The mean number of live trees per acre is shown in table 2 by 2-inch diameter classes, by no, low, high, and all sites, and each forest cover type. The number of plots for each forest cover type and site is shown on

Table 2. Summary Data in 2-inch Diameter Classes for Live Trees Per Acre.

	DIAMETER, DBH/DRC																		
	0-1.9	2-3.9	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16-17.9	18-19.9	20-21.9	22-23.9	24-25.9	26-27.9	28-29.9	30-31.9	32+	Total Trees	Number of Plots
INYON-JUNIPER																			
O SI	988	77	50	31	20	15	10	6	7	6	2	3	2	2	0	0	1	1220	52
OW SI	607	81	57	36	32	13	10	6	8	5	3	5	2	3	1	1	1	871	23
I SI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L SI	871	78	52	33	24	14	10	6	7	6	2	4	2	2	0	0	1	1113	75
ONDEROSA PINE																			
O SI	943	74	53	38	22	18	15	12	9	7	4	6	3	2	1	1	1	1209	137
OW SI	237	37	24	17	13	11	10	9	7	6	5	3	2	1	1	0	1	384	219
SI	316	45	29	20	14	12	10	8	7	6	6	8	3	2	1	0	1	488	384
L SI	409	48	32	22	15	13	11	9	7	6	5	6	3	2	1	0	1	591	740
IXED-SPECIES																			
O SI	741	94	60	43	27	24	18	13	9	8	6	5	3	2	1	2	4	1060	126
OW SI	399	84	56	38	31	21	16	14	8	8	6	4	2	2	1	1	2	693	72
SI	510	103	66	40	25	21	18	13	10	8	7	10	2	1	1	1	1	837	289
L SI	553	98	63	40	26	22	18	13	9	8	7	8	2	1	1	1	2	873	487
RUCE-FIR																			
O SI	806	114	76	52	51	44	32	22	13	11	7	4	2	2	0	0	0	1236	31
W SI	850	136	89	61	45	36	29	19	14	8	8	4	3	2	1	1	1	1307	99
SI	854	125	77	56	38	32	31	22	14	10	7	5	2	1	1	1	1	1277	143
L SI	847	128	81	57	42	35	30	21	14	9	7	5	2	1	1	1	1	1283	273

Table 3. Summary Data in 2-inch Diameter Classes for Dead Trees Per Acre.

	DIAMETER, DBH/DRC																	
	0-1.9	2-3.9	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16-17.9	18-19.9	20-21.9	22-23.9	24-25.9	26-27.9	28-29.9	30-31.9	32+	Total Trees	Num of Pl
PINYON-JUNIPER																			
NO SI	29	9	4	2	2	1	0	1	1	0	0	0	0	0	0	0	0	49	
LOW SI	36	15	7	2	2	0	0	0	0	0	0	0	0	0	0	0	0	62	
HI SI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
ALL SI	31	11	5	2	2	1	0	1	1	0	0	0	0	0	0	0	0	53	
PONDEROSA PINE																			
NO SI	9	9	4	2	1	1	1	1	0	0	1	1	1	0	0	0	0	31	1
LOW SI	5	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	8	2
HI SI	5	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	10	3
ALL SI	6	3	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	13	7
MIXED-SPECIES																			
NO SI	12	8	7	5	2	2	2	1	1	1	0	1	0	0	0	0	0	42	1
LOW SI	31	20	7	6	3	2	1	1	1	0	0	0	0	0	0	0	0	72	
HI SI	12	13	8	4	3	2	2	1	1	1	0	1	0	0	0	0	0	48	2
ALL SI	15	13	8	5	3	2	2	1	1	1	0	1	0	0	0	0	0	50	4
SPRUCE-FIR																			
NO SI	17	20	13	12	10	9	3	10	3	3	2	1	0	0	0	0	0	103	
LOW SI	30	21	16	9	8	7	5	4	2	2	2	0	1	0	0	0	0	107	
HI SI	22	19	14	10	7	7	5	4	2	2	1	1	1	0	0	0	0	95	1
ALL SI	24	20	15	10	8	7	5	5	2	2	1	1	1	0	0	0	0	100	2

the right side of the table. The all site plot number represents the total of no, low, and high site plots. No site means that the site tree data was not calculated because site tree information was not complete.

The mean number of dead standing trees per acre is shown in table 3 by 2-inch diameter classes, by no, low, high, and all sites, and each forest cover type. The number of plots for each forest cover type and site is shown on the right side of the table. The all site plot number represents the total of no, low, and high site plots.

The mean square foot basal area per acre is shown in table 4 by 2-inch diameter classes, by no, low, high, and all sites and each forest cover type. The number of plots for each forest cover type and site is shown on the right side of the table. The all site plot number represents the total of no, low, and hi plots.

The data were then used to compare the nu and diameter of live trees per acre, number a diameter of standing dead trees per acre, and basal area per acre to the proposed guidelines each forest cover type and site capability pote table 1. Data were not collected for tree age, d dead trees, height of standing dead trees or to canopy cover so these attributes could not be Since there is no established break in site cap potential for pinyon-juniper the same plots we tested using both high and low standards.

Because tree diameter data was collected b size classes it was not possible to calculate the number of plots meeting or exceeding the mini

Table 4. Summary Data in 2-inch Diameter Classes for Basal Area Per Acre.

	DIAMETER, DBH/DRC																	
	0-1.9	2-3.9	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16-17.9	18-19.9	20-21.9	22-23.9	24-25.9	26-27.9	28-29.9	30-31.9	32+	Total BA	Num of Pl
PINYON-JUNIPER																			
NO SI	0	1	7	8	9	10	9	8	12	12	5	9	8	7	1	1	10	117	
LOW SI	0	1	8	10	14	8	9	7	12	10	8	13	8	11	4	5	12	140	
HI SI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
ALL SI	0	1	7	9	11	9	9	8	12	11	6	10	8	8	2	2	11	124	
PONDEROSA PINE																			
NO SI	0	1	7	10	10	12	13	15	15	14	11	17	9	9	4	5	9	161	1
LOW SI	0	0	3	5	6	7	9	11	11	13	12	8	6	6	2	3	5	107	2
HI SI	0	0	4	5	6	8	9	10	12	13	15	22	10	7	6	2	7	136	3
ALL SI	0	0	4	6	7	8	10	11	12	13	13	17	9	7	4	3	7	132	7
MIXED-SPECIES																			
NO SI	0	0	8	11	12	16	17	16	14	15	14	13	9	8	7	8	32	200	11
LOW SI	0	0	8	10	14	14	15	18	13	16	16	12	7	9	4	5	17	178	
HI SI	0	0	9	11	11	14	17	16	16	15	17	28	6	5	3	4	11	183	2
ALL SI	0	0	9	11	12	15	17	16	15	15	16	22	7	6	4	5	17	187	4
SPRUCE-FIR																			
NO SI	0	0	10	14	23	29	30	26	21	22	16	12	6	7	2	2	0	220	3
LOW SI	0	0	12	16	20	24	27	24	22	15	18	13	9	6	5	3	9	223	9
HI SI	0	0	11	15	17	21	29	27	22	19	17	15	5	5	3	3	5	214	14
ALL SI	0	0	11	15	19	23	28	26	22	18	17	14	7	6	4	3	6	218	27

diameter criteria when the proposed value fell in the middle of a size class. Consequently, it was necessary to run some tests using all data within the size class of the proposed value.

Tests were conducted to determine the number and percent of plots in each forest cover type and site potential that met or exceeded the proposed minimums in table 1. This testing method was useful in identifying attributes that have a low proportion of plots satisfying the proposed standards, which would suggest that the minimum criteria are set too high. This method, displayed in table 5, could not provide further analysis of the attributes which had 100 percent of the plots meeting or exceeding the proposed minimum guidelines. A second test was therefore conducted to find out how far they exceed the proposed minimum standards. The test compared the mean values for each attribute in the summary tables 3, 4, and 5, to the proposed guidelines in table 1. This provided a partial analysis of the relationships between plot averages and the proposed guidelines and is displayed in table 6.

RESULTS

The percent of plots concurring with (meeting or exceeding) the proposed minimum guidelines for each attribute are shown by forest cover type in table 5. With one exception (ponderosa pine basal area) low site attributes had levels of concurrence that were equal to or higher than their high site counterparts.

Comparisons of proposed minimum attributes to the mean plot values are displayed in table 6. In general, attributes with a level of concurrence at or near 100% have mean values which are much higher than the proposed minimum standards. Pinyon-juniper plots showed the greatest difference between mean values and proposed minimum guidelines.

Comparison of the plot data to the proposed guidelines for each attribute yielded the following results:

Basal Area - With two exceptions (low site spruce-fir and ponderosa pine), basal area had the highest level of concurrence for any forest type and site group (table 5). Low and high site indexes usually had similar levels of concurrence. Mean plot values in all forest types exceeded proposed minimum guidelines by at least 51% in all cases (table 6).

Dead Trees - This attribute always had the lowest level of concurrence of any variable. The level of concurrence among low site plots was always equal to or higher than high site plots (table 5).

Live Trees - In general, low site plots had a higher level of concurrence for this attribute than high site plots (table 5). Where two sets of values

Table 5. Test Results of Individual Attributes by Forest Type.

PINYON-JUNIPER					
LOW SI	NUMBER OF PLOTS	PERCENT CONCUR	HIGH SI	NUMBER OF PLOTS	PERCENT CONCUR
Total	23	100	Total	23	100
BA 5 sq. ft.+	23	100	BA 23 sq.ft.+	23	100
Dead Trees 8"+	5	22	Dead Trees 8"+	5	22
Live Trees 8"+	23	100	Live Trees 12"+	21	91
Live Trees 10"+	23	100			
PONDEROSA PINE					
LOW SI	NUMBER OF PLOTS	PERCENT CONCUR	HIGH SI	NUMBER OF PLOTS	PERCENT CONCUR
Total	219	100	Total	384	100
BA 70 sq.ft.+	155	71	BA 90 sq.ft.+	304	79
Dead Trees 12"+	31	14	Dead Trees 12"+	51	13
Live Trees 14"+	171	78	Live Trees 20"+	210	55
Live Trees 18"+	107	49	Live Trees 24"+	62	16
MIXED-SPECIES					
OW SI	NUMBER OF PLOTS	PERCENT CONCUR	HIGH SI	NUMBER OF PLOTS	PERCENT CONCUR
tal	72	100	Total	289	100
A 80 sq.ft.+	67	93	BA 100 sq.ft.+	264	91
ead Trees 12"+	20	28	Dead Trees 16"+	55	19
ve Trees 18"+	47	65	Live Trees 20"+	168	58
SPRUCE-FIR					
)W SI	NUMBER OF PLOTS	PERCENT CONCUR	HIGH SI	NUMBER OF PLOTS	PERCENT CONCUR
tal	99	100	Total	143	100
120 sq.ft.+	95	96	BA 140 sq.ft.+	134	94
ad Trees 12"+	67	68	Dead Trees 16"+	54	38
e Trees 10"+	99	100	Live Trees 14"+	117	82
e Trees 12"+	98	99	Live Trees 16"+	93	65

Table 6. Comparison of proposed minimum attributes and averages by forest cover type.

BASAL AREA

	Proposed Miminum	Average Value	Pct. of Minimum
Pinyon-juniper, Low SI	5	140	2,800
Pinyon-juniper, High SI	23	140	609
Ponderosa Pine, Low SI	70	107	153
Ponderosa Pine, High SI	90	136	151
Mixed-species, Low SI	80	178	223
Mixed-species, High SI	100	183	183
Spruce-fir, Low SI	120	223	186
Spruce-fir, High SI	140	214	153

DEAD TREES PER ACRE

	Proposed Miminum	Average Value	Pct. of Minimum
Pinyon-juniper, Low SI	0.5	2	400
Pinyon-juniper, High SI	1	0	0
Ponderosa Pine, Low SI	1	0	0
Ponderosa Pine, High SI	1	0	0
Mixed-species, Low SI	2.5	2	80
Mixed-species, High SI	2.5	3	120
Spruce-fir, Low SI	3	16	533
Spruce-fir, High SI	4	7	175

LIVE TREES PER ACRE

	Proposed Miminum	Average Value	Pct. of Minimum
Pinyon-juniper, Low SI	12	90	750
Pinyon-juniper, High SI	30	90	300
Ponderosa Pine, Low SI	20/12	35/19	175/158
Ponderosa Pine, High SI	20/14	21/7	105/50
Mixed-species, Low SI	12	26	217
Mixed-species, High SI	16	23	144
Spruce-fir, Low SI	20/15	126/90	630/600
Spruce-fir, High SI	30/25	64/42	213/168

were proposed, the smaller tree diameter had a higher level of concurrence than the larger tree diameter.

Comparison of the plot data to the proposed guidelines yielded the following results for each forest cover type:

Pinyon-Juniper - All live tree attributes had over 90% concurrence (table 5). There was no difference in results between the 8+ and 10+ inch diameters for low site live trees. Mean basal area values were extremely high relative to the proposed minimum values (table 6).

Ponderosa Pine - Levels of concurrence were higher for the density of live trees on low site plots than high site plots, and also higher with the smaller of the two diameter limits (table 5). Levels of concurrence for dead trees were almost the same for both high and low site plots. These values were lower than for any other forest cover type, and both had mean values of zero (table 6).

Mixed-Species - Over 90% of both high and low site plots met or exceeded the proposed minimum standards for basal area (table 5). The level or concurrence for live tree attributes was similar for both high and low sites.

Spruce-Fir - Over 90% of both high and low site plots met or exceeded the proposed minimum standards for basal area (table 5). Low site plots were tested for both 10+ and 12+ inch diameter live trees, yielding similar results for each, with both h. over 90% concurrence. The test results of the high site live tree diameter variables (14+ an inches) were quite different, as were the resu high and low site dead trees.

DISCUSSIONS AND RECOMMENDA'

There is always a chance that the habitat t data used for the old-growth data base is biase towards heavier than normal tree densities. P fire suppression in the early 1900s, forests in t southwest were burned by low intensity groun at 2 to 15 year intervals, ponderosa pine), 5 to year intervals, mixed-conifer, and lesser freque to stand replacement fires in the spruce-fir (Co 1960, White 1985, Swetnam 1988, Covington an Moore 1991)

The small number of pinyon-juniper plots lim the reliability of the results from this forest cov type. Additional plot data which was collected in pinyon-juniper habitat types is needed to increa accuracy of the summary data and subsequent analysis.

Attributes with low levels of concurrence may minimum standards which are set too high. Sinc plot data represents the best available example o what old-growth is, there should be a strong corr tion between the plot data and the proposed guid lines. Adjusting the minimum standards to obtai high level of concurrence would seem to be justifi

The number and size of dead trees consistently the lowest level of concurrence of any attribute tested. It is possible however, that the proposed minimum guidelines for this attribute are set appr priately. Past management practices may have reduced the number of standing snags to unnatura low levels throughout the Region. Rather than lowering the proposed minimum standards, manag ment practices need to recruit new snags.

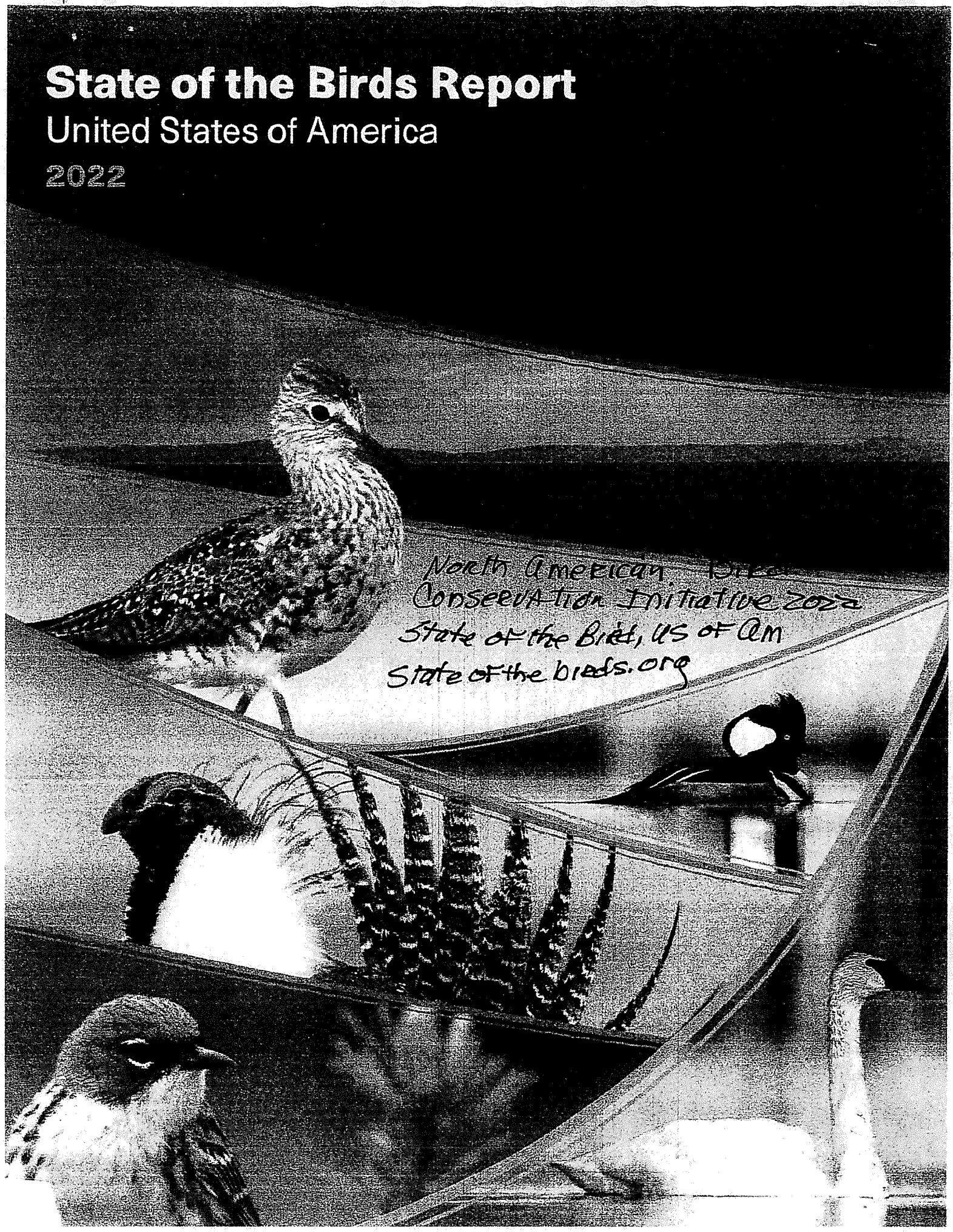
Attributes which have concurrence at or near 100% also need to be examined. Table 5 suggests which guidelines may be set too low by displaying mean values that greatly exceed the proposed mini mum standards. Basal area should be looked at especially carefully. Not only was it the attribute which had the highest level of concurrence most oft but the calculated value for basal area was probably too low in many instances. Due to the variable cut-o point and subsequent lumping of data when record ing diameters, the number of 20-inch and 22-inch trees is overestimated while the number of trees ov 22 inches is underestimated. Because basal area is function of tree diameter, the total basal area may b to low on any plot containing lumped diameter data and therefore to low in the plot summary data.

When considering adjustment of site capability potential, special considerations may be in order. Th site indexes calculated for many of the plots are too low due to the use of the largest, oldest trees near th plot for site trees. The mean annual increment for

State of the Birds Report

United States of America

2022



North American Bird Conservation Initiative 2022
State of the Birds, US of AM
stateofthebirds.org

The United States and Canada have lost 3 billion breeding birds since 1970—a loss of 1 in 4 birds, according to research published in *Science* in 2019. This steep decline in abundance can be reversed with new scales of conservation actions that benefit not only birds but also wildlife and people.

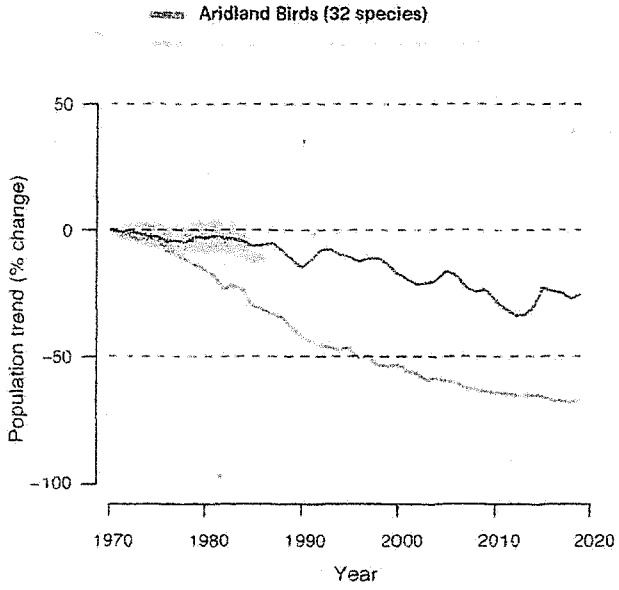
Lesser Yellowlegs

We All Win


Greater Sage-Grouse

ARIDLAND BIRDS
A Key Role for Public Lands

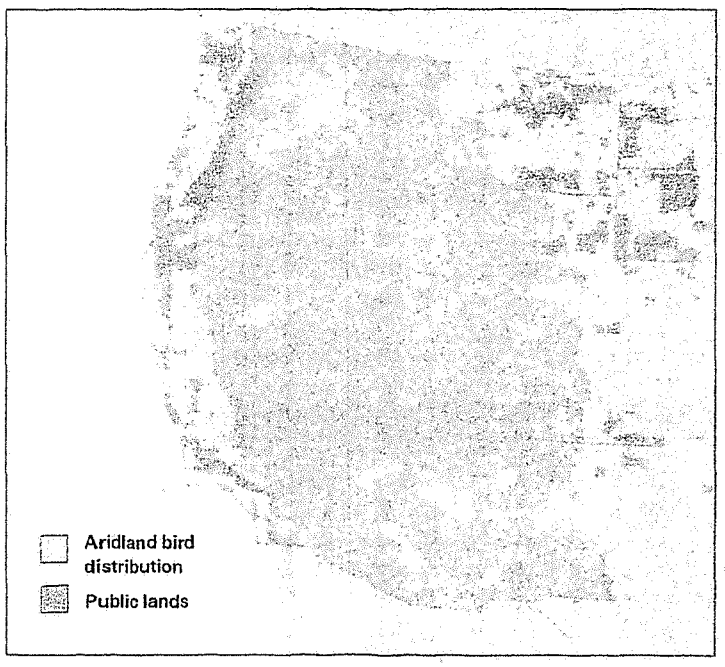
Status: Long-term declines with unrelenting habitat threats



Aridland birds have been in a long-term decline, with a slight improvement since 2012. Fires, drought, invasive plants, development, unsustainable grazing, and energy extraction pressures on habitat are all driving aridland bird declines.

- Several aridland birds (such as Chihuahuan Raven, Sage Thrasher, and Pyrrhuloxia) exhibit accelerated rates of decline since 2010.
- and have experienced long-term declines, but the population has stabilized in the past decade.
- shows a continued steep decline that warrants increased voluntary habitat conservation incentives and renewed strong federal and state protections.

Public Lands Are Essential for Aridland Bird Conservation
The federal government and state agencies have a vital role to play in turning around bird declines in sagebrush and desert habitats. According to the 2011 State of the Birds report, public lands in the American West support more than half of the breeding distribution of aridland birds. Bureau of Land Management lands are particularly important, supporting almost a quarter of the distribution of all aridland birds and more than two-thirds of the U.S. distributions of Sage Thrasher and Sagebrush Sparrow, both species with declining populations. U.S. Forest Service lands in coastal chaparral habitats are important for the declining Wrentit. National Park Service lands are important for some desert bird species, such as the Bendire's Thrasher (a Tipping Point species). The 2011 State of the Birds Report found that about 80% of publicly owned aridlands were vulnerable to activities that could potentially degrade bird habitat—including energy development, off-road vehicle traffic, grazing, mining, and logging. Aridland bird habitat conservation can be compatible with multiple land uses, but management plans for these landscapes need to include measures to ensure long-term healthy populations of aridland birds.



WESTERN PUBLIC LANDS ARE HABITAT FOR ARIDLAND BIRDS
This map shows the cumulative range for 30 aridland bird species in North America, with the vast majority of that range falling within the boundaries of federal and state public lands. Source: Aridland bird data from Bird Conservation Regions, Bird Studies Canada and NABCI. Public lands map from GISGeography.com.

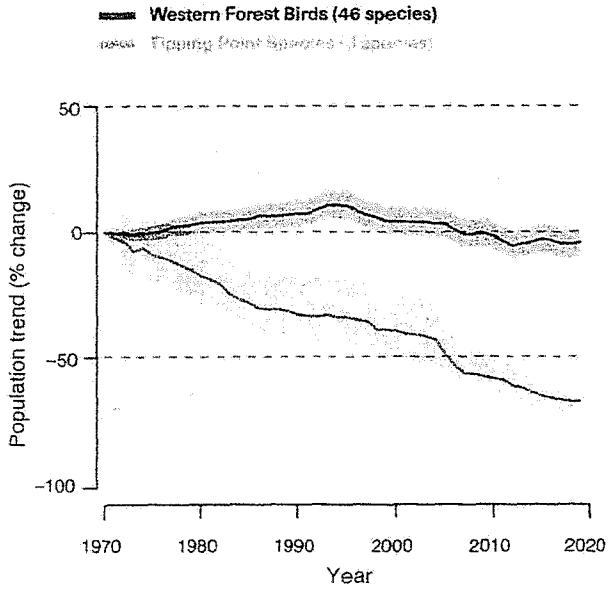
WESTERN FOREST BIRDS

Restoring Natural Cycles for Forest Health

STATUS: Stable overall, but with warning signs

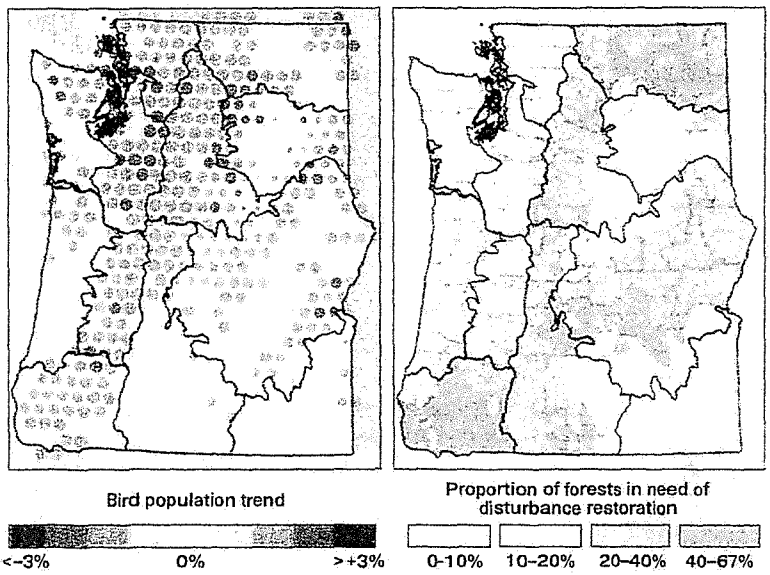
The overall population for the western forest birds group is much the same as it was 50 years ago, aided by protected habitats. But since reaching recent highs in the early 1990s, western forest birds have declined by nearly 20%.

- Almost half of this group (19 species) currently have declining population trends.
- Five species have lost more than half of their population since 1970, including Tipping Point species such as Pinyon Jay and Rufous Hummingbird with poorly understood life cycles. More science is needed to identify the drivers of their declines.
- Recent declining trends among Oak Titmouse, Williamson's Sapsucker, and other birds appear to be associated with the disruption of natural disturbance patterns such as fire cycles.



Birds Are Declining Where Western Forests Are Stressed

For most of the past 100 years, western forests have been managed to encourage conifer tree dominance and discourage fires. But for many centuries before the 1900s, fires were common on this landscape, both natural wildfires and intentional burns by Indigenous peoples. Today those historic disturbance patterns that created a mosaic of conifer and broadleaf forest cover and successional stages have been disrupted, and large swaths of western forest landscapes have departed from their natural range of tree species and structural diversity. These areas of forest departure from natural patterns are also hotspots for western forest bird declines. Furthermore, these compromised forests have very little resilience to the forces of wildfire and climate change, which puts greater forest landscape health and forest resources (such as water reservoirs) at risk of disaster. Investments in forest restoration can turn around this dim outlook for western forests and western forest birds.



BIRD DECLINES IN FORESTS THAT HAVE DEPARTED FROM HISTORIC CYCLES

According to population trends generated by eBird data, bird numbers tend to be declining in forests that have departed from historic conditions and are most in need of disturbance restoration. Sources: Cornell Lab | eBird data 2007–2019 (left map); DeMeo et al, "Expanding Our Understanding of Forest Structural Restoration Needs in the Pacific Northwest," *Northwest Science*, Winter 2018 (right map).

Bird Declines Are Reaching a Tipping Point

Sounding an Alarm About Steep Population Losses

In 2019, a study of 529 bird species with adequate long-term data for analysis (*Science*, Rosenberg et al.) found that 303 species in North America were declining—more than half of the bird species studied.

Now scientists with the Road to Recovery initiative have issued an alert for 90 declining bird species—birds that are not yet federally listed as threatened or endangered, but that have lost half or more of their breeding population since 1970. The scientists further identified a subset of 70 Tipping Point species that could lose another half or more of their populations in the next 50 years, based on recent trajectories and expert assessments.

These Tipping Point species are high priorities for science and conservation because of their high vulnerability to extinction, high urgency, and steep population declines where known. All are included on the Birds of Conservation Concern List of the U.S. Fish and Wildlife Service and/or state lists of Species of Greatest Conservation Need.

Two-thirds of Rufous Hummingbirds have been lost in the past 50 years.

On Alert: All of these bird species have lost half of their populations in the past 50 years

Baird's Sparrow
Black-billed Cuckoo
Black Skimmer
Black Swift
Canada Warbler
Cerulean Warbler
Clark's Grebe
Eastern Whip-poor-will
Grace's Warbler ✓
Long-billed Dowitcher
Mourning Warbler
Olive-sided Flycatcher ✓
Red-headed Woodpecker ✓
Rock Sandpiper
Snowy Owl
Surfbird
Thick-billed Longspur
Western Grebe
Wilson's Plover
Wood Thrush

Allen's Hummingbird
American Golden-Plover
Ashy Storm-Petrel*
Audubon's Shearwater*
Bachman's Sparrow
Band-rumped Storm-Petrel*
Bendire's Thrasher
Bicknell's Thrush*
Black-capped Petrel*
Black-chinned Sparrow
Black-footed Albatross*
Black-vented Shearwater*
Black Rail*
Black Rosy-Finch*
Black Scoter
Bobolink
Bristle-thighed Curlew*
Brown-capped Rosy-Finch*

Buff-breasted Sandpiper
Cassia Crossbill*
Chestnut-collared Longspur
Chimney Swift
Craveri's Murrelet*
Elegant Tern*
Evening Grosbeak ✓
Fea's Petrel*
Golden-winged Warbler
Great Black-backed Gull
Greater Sage-Grouse ✓
Guadalupe Murrelet*
Harris's Sparrow
Heermann's Gull*
Henslow's Sparrow
Hudsonian Godwit
Ivory Gull*
King Eider

King Rail
Kittlitz's Murrelet*
Laysan Albatross*
Least Tern
LeConte's Sparrow
LeConte's Thrasher
Lesser Prairie-Chicken*
Lesser Yellowlegs
Mottled Duck
Mountain Plover
Murphy's Petrel*
Parkinson's Petrel*
Pectoral Sandpiper
Pinyon Jay ✓
Prairie Warbler
Red-faced Cormorant
Red-legged Kittiwake*
Ruddy Turnstone

Rufous Hummingbird ✓
Saltmarsh Sparrow*
Scripps's Murrelet*
Seaside Sparrow*
Semipalmated Sandpiper
Short-billed Dowitcher
Sprague's Pipit
Stilt Sandpiper
Townsend's Storm-Petrel*
Tricolored Blackbird*
Wandering Tattler
Whimbrel
Whiskered Auklet*
Yellow-billed Loon
Yellow-billed Magpie
Yellow Rail*

These Tipping Point species are on a trajectory to lose another 50% of their remnant populations in the next 50 years if nothing changes.

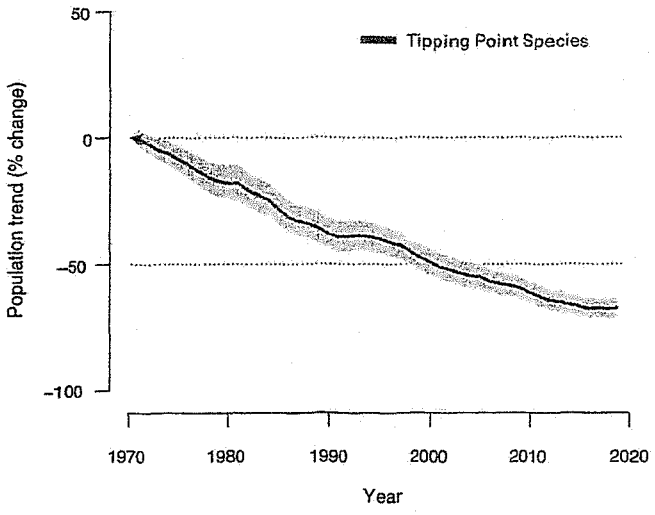
These 90 bird species lost 50% or more of their populations during 1970–2019. The Tipping Point species are on a trajectory to lose another 50% of their populations in the next 50 years (39 species), or already have perilously small populations and continue to face high threats, but lack sufficient monitoring data (31 species, indicated with an asterisk). For the USFWS Birds of Conservation Concern list, visit fws.gov/media/birds-conservation-concern-2021pdf.

The Next Set of Species Plummeting Toward Endangered Status

Of the 1,093 bird species protected under the Migratory Bird Treaty Act, 89 birds have received additional protections as either threatened or endangered under the U.S. Endangered Species Act to prevent their extinction.

The Tipping Point species represent another 70 birds that could be next to face threatened or endangered status. Cumulatively, the Tipping Point species that have sufficient data for monitoring have lost more than two-thirds of their populations in the past 50 years.

Tipping Point species come from varied habitats, but they all have the same urgency—immediate science and conservation actions are needed to turn around declines.



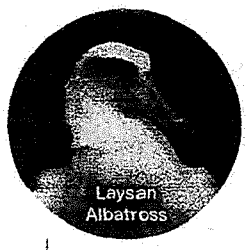
70 Tipping Point Species

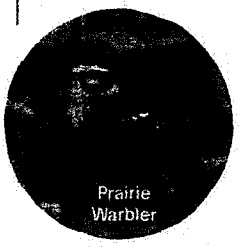
Urgent action is needed to help these birds before they become endangered.

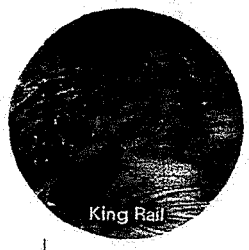
GRASSLAND BIRDS
Prairie specialists such as Mountain Plover, Sprague's Pipit, and Chestnut-collared Longspur have lost more than 75% of their populations since 1970.

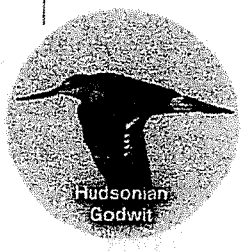
FOREST BIRDS
The steepest declines among forest birds include species that specialize on tree seeds (e.g., Pinyon Jay), long-distance migrants (e.g., Bicknell's Thrush), and aerial insect-eating specialists (e.g., Chimney Swift).

ARCTIC & ALPINE TUNDRA
Shrinking habitats due to changing climate and resource extraction threaten Arctic-breeding shorebirds (e.g., Hudsonian Godwit and Whimbrel) and alpine birds (e.g., Black Rosy-Finch).









COASTAL & OCEANIC
Nearly a quarter of seabirds found in U.S. waters are at risk of an Endangered listing, including murrelets, albatrosses, petrels, and shearwaters.

ARIDLAND BIRDS
Aridland birds are experiencing long-term declines, including Allen's Hummingbird, Bendire's Thrasher, and Greater Sage-Grouse.

WETLAND BIRDS
Though many waterbirds benefited from decades of wetland conservation, steep bird declines are still occurring in coastal saltmarshes (e.g., Saltmarsh Sparrow), freshwater marshes (e.g., Yellow Rail), and beaches (e.g., Least Tern).

North Am. Bird Cons Initiative 2022. State of the Birds, US & Can 2022. State of the Birds.org

Trees and forests

Very cool: trees stalling effects of global heating in eastern US, study finds

Vast reforestation a major reason for 'warming hole' across parts of US where temperatures have flatlined or cooled

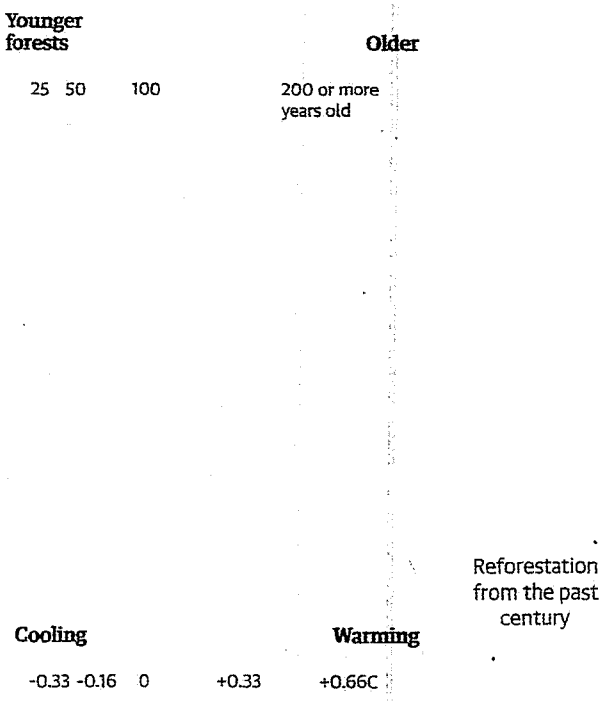
Oliver Milman

@olliemilman

Sat 17 Feb 2024 05.00 EST

Trees provide innumerable benefits to the world, from food to shelter to oxygen, but researchers have now found their dramatic rebound in the eastern US has delivered a further, stunning feat – the curtailing of the soaring temperatures caused by the climate crisis.

While the US, like the rest of the world, has heated up since industrial times due to the burning of fossil fuels, scientists have long been puzzled by a so-called "warming hole" over parts of the US south-east where temperatures have flatlined, or even cooled, despite the unmistakable broader warming trend.



A major reason for this anomaly, the new study finds, is the vast reforestation of much of the eastern US following the initial loss of large numbers of trees in the wake of European settlement in America. Such large expanses have been reforested in the past century – with enough trees sprouting back to cover an area larger than England – that it has

Civilian Conservation Corps workers plant 15,000,000 trees across the wastelands of southern Mississippi on 11 April 1940. They are part of the United Forest Service which will re-establish forests destroyed by logging and lumbering operations decades ago. Photograph: AP

"Moving forward, we need to think about tree planting not just as a way to absorb carbon dioxide but also the cooling effects in adapting for climate change, to help cities be resilient against these very hot temperatures."

Patrick Gonzalez, a University of California, Berkeley, climate change scientist and forest ecologist who wasn't involved in the new study, said the work provides "strong support" to the theory of cooling trees.

"Cutting carbon pollution from cars, power plants and other human sources that burn coal, oil and methane remains the essential solution to halt climate change," he said. "Natural regeneration of trees and reforestation, where ecologically appropriate, can contribute substantially."

Barnes, too, stressed that reforestation was no substitute for the need to drastically cut planet-heating emissions, which hit a new global high last year.

"Nature-based climate solutions like tree planting won't get us out of this climate change problem," she said. "If anyone thinks we can just plant a few trees and be OK, they are wrong – we need a massive reduction in fossil fuel emissions to hit our targets. Reforestation is something that needs to happen in addition to, not instead of, cutting emissions."

to reverse from around the 1920s as more people began to move into cities, leaving marginal land to become populated again with trees. The US government, meanwhile, embarked upon an aggressive tree-planting program, with these factors leading to about 15m hectares of reforested area in the past century in the eastern US.

People work to reforest Allegheny National Forest in Pennsylvania circa 1934. Photograph: Universal History Archive/Universal Images Group via Getty Images

The recovery of the US's eastern forests has blunted global heating mainly through the trees' transpiration, in which water is drawn up through the roots to the leaves and then released into the air as vapor, slightly cooling the surrounding area.

By poring over data from satellites and weather stations located across the eastern US from 1900 to 2000, Barnes and her colleagues found reforested areas have provided this cooling impact on a grand scale, with most of this effect occurring within 400 meters of the trees.

In all, the replenished forests today cool the eastern US by 1C to 2C (1.8F to 3.6F) each year. The cooling effect is strongest on the hottest days in summer, when trees lower temperatures by 2C to 5C (3.6F to 9F), the researchers found.

The researchers cautioned that bringing back trees hasn't been the sole cause of the stalled warming, with factors such as airborne pollutants, which block incoming sunlight, and agricultural irrigation also potential causes. But Barnes said that the findings should further bolster efforts to provide thoughtful reforestation, particularly near urban communities that suffer particularly scorching temperatures due to a lack of shady trees.

"Trees have a really beneficial impact upon surface temperatures through transpiration, which is similar to human sweating, and they have really cooled things off a lot," said Barnes.

Old-Growth Descriptions for the Major Forest Cover Types in the Rocky Mountain Region[1]

Mel S. Mehl[2]

Abstract.–Old-growth descriptions have been developed for each of the major forest cover types in the Rocky Mountain Region of the Forest Service. Included with each description is a minimum list of tree and stand variables that characterize old growth. Additional attributes are listed that affect the quality of old growth. These descriptions will be used to locate, map, and inventory old-growth forests for forest planning.

INTRODUCTION

This document describes the old-growth forest conditions for the major forest cover types in the Rocky Mountain Region (Region 2) of the Forest Service. Region 2 covers the states of Colorado, Wyoming, South Dakota, Kansas and Nebraska.

These old-growth descriptions are not precise definitions. There is a certain amount of subjectivity in defining old growth. Old growth is conceptual and difficult to define precisely. For that reason the term "description" was chosen instead of "definition." They describe the ecologically important structural features of old-growth forest ecosystems. They include a list of attributes measurable from stand-level inventories that characterize old-growth ecosystems. There are intangible elements, various functions and interactions occurring in old-growth ecosystems and the composition of the understory vegetation that are not part of these descriptions.

The following descriptions are the first attempt to describe old growth structurally by major forest cover type for Region 2. They form the collective knowledge of what is thought to describe old growth. These descriptions will be dynamic and will be modified as we learn more about the dynamics of old-growth ecosystems and its need and influence on the landscape.

Descriptions have been developed for the Engelmann spruce/subalpine fir, Douglas-fir, lodgepole pine, ponderosa pine, aspen and pinyon-juniper forest cover types. Ponderosa pine grows in 3 distinct topographical areas in Region 2: the Black Hills, front range of the Rocky Mountains, and southwest Colorado, each with different stand characteristics. Separate old-growth descriptions have been developed for each area.

The forest cover types are defined in the Society of American Foresters (SAF) handbook *Forest Cover Types of the United State and Canada,* 1980. These cover types are those by which most inventory and management is done. Descriptions for the minor forest types such as limber pine or white pine will be added in the future.

These descriptions and associated attributes will be used to map and inventory old growth in the Region for Forest planning. They are general. For project level work detailed site specific analyses may be needed.

The descriptions follow a format developed by the National Old-Growth Task Group.

Description

Old-growth forests are unique ecosystems that are an important component of biological diversity. Old growth occurs at some point in the later stages of the development of a stand (fig. 1).

A stand that has reached an old-growth condition has developed a diversity of functions and interactions that did not exist in earlier stages. The later stages of development also differ from earlier stages by structure such as tree size, standing and down dead trees, number of canopy levels, age and the composition of the understory species.

The age at which old growth develops and the structural attributes that characterize old growth will vary by forest cover type, climate, site conditions and past disturbances. However, old growth is typically distinguished from younger growth by several of the following stand attributes:

- large trees for species and site.
- variation in tree sizes and spacing.
- standing and down dead trees.
- decadence in the form of broken or deformed tops or bole and root decay.
- multiple canopy layers.
- gaps in the tree canopy and understory patchiness.

[1]*Paper presented at Old-Growth Forests in the Rocky Mountains and Southwest Conference, Portal, AZ, March 9-13, 1992.*

[2]*Regional Old-Growth Coordinator, USDA-Forest Service, Rocky Mountain Region, P.O. Box 25127, Lakewood, CO., 80225*

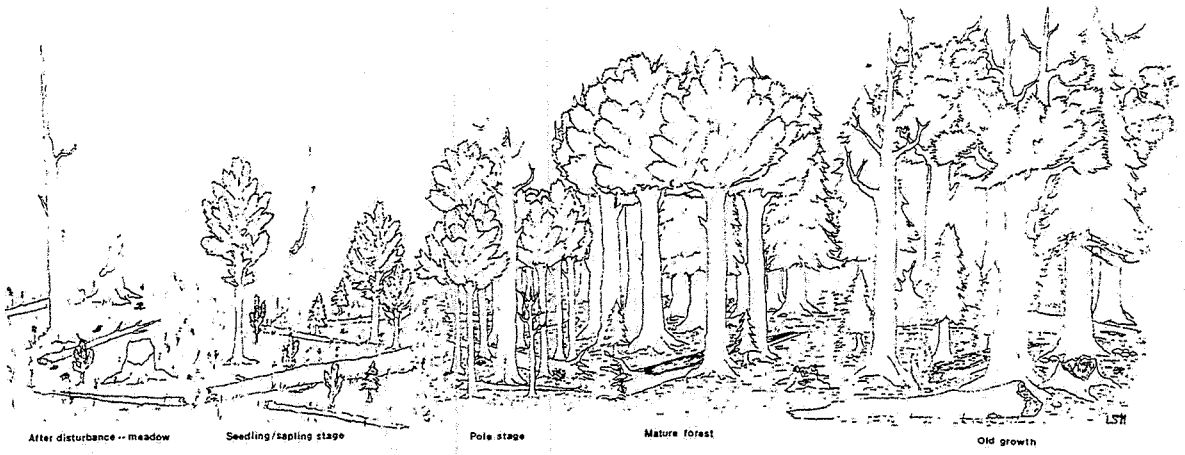


Figure 1. Developmental stages of a stand to an old-growth condition.

A stand may contain some trees that meet the criteria for old growth but the stand as a whole could lack the functions and interactions of an old-growth ecosystem and would not be considered old growth.

Old growth encompasses both older forests dominated by fire-dependent species and forests dominated by shade tolerant species. Different stages or qualities of old growth will be recognizable in many forest cover types. Sporadic, low to moderate severity disturbances are an integral part of the internal dynamics of many old-growth ecosystems. Canopy openings resulting from the death of overstory trees often give rise to patches of small trees, shrubs, and herbs in the understory. Frequent, low intensity fires are important for some species to maintain their dominance on a site.

Old growth is not necessarily "virgin" or "primeval". It could develop following human disturbances. It could also develop from man's indirect influence on the landscape by the control of fire.

Attributes

There are many attributes that could be used to characterize old growth, but these descriptions use attributes that are tree and stand-level characteristics such as diameter, canopy layers or patchiness. While there may be some attributes that seem applicable to all cover types, there is not one universal set of attributes that can adequately describe old growth for all cover types.

Each Region, as directed by the National Old-Growth Task Group, was to use a basic set of attributes to describe old growth. These are referred to as the "standard" attributes. Where necessary each Region had the option to include "additional" attributes to more fully describe old growth. In combination they provide the minimum requirements for determining if a stand is old growth.

A special set of attributes called "quality attributes" have been added. These are items that further enhance the value of an old-growth stand once it has been determined to be old growth based on the above minimums. They are not required for old growth, but provide higher quality old growth if present. These criteria would be useful for deciding which old-growth stands are the most important for retention.

These attributes are tree and stand characteristics that are normally used in stand inventories. Table 1 summarizes the attributes by forest cover type. The glossary at the end of this paper defines each attribute. They are readily identifiable and measurable in a consistent manner. In addition the standard attributes are generally obtainable from remote sensing sources such as aerial photography. The additional and quality attributes may require some field work to collect.

The minimum stand size required for a stand to be old growth was not considered in these descriptions. Managers will decide the appropriate size as configuration, location and position in the landscape are also important in determining the value of a stand as old growth.

Old growth may have evidence of past treatment including stumps, slash, down logs, roads, fences and other improvements. However, this may affect the quality of old growth.

Development of Descriptions

During the summer of 1990, workshops were held in various locations throughout the Region (fig 2).

The purpose was to visit old-growth sites and discuss the tree and stand related attributes that could describe these old-growth sites. Attendees at the workshops included District, Forest and Regional staff and scientists from the Rocky Mountain Research Station. Each workshop was focused on a specific forest cover type. From the workshops a list of tree and stand attributes by each forest cover type was developed descriptive of old growth. The description and list of attributes for the pinyon-juniper cover type were adapted from Region 3.

Figure 2. Workshop on the Arapaho/Roosevelt NF looking at lodgepole pine old growth.

The descriptions and lists were then sent out for review and comments to additional Regional and Rocky Mountain Station staff and interested publics.

SPRUCE-FIR - SAF COVER TYPE 206

Narrative

Engelmann spruce *(Pica engelmannii)* and subalpine fir *(Abies lasiocarpa)* comprise the spruce/fir forest cover type in the subalpine zone in the Rocky Mountain Region. Spruce-fir occupies the highest and coldest forest area in the Region and is generally found from 9,000 to 11,000 feet but may grow as low as 8,000 feet and as high as 12,000 feet or timberline.

Engelmann spruce and subalpine fir are extremely shade tolerant compared to the other major forest species. By being shade tolerant they can reproduce under themselves and barring any major disturbance, perpetuate the stand. Subalpine fir is more shade tolerant than Engelmann spruce and may reproduce vegetatively by layering. In younger stands subalpine fir may be the major component of the forest type. However, it is shorter lived than Engelmann spruce. Consequently, most of the overstory in a spruce-fir old-growth stand is Engelmann spruce. The under-

Table 1.–The minimum criteria for the structural attributes used to determine old growth and those that add a quality attachment. Attributes with an "X" or a numerical value are considered "must" criteria. Those with a "Q" are quality criteria. The quality attributes are not required for old growth, but provide for higher quality old growth if present. Any of the "must" criteria in excess of the minimums could also indicate a higher quality of old growth.

Forest Cover Type, Name	Spruce/ Fir	Douglas-Fir	Lodgepole Pine	Ponderosa Pine			Aspen	Pinyon-Juniper
				Front Rng	Blk Hills	So. West		
Forest Cover Type, SAF Code	**206**	**210**	**218**	**237**	**237**	**237**	**217**	**239**
STANDARD ATTRIBUTES								
LIVE TREES:								
Upper Canopy								
DBH/DRC	16	18	10	16	16	18	14	12
TREES/ACRE	10	10	10	10	10	10	20	30
AGE	200	200	150	200	160	160	100	200
VARIATION IN DIAMETER	X	X		X	Q	X	Q	X
DECADENCE	X	X	X	X	X	X	X	X
MULTIPLE CANOPY LAYERS	X	Q	Q				Q	
DEAD TREES:								
Standing								
DBH/DRC	10	10	8	10	10	10	10	10
TREES/ACRE	2	2	2	2	2	2	Q	1
Down								
PIECES/ACRE	X	X	X	Q	Q	Q	Q	2
ADDITIONAL/QUALITY ATTRIBUTES								
SLOW GROWING (MAIN CANOPY)	X	X	X	X	X	X	X	
CANOPY CLOSURE 50% PLUS							X	
CANOPY CLOSURE 35% PLUS								X
WIDE RANGE OF VIGOR	Q	X		X				
NET GROWTH NEAR ZERO	X		Q			Q		
PATCHINESS	X	Q	Q					
MANY STAGES OF DECOMPOSITION	X		Q			X		
MULTIPLE TREE SPECIES			Q				Q	
DISTINCTIVE BARK	Q			Q	Q	Q		
DISTINCTIVE CROWNS			Q	Q	Q	Q		

story may still have an abundance subalpine fir due to it's high tolerance to shade and vegetative layering. Engelmann spruce life span averages 350 to 400 years with 500-year-old or more trees not uncommon. Trees over 250 years are not uncommon for subalpine fir but most are 150 to 200 years old. It is quite susceptible to heart rot and generally dies at an earlier age than Engelmann spruce.

Spruce-fir is climax in the range that it occupies. No other tree species will replace it. The only time the stand would be replaced by another species is when a major disturbance like fire would occur, opening up the stand to sunlight. Less shade tolerant species then could occupy the site. Over time, up to 300 years or so, the more shade tolerant Engelmann spruce and subalpine fir would re-dominate the site.

After a stand replacing event such as fire or clear felling, lodgepole pine or aspen will be the replacing species at the lower elevational range of spruce-fir. If there is a sufficient seed source, spruce-fir will begin to develop in the understory and the lodgepole will begin to break apart with the stand reverting back to spruce-fir. Where there is not a sufficient spruce-fir seed source the stand will remain in lodgepole pine or aspen.

When at climax the stands are usually quite stable and will remain on the site indefinitely until replaced because of fire, logging, insect, disease, windstorm or other major disturbance.

Description

Spruce-fir old-growth stands are at climax and generally have a high number of large, old trees with an understory of shrubs and small subalpine firs. The percentage of canopy closure can vary. There is usually a considerable amount of standing dead and down trees making it quite difficult at times to walk through the stand (fig. 3).

Figure 3. Down trees in an old-growth spruce-fir stand on the Arapaho/ Roosevelt NF.

There can be lichens hanging from the tree branches and on the stems of the trees. It usually contains a mixture of different tree sizes providing a variety of structure within the stand. The upper canopy would consist of a cohort of older trees that are slow growing. These older trees can be characterized as having dead or broken tops, having flattened and open crowns, containing rot and possibly having bark that is reddish in color. Other tree species could be present such as lodgepole pine or aspen but generally would be scattered within the stand and at the lower elevations.

Attributes

Table 2 lists the tree attributes that are being used to describe spruce-fir old growth.

Table 2–Summary of Old-Growth Attributes for Spruce Fir – SAF Cover Type Code 206

STANDARD ATTRIBUTES	
LIVE TREES:	
Upper Canopy - Older Component	
Minimum DBH (inches)	16
Minimum Number of Trees Per Acre	10
Minimum Age	200
Variation in Tree Diameter	Yes
Decadence - dead, broken or deformed tops and/or bole or root rot	Yes
Multiple Tree Canopy Layers	Yes
DEAD TREES:	
Standing	
Minimum DBH (inches)	10
Number of Trees Per Acre	2
Down	
Minimum Pieces Per Acre	Some
ADDITIONAL ATTRIBUTES:	
Trees in Upper Canopy Are Slow Growing	Yes
Net Growth Near Zero	Yes
Patchiness	Yes
Many Stages of Decomposition	Yes
QUALITY ATTRIBUTES:	
Above Attributes in Excess of Minimums	Yes
Wide Range of Tree Vigor	Yes
Distinctive Bark	Yes

INTERIOR DOUGLAS-FIR – SAF COVER TYPE 210

Narrative

The interior Douglas-fir (*Pseudotsuga menziesii* var. glauca) cover type occurs throughout Region

2 from 6,000 to 10,000 feet in elevation. It occurs as pure stands or in association with other species such as Engelmann spruce and subalpine fir at higher elevations to lodgepole pine and aspen at its mid-elevational range and to ponderosa pine in its lower elevational range. In southwest Colorado, it grows with white fir and ponderosa pine were it is also referred to as mixed conifer.

Interior Douglas-fir is much different than the coastal variety of the Pacific Northwest. It grows in a drier climate and does not attain the growth, size or age of the Douglas-fir *(Pseudotsuga menziesii var. menziesii)* of the Pacific coast.

Douglas-fir is more shade tolerant than pine and aspen but less tolerant than Engelmann spruce or subalpine fir. When growing in association with spruce-fir it will be seral giving way eventually to the more shade tolerant spruce-fir. When growing in association with ponderosa pine, lodgepole pine or aspen it often dominates these species becoming the climax species if succession is not interrupted by a major disturbance such as fire.

Since Douglas-fir is shade tolerant, it can reproduce under its own canopy. This results in old stands of pure Douglas-fir that tend to be uneven-aged rather than single-aged. These pure stands most likely originated from fire. They remain over time because of Douglas-fir's ability to survive successive fires due to rapid growth, thick corky bark, ability to form adventitious roots and the longer fire interval on cool and moist north facing slopes. These stands generally reach a maximum age of 400 years old although some have reached an age of 700 years.

Where Douglas-fir grows in pure stands, it is usually on cooler and damper north facing slopes. Along the front range of Colorado, these stands have been heavily damaged by a spruce budworm infestation that began in the mid 1980's.

Insects often modify the structure of older Douglas-fir stands, creating large gaps or patches and groups of dead trees. This produces a patchy stand of large trees with Douglas-fir seedlings and saplings growing in the gaps giving the stand more vertical structure and an uneven aged composition.

At its lower elevational range, it has been easily accessible and influenced by post settlement activities. It has been heavily utilized for mining timbers and lumber and for recreation. Consequently few stands of old-growth Douglas-fir exist at lower elevations. However, its area is increasing in the lower elevations as it is replacing ponderosa pine especially on the cooler more moist north facing slopes. The frequent low intensity fires that kept Douglas-fir from becoming established in the ponderosa pine type have been reduced, allowing Douglas-fir to become established under the ponderosa pine.

Description

An old-growth Douglas-fir stand would consist of an overstory of trees that are predominately or entirely Douglas-fir. On the cooler, more moist, north facing slopes it may be growing in association with spruce-fir or white fir. On drier sites old-growth Douglas-fir could be associated with ponderosa pine, lodgepole pine and aspen. Where the site is dry, the stand would be more open-grown compared to a cooler, more moist site such as a north facing slope or drainage bottom. Some dead standing trees and down dead trees would be present. Some of the overstory trees would have large and open branched, flattened or dead tops and contain some rot.

Attributes

The following table lists the tree attributes that are being used to describe Douglas-fir old-growth:

Table 3–Summary of Old-Growth Attributes
Interior Douglas-Fir – SAF Cover Type 210

STANDARD ATTRIBUTES	
LIVE TREES:	
Upper Canopy - Older Component	
Minimum DBH (inches)	18
Minimum Number of Trees Per Acre	10
Minimum Age	200
Variation in Tree Diameter	Yes
Decadence - dead, broken or deformed tops and/or bole or root rot	Yes
Multiple Tree Canopy Layers	No
DEAD TREES:	
Standing	
Minimum DBH (inches)	10
Minimum Number of Trees Per Acre	2
Down	
Minimum Pieces Per Acre	Some
ADDITIONAL ATTRIBUTES:	
Trees in Upper Canopy Are Slow Growing	Yes
Wide Range of Tree Vigor	Yes
QUALITY ATTRIBUTES:	
Above Attributes in Excess of Minimums	Yes
Multiple Tree Canopy Layers	Yes
Patchiness	Yes

LODGEPOLE PINE - SAF COVER TYPE 218

Narrative

The lodgepole pine (*Pinus contorta* var. latifolia) cover type in Region 2 consists of extensive stands of pure lodgepole pine or, to a lesser extent, stands in association with other species such as Engelmann spruce, subalpine fir, or aspen. It occurs between 7,500 feet and 11,500

feet elevation but reaches maximum development in the upper montane and lower subalpine zones on south and west facing slopes between 9,000 and 10,000 feet elevation.

In contrast to the shade tolerant Engelmann spruce and subalpine fir, lodgepole pine is shade intolerant and is an aggressive pioneer developing on sites recently opened up due to fire, insects and disease, windstorms, clearcutting or other major stand removing disturbance. Lodgepole pine stands that are 350 to 400 years old exist but they are uncommon. The average life span of lodgepole pine is probably closer to 250 years or less because of the frequency of stand replacing disturbances such as fire. Fires are more frequent in lodgepole pine than spruce-fir as they occur in a warmer and dryer environment.

Lodgepole pine is generally considered a seral species. That is, it will be replaced by the more shade tolerant Engelmann spruce and subalpine fir. Most lodgepole pine stands become established after stand replacing events such as fire. As the lodgepole pine matures Engelmann spruce and subalpine fir will appear as the understory eventually replacing the overstory lodgepole pine. The stand will remain as spruce-fir until another stand replacing event occurs.

There are instances when lodgepole pine can be considered climax. In areas where a seed source of more shade tolerant trees species does not exist or the site is marginal for other tree species, the lodgepole pine stand will not be replaced. If there is a stand replacing occurrence like fire the stand will re-seed with lodgepole pine. If not disturbed the stand will begin to develop gaps in the tree canopy as trees die. These gaps will allow sunlight to reach seedlings, renewing the stand but a stand with a more varied structure. Over successive generations the stand would develop a structure more consistent of old growth in shade tolerant species. When fire was more prevalent few stands would have had the opportunity to reach this structure.

When the overstory trees in a lodgepole pine stand begin to die and fall, the overstory probably will not persist for more than 50 years or so.

Description

Many people do not believe that lodgepole pine old growth really exists. Using a definition of old-growth where a stand must be climax would eliminate much of the Region's lodgepole pine as old growth. However, the seral lodgepole pine condition can exhibit old-growth characteristics albeit they may not last long in one place, but overall in a landscape this old-growth condition can exist for quite some time. Lodgepole pine is more dynamic in its landscape behavior than the more shade tolerant species such as Engelmann spruce or subalpine fir.

In a seral condition lodgepole pine old growth would be described as having an overstory of large old trees without lower limbs, with dead or dying tops and with crowns that are sparse, open branched and somewhat flattened (fig 4).

The stand would probably have mistletoe, rust or stem rot present contributing to the decadence of the overstory. The understory would consist of Engelmann spruce and subalpine fir. Depending on the age of the understory there could be a fair amount of structure and variation in tree diameters within the stand. Some down material would be present, increasing as the overstory continued to degenerate. It is important to note that when the older lodgepole pine is replaced by the understory, the stand is no longer old growth. The stand would be a young spruce-fir stand.

Where lodgepole pine is considered climax, old growth will again include large old trees lacking lower limbs and with dead or dying tops and crowns with sparse foliage, open branched, misshapened and somewhat flattened. It would probably have mistletoe, rust and/or stem rot present contributing to the decadence of the overstory. However, it will not have the spruce-fir understory. It will most likely have one canopy layer and thus not much structure. There probably would be very little variation in tree diameter. There may be a lot or little down dead material depending on how advanced the decline is of the overstory. In stands that are very old perhaps 300 or more years old, there may be a fair amount of stand structure developed due to trees developing in openings created by trees in the original overstory that had fallen.

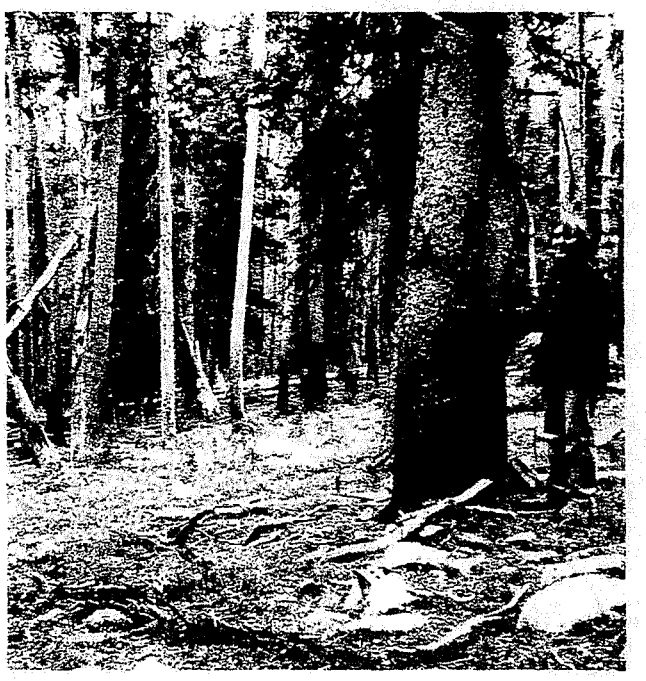


Figure 4. Seral old-growth lodgepole pine stand.

feet elevation but reaches maximum development in the upper montane and lower subalpine zones on south and west facing slopes between 9,000 and 10,000 feet elevation.

In contrast to the shade tolerant Engelmann spruce and subalpine fir, lodgepole pine is shade intolerant and is an aggressive pioneer developing on sites recently opened up due to fire, insects and disease, windstorms, clearcutting or other major stand removing disturbance. Lodgepole pine stands that are 350 to 400 years old exist but they are uncommon. The average life span of lodgepole pine is probably closer to 250 years or less because of the frequency of stand replacing disturbances such as fire. Fires are more frequent in lodgepole pine than spruce-fir as they occur in a warmer and dryer environment.

Lodgepole pine is generally considered a seral species. That is, it will be replaced by the more shade tolerant Engelmann spruce and subalpine fir. Most lodgepole pine stands become established after stand replacing events such as fire. As the lodgepole pine matures Engelmann spruce and subalpine fir will appear as the understory eventually replacing the overstory lodgepole pine. The stand will remain as spruce-fir until another stand replacing event occurs.

There are instances when lodgepole pine can be considered climax. In areas where a seed source of more shade tolerant trees species does not exist or the site is marginal for other tree species, the lodgepole pine stand will not be replaced. If there is a stand replacing occurrence like fire the stand will re-seed with lodgepole pine. If not disturbed the stand will begin to develop gaps in the tree canopy as trees die. These gaps will allow sunlight to reach seedlings, renewing the stand but a stand with a more varied structure. Over successive generations the stand would develop a structure more consistent of old growth in shade tolerant species. When fire was more prevalent few stands would have had the opportunity to reach this structure.

When the overstory trees in a lodgepole pine stand begin to die and fall, the overstory probably will not persist for more than 50 years or so.

Description

Many people do not believe that lodgepole pine old growth really exists. Using a definition of old-growth where a stand must be climax would eliminate much of the Region's lodgepole pine as old growth. However, the seral lodgepole pine condition can exhibit old-growth characteristics albeit they may not last long in one place, but overall in a landscape this old-growth condition can exist for quite some time. Lodgepole pine is more dynamic in its landscape behavior than the more shade tolerant species such as Engelmann spruce or subalpine fir.

In a seral condition lodgepole pine old growth would be described as having an overstory of large old trees without lower limbs, with dead or dying tops and with crowns that are sparse, open branched and somewhat flattened (fig 4).

The stand would probably have mistletoe, rust or stem rot present contributing to the decadence of the overstory. The understory would consist of Engelmann spruce and subalpine fir. Depending on the age of the understory there could be a fair amount of structure and variation in tree diameters within the stand. Some down material would be present, increasing as the overstory continued to degenerate. It is important to note that when the older lodgepole pine is replaced by the understory, the stand is no longer old growth. The stand would be a young spruce-fir stand.

Where lodgepole pine is considered climax, old growth will again include large old trees lacking lower limbs and with dead or dying tops and crowns with sparse foliage, open branched, misshapened and somewhat flattened. It would probably have mistletoe, rust and/or stem rot present contributing to the decadence of the overstory. However, it will not have the spruce-fir understory. It will most likely have one canopy layer and thus not much structure. There probably would be very little variation in tree diameter. There may be a lot or little down dead material depending on how advanced the decline is of the overstory. In stands that are very old perhaps 300 or more years old, there may be a fair amount of stand structure developed due to trees developing in openings created by trees in the original overstory that had fallen.

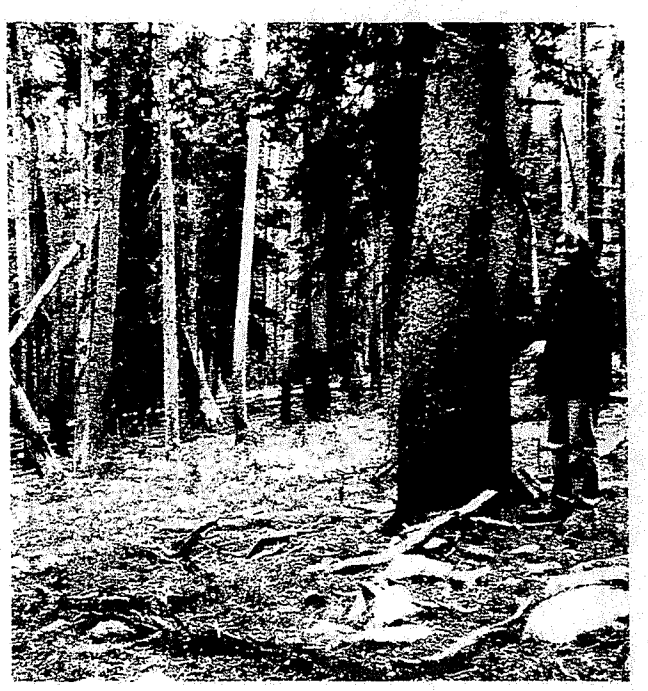


Figure 4. Seral old-growth lodgepole pine stand.

Attributes

The following table lists the tree attributes that are being used to describe lodgepole pine old growth.

Table 4–Summary of Old-Growth Attributes
Lodgepole Pine – SAF Cover Type 218

STANDARD ATTRIBUTES	
LIVE TREES:	
Upper Canopy - Older Component	
Minimum DBH (inches)	10
Minimum Number of Trees Per Acre	10
Minimum Age	150
Variation in Tree Diameter	No
Decadence - dead, broken or deformed tops and/or bole or root rot	Yes
Multiple Tree Canopy Layers	No
DEAD TREES:	
Standing	
Minimum DBH (inches)	8
Number of Trees Per Acre	2
Down	
Minimum Pieces Per Acre	Some
ADDITIONAL ATTRIBUTES:	
Trees in Upper Canopy Are Slow Growing	Yes
QUALITY ATTRIBUTES:	
Above Attributes in Excess of Minimums	Yes
Net Growth Near Zero	Yes
Multiple Tree Canopy Layers	Yes
Multiple Tree Species	Yes
Patchiness	Yes
Many Stages of Decomposition	Yes
Distinctive Crowns in the Upper Canopy	Yes

INTERIOR PONDEROSA PINE – SAF COVER TYPE 237 (Front Range)

Narrative

Front Range ponderosa pine (*Pinus ponderosa* var. scopulorum) forests extend along the east slope of the Rocky Mountains from south of Pueblo on the Pike/San Isabel National Forest north to the Laramie Peak area on the Medicine Bow National Forest. It occurs at elevations between 6,000 and 8,000 feet, lower than the other Rocky Mountain conifers except for pinyon juniper and is well adapted to the warm dry sites at these lower elevations. Although there are stands of pure ponderosa pine, it frequently occurs with Douglas-fir and is often referred to as mixed conifer.

Ponderosa pine is shade intolerant. It occurs in stands that are open-grown, often lower in stocking than other conifers and interspersed with meadows and parks. Fire has played a very important role in shaping ponderosa pine stands. In the past cool, light ground fires would burn through ponderosa pine stands every 8-15 years, removing competing understory vegetation, down dead material and young trees. This resulted in developing irregular shaped stands with even-aged groups of trees varying in size. Patchy distribution of clumps of trees varying in size, age and density are characteristic of naturally occurring ponderosa pine forests.

Where ponderosa pine is the sole species or fire is still part of the ecology, it can be considered the climax species. These stands develop into and remain as open-grown, irregular and uneven-aged stands. Some stands with trees over 450 years do exist but 300 to 350 year old trees are more common.

Where fire has been excluded and the more shade tolerant Douglas-fir is present, ponderosa pine is generally considered seral. The open-grown stands develop an understory of more shade tolerant species such as Douglas-fir. These more shade tolerant species will replace the ponderosa pine if not removed whether by fire or some other means. On sites more marginal in growing conditions it can exist with other species and not be replaced by them.

The lower elevations where ponderosa pine grows are easily accessible and have been highly influenced by man's activities compared to conifers growing at higher elevations. Consequently, most ponderosa pine stands have been harvested for mining timber, lumber and railroad ties and used heavily for recreation. As a result few stands of ponderosa pine over 150 years old exist except in isolated areas that were difficult to access.

Description

Where ponderosa pine is climax and fire has been present, stands will contain clumps of large uneven-aged trees with little understory or down woody material and few if any standing dead trees (fig. 5).

Where fire has been controlled or less frequent there will be old large trees with smaller size trees in the understory giving the stand some structure. Dead down material will be present in varying amounts along with some standing dead trees. In both cases the large old trees will have irregular, open and large branched crowns and have lost their lower branches. The bark will also be thick, have large and somewhat concave

plates and have a lighter color compared to younger trees. Burls and other deformities may be present including fire scars that could be completely healed over.

Where ponderosa pine is seral due to the lack of frequent fires or the site is outside its normal range, stands will contain large trees with a multi-layer canopy and contain various amounts of standing and down dead trees (fig. 6).

It has an understory component of smaller trees including the more shade tolerant Douglas-fir filling in the openings between the groups of older ponderosa pine.

Attributes

The following table lists the tree attributes that are being used to describe Front Range ponderosa pine old growth.

Table 5–Summary of Old-Growth Attributes
Interior Ponderosa Pine – SAF Cover Type 237
(Front Range)

STANDARD ATTRIBUTES	
LIVE TREES:	
Upper Canopy - Older Component	
Minimum DBH (inches)	16
Minimum Number of Trees Per Acre	10
Minimum Age	200
Variation in Tree Diameter	Yes
Decadence - dead, broken or deformed tops and/or bole or root rot	Yes
Multiple Tree Canopy Layers	No
DEAD TREES:	
Standing	
Minimum DBH (inches)	10
Number of Trees Per Acre	2
Down	
Minimum Pieces Per Acre	None
ADDITIONAL ATTRIBUTES:	
Trees in Upper Canopy Are Slow Growing	Yes
Wide Range of Vigor	Yes
QUALITY ATTRIBUTES:	
Above Attributes in Excess of Minimums	Yes
Distinctive Bark	Yes
Down Dead Trees	Yes
Distinctive Crowns in the Upper Canopy	Yes

INTERIOR PONDEROSA PINE – SAF COVER TYPE 237 (Black Hills)

Narrative

Black Hills ponderosa pine (*Pinus ponderosa* var. scopulorum) occurs in Region 2 in the Black Hills of South Dakota and Wyoming and the Bear Lodge Mountains of Wyoming. Here it forms a

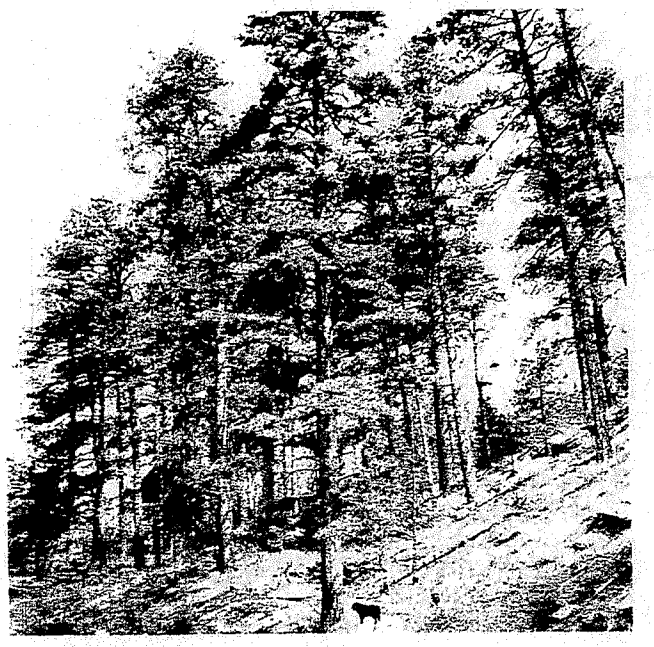


Figure 5. Old-growth ponderosa pine on the Arapaho/Roosevelt NF with little understory.

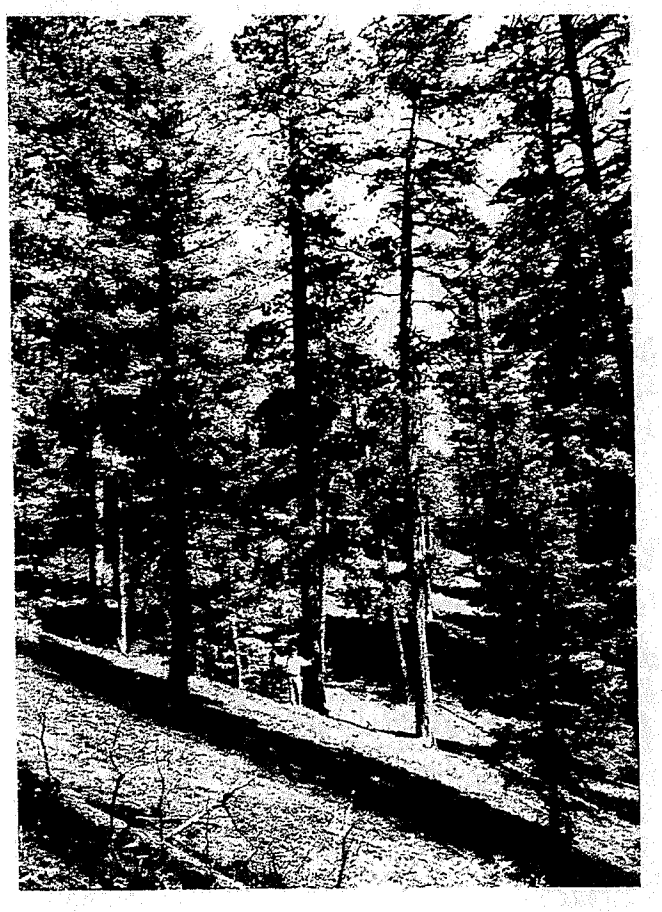


Figure 6. Old-growth ponderosa pine on the Manitou Experimental Forest with some understory and down material.

unique and isolated ecotype of the interior ponderosa pine type. It usually grows in pure stands at 3,600 to 7,000 feet in elevation.

Old photographs show ponderosa pine growing in even-aged clumps or groups of trees apparently before the 1870's. These groups or clumps were separated by grassy areas or parks. This condition dominated the landscape and was similar to that of ponderosa pine in other parts of the Rocky Mountain Region where periodic low intensity fires removed competing vegetation and prevented large numbers of trees from maturing.

Where periodic, low intensity fires were not part of the ecosystem, ponderosa pine grew in a multi-storied and a more homogeneous and denser condition with standing dead and down trees.

A few old ponderosa pine stands, about 350 years old, remain in the Black Hills. Virtually all of the accessible areas have been cut over at least once since the mid 1870's. The open-grown clumps of ponderosa pine have been converted to stands with an older overstory and a young understory through harvesting and intensive management. The amount of stocking has been dramatically increased with the control of fire.

Ponderosa pine is considered a climax species in the Black Hills. After fire or other disturbances, the stand may temporarily be replaced by other plant species but will soon return to ponderosa pine.

Since little old-growth ponderosa pine remains in the Black Hills old growth will have to develop from existing stands. It will take active management to return existing stands to an old-growth condition similar to that which dominated the landscape at pre-settlement.

Where old-growth stands do exist a dense understory of younger trees has developed due to the absence of fire. This is dramatically different from what existed as old growth prior to the 1870's.

Description

Where periodic, low intensity fires have been part of the ecosystem, old-growth stands would consist of clumps or groups of trees with grasses in the openings between the clumps. They would contain large old trees with open branches, irregular and flattened crowns. The clumps or groups of trees would contain little down dead material and few small trees.

Where periodic, low intensity fires have not been part of the ecosystem, old-growth stands would contain large old trees with open branches and irregular crowns. The stands would have multiple canopy layers made up of various aged trees. They would be well stocked with trees and contain standing dead and down trees.

Attributes

The following table lists the tree attributes that are being used to describe Black Hills ponderosa pine old growth.

Table 6–Summary of Old-Growth Attributes
Interior Ponderosa Pine – SAF Cover Type 237
(Black Hills)

STANDARD ATTRIBUTES	
LIVE TREES:	
Upper Canopy - Older Component	
Minimum DBH..(inches)	16
Minimum Number of Trees Per Acre	10
Minimum Age	160
Variation in Tree Diameter	No
Decadence - dead, broken or deformed tops and/or bole or root rot	Yes
Multiple Tree Canopy Layers	No
DEAD TREES:	
Standing	
Minimum DBH (inches)	10
Number of Trees Per Acre	2
Down	
Minimum Pieces Per Acre	None
ADDITIONAL ATTRIBUTES:	
Trees in Upper Canopy Are Slow Growing	Yes
QUALITY ATTRIBUTES:	
Above Attributes in Excess of Minimums	Yes
Distinctive Bark	Yes
Variation in Tree Diameter	Yes
Down Dead Trees	Yes

INTERIOR PONDEROSA PINE – SAF COVER TYPE 237 (Southwest)

Narrative

Southwest ponderosa pine (*Pinus ponderosa* var. scopulorum) occurs in Region 2 in the southwest portion of Colorado, but covers extensive areas of Arizona, New Mexico and southern Utah. As with ponderosa pine elsewhere, it occurs at the lower elevations between 6,000 and 8,000 feet. It reaches maximum development between 7,000 and 7,800 feet where it is a climax forest.

Southwestern ponderosa pine is shade intolerant. It occurs in stands that are open-grown, often poorly stocked and interspersed with meadows and parks. Fire has played a very important role in shaping ponderosa pine stands. In the past, low intensity fires would burn through ponderosa pine stands every 8-15 years, removing competing understory vegetation and down material. This resulted in irregular shaped stands of even-aged groups of trees varying in size, age and density. There is a greater variation in age groups than for ponderosa pine elsewhere as the occurrence of having good moisture, seed production and germination is quite infrequent.

At the lower elevation limits, pinyon-juniper may grow in association with ponderosa pine.

Where ponderosa pine is the sole species or low stocking and frequent fires are still part of the ecosystem, it can be considered a climax species. Some stands with trees over 450 years do exist but more commonly contain trees 300 to 350 years old.

Where periodic low intensity fires have been eliminated from the ecosystem, allowing more shade tolerant species such as Douglas-fir or white fir to survive, ponderosa pine is seral. It will eventually be replaced by more shade tolerant species. The existing open-grown stands are developing understories of Douglas-fir, white fir, and blue spruce with Gambel oak filling in the openings. These old-growth stands will eventually be replaced by these species if fire or some other low intensity disturbance is kept out of the ecosystem.

As with ponderosa pine elsewhere, it has been easy to access and has been heavily used since the mining days of the 1850's. It has been harvested for many things such as mine props, railroad ties, lumber, and firewood. Grasses growing in the open areas provided forage for livestock. Harvesting in the last 30 years or so has generally been by selection and has maintained the uneven-aged structure of old-growth stands. However, with the exclusion of fire, these stands are developing thick understories of Gambel oak, pine and Douglas-fir with a buildup of down dead material, providing excellent conditions for catastrophic fires that could completely eliminate the stands. Ponderosa pine will be replaced by the more shade tolerant species such as Douglas-fir. The dense Gambel oak understory is also difficult to remove, further complicating ponderosa pine being returned to a pre-settlement old-growth condition through management.

Description

Where fire has been present, stands will be climax and contain groups of large, old trees with little understory vegetation or down woody material and few standing dead trees. The age difference of the groups of trees would be large. Where fire is less frequent there will also be smaller size trees in the understory giving the stand some structure with various canopy layers. Dead, down material will be present in varying amounts along with some standing dead trees. In both cases the large old trees will have irregular open, large branched crowns (fig. 7). The bark will be lighter in color, almost yellow, thick and some will likely have basal fire scars.

Where ponderosa pine is seral, generally where fire has been controlled or outside of its optimum elevational range, stands will contain large trees with a multi-layer canopy with various amounts of down, dead material and standing dead trees

Figure 7. Large open-branched crown of an old ponderosa pine tree on the San Juan NF in southwestern Colorado.

Figure 8. An old-growth ponderosa pine stand on the San Juan NF with Douglas-fir and Gambel oak in the understory. Note the horse and rider in the lower left foreground.

(fig. 8). It will have an understory component of smaller trees such as Douglas-fir, blue spruce, white fir and Gambel oak, filling in the openings between the groups of the large older ponderosa pine. Eventually these species will replace ponderosa pine. There would be varying amounts of dead, down material and some standing dead trees. The large old trees will have irregular open, large branched crowns. The bark will be lighter in color, almost yellow and thick or platy.

Attributes

The following table lists the tree attributes that are being used to describe southwest ponderosa pine old growth.

Table 7–Summary of Old-Growth Attributes Interior Ponderosa Pine – SAF Cover Type 237 (Southwest)

STANDARD ATTRIBUTES	
LIVE TREES:	
Upper Canopy - Older Component	
Minimum DBH (inches)	18
Minimum Number of Trees Per Acre	10
Minimum Age	160
Variation in Tree Diameter	Yes
Decadence - dead, broken or deformed tops and/or bole or root rot	Yes
Multiple Tree Canopy Layers	No
DEAD TREES:	
Standing	
Minimum DBH (inches)	10
Number of Trees Per Acre	2
Down	
Minimum Pieces Per Acre	None
ADDITIONAL ATTRIBUTES:	
Trees in Upper Canopy Are Slow Growing	Yes
QUALITY ATTRIBUTES:	
Above Attributes in Excess of Minimums	Yes
Distinctive Bark	Yes
Down Dead Trees	Yes
Distinctive Crowns	Yes

ASPEN - SAF COVER TYPE 217

Narrative

The aspen *(Populus tremuloides)* cover type occurs throughout Region 2 and is associated with both montane and subalpine vegetation. Aspen is found within a broad elevational and moisture gradient occurring on all aspects and slopes, with the most extensive aspen forests occurring between 8,500 and 10,000 feet elevation, similar in elevation to lodgepole pine.

Aspen is the most shade intolerant tree species in the Rocky Mountain Region. Unlike the other major tree species in the Region, most aspen regeneration is by sprouting or suckering rather than by seeding. Aspen does produce seed but requires a bare mineral soil with constant moisture to germinate. Rarely does this occur. Typically aspen regenerates after a major disturbance such as fire, abnormal wind or snow storms, or harvesting by clear felling. In conifer stands where aspen is a minor component, the majority of the regeneration after a stand replacing disturbance can be aspen. Aspen stands can reach an age of 160 or more years but the average life span is probably closer to 125 years.

Like lodgepole pine, aspen is generally considered a seral species. And like lodgepole pine, most aspen stands regenerate following some major stand replacing event such as fire. As the aspen matures, it will be usually replaced by the more shade tolerant Engelmann spruce and subalpine fir and in southwest Colorado also by white fir and Douglas-fir. The stand may still contain some scattered aspen.

In areas where no Engelmann spruce or subalpine fir seed source exists, the aspen stand will not be replaced by another species and can be considered climax. Two things could happen. The stand could reach its maximum life span and the overstory aspen trees rapidly fall with reproduction being sparse as aspen generally requires a major disturbance to initiate abundant sprouting. Or the overstory aspen trees could gradually fall. This path could have two possible results. The stand would not reproduce under itself. Or it would reproduce under itself, creating a multilevel canopy of various tree ages. This condition could continue for many generations. In any case it is difficult to predict which path the stand would take. Any down dead material would quickly decompose.

Description

Many people believe that aspen old growth does not exist. Using a definition of old growth where a stand must be climax to be old growth would eliminate much of the Region's aspen as old growth. However, the seral aspen condition can exhibit some old-growth characteristics. They may not last long in one place but overall in the landscape this old-growth condition can exist for quite sometime.

In a seral condition aspen old growth would be characterized as having a single canopy level of old trees. The aspen would be the overstory which would be closed with an understory of Engelmann spruce and subalpine fir. However, there could be instances where the conifers have become the overstory. Depending on the age of the understory could be a fair amount of structure and variation in tree diameters. There probably would not be much dead down material until the aspen stand began to degenerate. Then the amount of down dead material would accu-

Figure 9. An old-growth climax aspen stand on the Grand Mesa, Uncompahgre and Gunnison NF near Kebler Pass. Stand is approximately 100 years old.

mulate quickly as the aspen stand would degenerate rapidly. It is important to note that if the understory conifers are relatively young, the remaining stand may not be old growth.

Where aspen is considered climax, old growth will again include a canopy of old large aspen trees which would be closed. However, the stand would have little structure as there would be no understory conifers and little down trees or standing dead trees (fig. 9).

Once stand deterioration started, mature stems could die and fall rather quickly, or the process might take some time. An overstory of various levels with trees of various ages and some down dead trees would then exist. This condition might exist over successive generations. However, if no regeneration occurred when stems died, a single canopied, thinly stocked stand containing gaps in the canopy and down dead trees might persist until all the remaining trees had fallen.

Attributes

The following table lists the tree attributes that are being used to describe aspen old growth.

Table 8–Summary of Old-Growth Attributes
Aspen – SAF COVER TYPE 217

STANDARD ATTRIBUTES	
LIVE TREES:	
Upper Canopy - Older Component	
Minimum DBH (inches)	14
Minimum Number of Trees Per Acre	20
Minimum Age	100
Variation in Tree Diameter	No
Decadence - dead, broken or deformed tops and/or bole or root rot	Yes
Multiple Tree Canopy Layers	No
DEAD TREES:	
Standing	
Minimum DBH (inches)	No
Minimum Number of Trees Per Acre	No
Down	
Minimum Pieces Per Acre	No
ADDITIONAL ATTRIBUTES:	
Trees in Upper Canopy Are Slow Growing	Yes
Canopy Closure Greater Than 50%	Yes
QUALITY ATTRIBUTES:	
Above Attributes in Excess of Minimums	Yes
Multiple Tree Canopy Layers	Yes
Multiple Tree Species	Yes
Standing Dead Trees 10" plus DBH	Yes
Down Dead Trees	Yes
Variation in Tree Diameters	Yes

PINYON-JUNIPER – SAF COVER TYPE 239

Narrative

Pinyon pine *(Pinus edulis)* and juniper *(Juniperus scopulorum)* comprise the pinyon-juniper cover type. Pinyon-juniper occurs as a forest type but more often as woodland as the trees are generally shorter than 20 feet and the crowns rarely touch. Pinyon-juniper is found in the southern and western portions of Region 2 extending just into the southern portion of Wyoming. Although pinyon-juniper usually refers to a mixture of both species it may consist of just either one. It occupies the lower and warmest elevations growing from 4,500 to 9,000 feet growing in a semiarid climate. It grows best just below the lower elevational range of ponderosa pine and may also intermix with ponderosa pine.

The stands exhibit considerable diversity in appearance and composition.

Stands may consist of all ages or one age. Dominant trees are often 400 years old. Trees 800 to 1000 years old have been recorded. The trees can be single stemmed or have a sprawling multi-stemmed character. A few stands may have closed canopies with single or both tree species, with little or no understory, but most stands are open-grown with widely scattered trees of one or both species with a wide variety of understory vegetation.

The pinyon-juniper woodland is shade intolerant. It is the climax cover type remaining on the

site until disturbed by fire. When disturbed by fire it will revert to grasses and eventually return to pinyon-juniper woodland.

The pinyon-juniper woodland has been used for grazing, firewood, building material and especially prized for its pine nuts for over 400 years. Few untouched natural stands probably exist. With the reduction in fire and possibly the reduction of competing grasses due to grazing, pinyon-juniper woodland is increasing its area and also tree densities within existing stands.

Description

An old-growth pinyon-juniper stand would be fairly open grown and contain a cohort of dominant old slow growing trees with little or no understory of grass or shrubs. The old trees would be single to multi-stemmed and shorter than the tree species at higher elevations. Being open grown it would be hard to distinguish if more than one tree canopy exists. The old trees would vary in diameter some would have dead branches/limbs including even part of the stem. There would be an occasional dead standing tree. Down dead material would exist and for quite awhile as the climate is semiarid. However a significant amount of the dead material would also exist on the live trees.

Attributes

The following table lists the tree attributes that are being used to describe pinyon-juniper old growth.

Table 9–Summary of Old-Growth Attributes
Pinyon-Juniper –
SAF COVER TYPE 239

STANDARD ATTRIBUTES	
LIVE TREES:	
Upper Canopy - Older Component	
Minimum DRC (inches)	12
Minimum Number of Trees Per Acre	30
Minimum Age	200
Variation in Tree Diameter	Yes
Decadence - dead, broken or deformed tops and/or bole or root rot	Yes
Multiple Tree Canopy Layers	No
DEAD TREES:	
Standing	
Minimum DRC (inches)	10
Number of Trees Per Acre	1
Down	
Minimum Pieces Per Acre	2
ADDITIONAL ATTRIBUTES:	
Trees in Upper Canopy Are Slow Growing	Yes
Canopy Closure Greater Than 35%	Yes

GLOSSARY OF OLD-GROWTH ATTRIBUTES

Forest Cover Type - a descriptive classification of forested land based on present occupancy of an area by tree species. Forest cover types are named after predominant tree species. Predominance is determined by basal area and the name is confined to one (ponderosa pine) or two (spruce-fir) species. The mixed-species/mixed conifer forest cover type is not a forest cover type in itself as defined by SAF but includes several forest cover types.

Attributes - The elements that are measured to determine the classification of a stand as old-growth. They are as follows:

Standard Attributes

1. **Live trees**:

   Upper canopy - a grouping of the taller (dominant and codominant) trees in the stand. For live trees the following attributes of minimum DBH, number of trees per acre, and age refer to the upper canopy of the stand. There must be an upper canopy of trees meeting these minimums for the stand to be considered old growth.

   Minimum DBH - this refers to trees in the upper canopy and not to average DBH for the stand which would generally be lower. It is the minimum DBH that would be required for the stand to be considered old growth. DBH is the diameter of a tree at 4.5 feet from the ground measured on the uphill side. It is generally outside bark. However, if the tree is dead and the bark has fallen then it would not include bark.

   Minimum DRC - this is used for woodland species such as pinyon-juniper. DRC is the diameter at the root collar. The root collar is the region where the root and stem merge.

   Minimum Number of Trees Per Acre - the minimum number of trees per acre in the upper canopy meeting or exceeding the above minimum DBH.

   Minimum Age - the minimum mean age of the trees in the upper canopy meeting or exceeding the above DBH. This would be total tree age. Age is just one part of the equation for a stand to be old growth. A stand could meet the minimum age requirements and may still not be old growth. Age has been included as an attribute to give an idea of what age old growth is thought to begin. It is the attributes that develop with age such as stand structure, dead trees, down material, distinctive bark, net stand growth near zero and tree decadence that need to be considered. Some stands may meet the minimum age require-

ment but have not yet developed these other attributes.

Variation in Tree Diameters - there are trees of various diameters present in the stand. This would allude to an uneven aged stand and/or a stand with more than one tree species. All of which suggest a more structured stand. No diameter ranges have been suggested as little is known what they should be. However it was common consensus that such an attribute is an important characteristic of old growth.

Decadence - this refers to the trees in the upper canopy. The tops or crowns of some of the trees are broken, dead, deformed or have sparse foliage or the stems have rot and/or root rot. These are indicators that the stand could be past maturity and declining. Growth is being succeeded by mortality. The stand is not young and vigorously growing. It could also mean that the stand has been infected with some disease and that's all. But if the above attributes are present in a stand, decadence would be a further indicator of old growth. No values are listed as no data is available on how many trees should have reached senescence.

Multiple Tree Canopy Layers - more than one tree canopy layer or story is present. A canopy layer or story is roughly a horizontal stratum or layer formed by the crowns of trees. A stand can have one to many canopy layers. Generally trees of the same age or species tend to grow to the same height in a stand. This height or horizontal layer formed by the tree crowns would be a canopy layer. The tallest canopy layer representing the most crown cover in a stand would generally be the upper canopy layer.

Dead Trees

Standing - a tree, vertical or near vertical, that is supporting itself or leaning on another tree. A standing dead tree is also called a snag.

> *Minimum DBH* - the minimum diameter at 4.5 feet that a dead tree would be considered for old growth.
>
> *Minimum Number of Trees Per Acre* - the minimum number of dead trees per acre that are equal to or above the minimum DBH to be considered for old growth.

Down - tree that has fallen down, is dead and laying horizontal. May be a whole tree or section of one. All, part or none of the whole tree or section may be touching the forest floor.

Additional and Quality Attributes

Trees in Upper Canopy Are Slow Growing - trees are growing slower than in the past. This indicates the stand has reached maturity and/or may be over-mature, that is past it's peak of maximum growth. Generally the crowns are beginning to flatten and become broader and more open.

Canopy Closure Greater Than 50% - 50% or more of the ground is covered by foliage of the upper canopy in a vertical projection.

Wide Range of Tree Vigor - trees in the stand are growing at various rates from vigorous growth to almost no growth.

Net Growth Near Zero - this applies to the stand as a whole. Basically the amount of new growth is offset by trees dying.

Patchiness - a stand has breaks in the upper canopy level and/or has openings. An opening is defined as an area within the stand that contains vegetation different than the majority of the stand, such as grasses, forbs, shrubs and young trees.

Many Stages of Decomposition - this refers to the dead material either standing or down. The dead material is in various conditions of decay.

Multiple Tree Species - there is more than one tree species in the stand.

Distinctive Bark - some species of trees with age acquire bark characteristics that are much different (distinctive) than when younger and vigorously growing. The bark becomes platy that is it has large patches with deep furrows in between the patches. The bark may also be different in color for some species. Darker for lodgepole pine, reddish for spruce-fir and light tan or yellow for ponderosa pine.

Distinctive Crowns in the Upper Canopy - as they age some species of conifer trees acquire crown characteristics that are much different than when young. The crowns loose their conical shape as growth diminishes with the crowns flattening. Crowns develop holes, become misshapen and foliage develops dead areas. Branching is more open with large branches. Part or all of the crown can die. These characteristics are very evident in older ponderosa pine and lodgepole pine trees. These characteristics can also be attributable to insects or pathogens so the other attributes need to be considered as well.

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Thinning alters avian occupancy in piñon–juniper woodlands

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ABSTRACT

Natural resource managers are increasingly applying tree reduction treatments to piñon–juniper woodlands to meet a range of ecological, social, and economic goals. However, treatment effects on woodland-obligate bird species are not well understood. We measured multiscale avian occupancy on 29 paired (control/treatment) sites in piñon–juniper woodlands in central Colorado, USA. We conducted point counts at 232 stations, 3 times each season in 2014 and 2015. We used hierarchical multiscale modeling to obtain unbiased estimates of landscape and local occupancy (i.e. probability of use) in treated and untreated sites for 31 species. Treatments reduced the occupancy of conifer obligates, including Mountain Chickadee (*Poecile gambeli*), Clark's Nutcracker (*Nucifraga columbiana*), and White-breasted Nuthatch (*Sitta carolinensis*), and increased occupancy of Lark Sparrow (*Chondestes grammacus*) and Mountain Bluebird (*Sialia currucoides*). Occupancy of Virginia's Warbler (*Oreothylpis virginiae*) and Gray Flycatcher (*Empidonax wrightii*), two piñon–juniper specialists, decreased at the landscape scale in treated sites, and Pinyon Jay (*Gymnorhinus cyanocephalus*) occupancy decreased at the local scale. Tree reduction treatments in piñon–juniper woodlands have the potential to reduce habitat quality for a suite of bird species of conservation concern. We suggest that treatments designed to retain higher tree density and basal area will benefit conifer-obligate and piñon–juniper specialist bird species.

RESUMEN

Los gestores de los recursos naturales aplican cada vez con mayor frecuencia tratamientos de raleo de árboles a los bosques de piñón y enebro para alcanzar una serie de objetivos ecológicos, sociales y económicos. Sin embargo, no se comprenden claramente los efectos de los tratamientos para las especies de aves que habitan de forma obligada en los bosques. Medimos la ocupación de las aves a múltiples escalas en 29 sitios pareados (control/tratamiento) en bosques de piñón y enebro en el centro de Colorado, EEUU. Realizamos conteos en puntos en 232 lugares, tres veces en cada estación en 2014 y 2015. Usamos modelos jerárquicos a escalas múltiples para obtener estimaciones no sesgadas de ocupación (i.e. probabilidad de uso) a escala de paisaje y local en sitios tratados y no tratados para 31 especies. Los tratamientos redujeron la ocupación de las especies que habitan en forma obligada los bosques de coníferas, incluyendo a *Poecile gambeli*, *Nucifraga columbiana* y *Sitta carolinensis*; y aumentaron la ocupación de *Chondestes grammacus* y *Sialia currucoides*. La ocupación de *Oreothylpis virginiae* y *Empidonax wrightii*, dos especialistas de los bosques de piñón y enebro, disminuyó a la escala de paisaje en los sitios tratados, y la ocupación de *Gymnorhinus cyanocephalus* disminuyó a escala local. Tres tratamientos de raleo de los bosques de piñón y enebro tienen el potencial de reducir la calidad de hábitat para un grupo de especies de aves de interés para la conservación. Sugerimos que los tratamientos diseñados para retener mayor diversidad de árboles y área basal beneficiarán a las especies de aves que habitan de forma obligada los bosques de coníferas y a las especialistas de piñón y enebro.

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INTRODUCTION

Piñon–juniper woodlands represent a diverse and ecologically important suite of North American forests, but one in which land managers may face particularly complex trade-offs and uncertainties (Romme et al. 2009). These woodlands are the third-largest vegetation type in the U.S. (West 1984, Laylock 1999), encompassing 40 million ha of western North America (Tausch and Hood 2007, Romme et al. 2009). The piñon–juniper vegetation type varies considerably in taxonomic composition (comprised of multiple species of *Juniperus* and *Pinus* subsection *Cembroides*), structure, and disturbance regimes (Jacobs 2008, Romme et al. 2009). Piñon–juniper woodlands have experienced large-scale regional expansions throughout much of the 20th century (Miller and Tausch 2001, Romme et al. 2009), but also abundant human efforts to reduce their extent. Drivers of expansion may include reduced herbaceous fuels and altered fire regimes associated with livestock grazing (Blackburn and Tueller 1970, Miller and Rose 1999, Miller and Tausch 2001, Tausch and Hood 2007), favorable recent climate variation (Blackburn and Tueller 1970, Miller and Rose 1999, Tausch and Hood 2007), woodland expansion and in-filling associated with recovery from older disturbance (Ko et al. 2011), and elevated atmospheric carbon dioxide (Soulé et al. 2004). Because these woodlands lacked commercial timber value (Johnson 1962), beginning in the 1940s, managers conducted large-scale deforestation primarily to provide forage for livestock (Box et al. 1966, Gottfried and Severson 1994). Piñon–juniper removal over large areas (e.g., chaining, cabling, bulldozing, burning, and use of chemical treatments) persisted until the 1970s when emerging concerns over multi-use management led to the implementation of smaller-scale treatments using different techniques (Aro 1971, Gottfried and Severson 1994).

Recently, tree removal in piñon–juniper woodlands has regained momentum and is increasingly applied in many western states to meet a variety of habitat management and fire mitigation objectives. To benefit at-risk sagebrush-obligate wildlife (Baruch-Mordo et al. 2013, Nelson and McAvoy 2013), managers frequently employ mastication, in which piñon and juniper trees are shredded and ground into mulch using heavy machinery (Miller et al. 2008, Frey et al. 2013; Knick et al. 2013, 2014). In the Great Basin, many projects employ hand-cutting with the intention of removing most trees (except old-growth juniper) while maintaining sagebrush cover (Holmes et al. 2017). Since the onset of the Sage Grouse Initiative (www.sagegrouseinitiative.com) in 2010, western juniper removal has increased by 1400% (Holmes et al. 2017). Managers have also thinned or eliminated large areas of piñon–juniper in recent years for fire hazard reduction as well as a variety of other wildlife habitat objectives (Brockway et al. 2002, Schwilk et al. 2009).

Tree removal treatments in piñon–juniper woodlands may have unintended impacts on a wide range of woodland-dependent biota, especially obligate birds already in decline. The piñon–juniper forest type provides nesting habitat for more breeding bird species than any other terrestrial ecosystem in the western U.S. (Balda and Masters 1980), including several at-risk woodland specialists experiencing long-term population declines (Sauer et al. 2017a, 2017b). Piñon–juniper bird communities differ substantially from those of other ecosystems and contribute significantly to landscape-scale avian biodiversity (Paulin et al. 1999, Francis et al. 2011). Among the obligate or near-obligate piñon–juniper birds, the Pinyon Jay (*Gymnorhinus cyanocephalus*) has declined 3.6% annually in western forests since 1966 (Sauer et al. 2017a, 2017b). The Black-throated Gray Warbler (*Setophaga nigrescens*; -1.3%) and Virginia's Warbler (*Oreothylpis virginiae*; -1.4%) have also declined over the last 50 yr (Sauer et al. 2017a, 2017b). Piñon–juniper specialists are listed as species of high conservation concern by Partners in Flight (Colorado Partners in Flight 2000, Gillihan 2006), the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service 2008), and the Intermountain West Joint Venture (Intermountain West Joint Venture 2013).

For bird species dependent on woodland canopy, tree removal treatments reduce habitat, with negative consequences for population persistence. In northwestern Colorado, after chaining treatments, abundance declined for 11 of 16 species studied, with greatest impacts on bark and foliage gleaners, as well as cavity nesters (O'Meara et al. 1981, Sedgwick and Ryder 1986). In the same area, woodland species such as the Black-throated Gray Warbler, Plumbeous Vireo (*Vireo plumbeus*), and Hermit Thrush (*Catharus guttatus*) declined in response to reduced canopy height and cover and lowered stand density (Sedgwick 1987). While forest bird species generally decline after thinning treatments (Bombaci and Pejchar 2016), edge and open habitat or shrubland species may increase, possibly balancing species richness across the landscape (Crow and van Wagtendonk 2010). A recent study showed positive responses by Brewer's Sparrow (*Spizella breweri*), Green-tailed Towhee (*Pipilo chlorurus*), and Vesper Sparrow (*Pooecetes gramineus*) to piñon–juniper removal by hand-thinning in sagebrush (Holmes et al. 2017).

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TABLE 2.

Model averaged landscape (Ψ) and local (θ) occupancy estimates for piñon–juniper birds in central Colorado during 2014–2015. Species are ordered by taxonomy within habitat grouping.

Species	Ψ			θ		
	Control	Mastication	Hand-thin	Control	Mastication	Hand-thin
Piñon–juniper specialists						
Gray Flycatcher	0.96	0.89	0.89	0.90	0.87	0.86
Pinyon Jay	0.58	0.67	0.70	0.84	0.53	0.42
Juniper Titmouse	0.81	0.80	0.79	0.92	0.91	0.89
Virginia's Warbler	0.86	0.76	0.79	0.86	0.83	0.84
Black-throated Gray Warbler	0.99	0.89	0.95	0.93	0.93	0.93
Mature conifer						
Mountain Chickadee	0.90	0.74	0.82	0.87	0.89	0.89
Yellow-rumped Warbler	0.53	0.49	0.50	0.82	0.81	0.85
Open conifer						
Steller's Jay	0.53	0.40	0.89	0.97	0.83	0.97
Clark's Nutcracker	0.84	0.59	0.58	0.92	0.94	0.93
Western Bluebird	0.43	0.43	0.48	0.59	0.67	0.69
Townsend's Solitaire	0.61	0.56	0.59	0.97	0.92	0.91
Chipping Sparrow	0.99	0.99	0.99	0.87	0.88	0.87
Western Tanager	0.95	0.89	0.88	1.0	0.98	0.99
Piñon–juniper shrubland						
Common Nighthawk	0.47	0.99	0.97	0.40	0.42	0.42
Ash-throated Flycatcher	0.75	0.76	0.76	0.92	0.92	0.79
Rufous-beous Vireo	0.94	0.96	0.96	0.95	0.95	0.95
Woodhouse's Scrub-Jay	0.96	0.98	0.96	0.99	0.99	0.69
Bushtit	0.89	0.87	0.87	0.75	0.64	0.62
Blue-gray Gnatcatcher	0.88	0.87	0.87	0.80	0.85	0.84

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	Control	Mastication	Hand-thin	Control	Mastication	Hand-thin
Spotted Towhee	0.99	0.97	0.98	0.97	0.98	0.98
Forest generalists						
Broad-tailed Hummingbird	0.96	0.95	0.94	0.89	0.85	0.84
Northern Flicker	0.61	0.48	0.94	0.96	0.95	0.97
Western Wood-Pewee	0.67	0.64	0.66	0.67	0.61	0.89
White-breasted Nuthatch	0.92	0.70	0.72	0.87	0.84	0.84
American Robin	0.72	0.74	0.86	0.66	0.83	0.85
Edge						
Mountain Bluebird	0.65	0.91	0.54	0.77	0.77	0.79
Lark Sparrow	0.84	0.82	0.84	0.02	0.62	0.11
Brown-headed Cowbird	0.65	0.64	0.65	0.88	0.95	0.95
Generalist						
Mourning Dove	0.92	0.90	0.90	1.0	1.0	1.0
Common Raven	0.70	0.71	0.69	0.95	0.97	0.98
Black-headed Grosbeak	0.93	0.93	0.94	0.88	0.81	0.75

View Large

Detection Probability

The best-fitting structure for 20 of the 31 species included an observer effect (for 8 of these species, it was the only effect). For 18 of these 20 species, more experienced observers had higher detection probabilities than less experienced observers, with the exception of Gray Flycatcher and Bushtit (*Psaltriparus minimus*; Table 3). More experienced observers detected 14 of the 20 species at higher rates than intermediate-level observers. In addition to Gray Flycatcher and Bushtit, intermediate-level observers detected Common Raven (*Corvus corax*), Black-headed Grosbeak, Ash-throated Flycatcher (*Myiarchus cinerascens*), and Western Tanager (*Piranga ludociviana*) at higher rates than the most experienced observers. Survey period appeared in 18 of the 31 species' top detection models. For 9 of these 18 species, detection was lower during mid-June compared to late May and for 13 species detection was lower in late June compared to late May. For 5 species, detection probability was higher after the first round of surveys in May including the highest detectability in early June for Virginia's Warbler and Western Bluebird (*Sialia mexicana*) and highest detection in late June for Common Nighthawk (*Chordeiles minor*), Western Wood-Pewee (*Contopus sordidulus*), and Ash-throated Flycatcher. Treatment appeared in 15 of the top detection models; 7 species (all conifer obligates plus Woodhouse's Scrub-Jay) had greater detection probabilities in controls and 7 species (all aligned more with open habitats) had greater detection probabilities in treatments. Baseline detection probabilities ranged from 0.02 for Common Nighthawk to 0.75 for Spotted Towhee.

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TABLE 3.

Discussion

Treatment Effects on Avian Occupancy

Our results demonstrate that tree thinning treatments alter the occupancy of numerous bird species, and reduce the occupancy of woodland specialists, in piñon–juniper habitats within our study area. Nineteen species had negative coefficients associated with landscape- and/or local-scale occupancy. These findings align with previous studies that document effects of piñon–juniper removal on bird communities both in the short and long term (O'Meara et al. 1981, Sedgwick and Ryder 1986, Crow and van Riper 2010, Bombaci et al. 2017, Gallo and Pejchar 2017). In an experimental study using 28 small treatment patches (1 ha) in the Piceance Basin of northwestern Colorado, woodland or open woodland bird habitat use declined in the first 2 yr following all treatment types (hydro-ax, roller chopping, and chaining) compared to control plots (Bombaci et al. 2017). In our study, 3 conifer obligates (Mountain Chickadee, White-breasted Nuthatch, and Clark's Nutcracker) exhibited strong negative effects of thinning and 5 other species exhibited lower occupancy on treated sites at the landscape scale. Reduced occupancy by these species was linked to substantial reduction in canopy cover and tree density across our study sites (Coop et al. 2017). These findings (Figure 3) suggest that woodland reduction treatments have the potential to affect regional distributions and populations of forest birds (Pavlacky et al. 2012). For the 4 species that showed local-scale declines (Figure 4), thinning treatments may reduce the number of suitable territories in highly managed areas.

Treatments reduced habitat suitability for several forest-obligate species and, simultaneously, enhanced habitat for some generalists and non-forest species. The strongest positive responses to treatments came from Mountain Bluebird at the landscape scale and the Lark Sparrow at the local scale. Both species strongly associate with ecotones (Power and Lombardo 1996, Martin and Parrish 2000) and their habitat structure was likely boosted by thinning treatments, especially where tree retention within the treatment area was prescribed.

Only one species, Pinyon Jay, showed inconsistent occupancy responses to treatments at the 2 different scales we modeled. At the local scale, occupancy was lower on treated sites (Figure 4), whereas at the landscape scale occupancy appeared to be higher in treatments (Figure 3). Pinyon Jays live in cohesive flocks and occupy large home ranges (Balda and Bateman 1971). They generally nest and roost in dense patches of piñon pine, but may forage for and cache pine seeds in relatively open forest stands that can be distant from the roost or nest (Johnson et al. 2011, K. Johnson personal communication). Thus, it may be that Pinyon Jays find treated landscapes suitable for occupancy as long as they contain sufficiently dense forest patches (that could accommodate nesting flocks numbering over 100 individuals). At finer scales of habitat use, Pinyon Jays may abandon treated forest patches that remove too much cover for nesting and roosting or severely reduce piñon pine seed availability.

Piñon–juniper woodland bird occupancy may remain highest in the absence of thinning, or if treatments are conducted, where tree canopy removal is minimized. Previous researchers found that woodland bird species responded negatively to treatments, especially entirely deforested patches (Bombaci and Pejchar 2016). To benefit woodland birds, researchers suggest avoiding clearcuts and, instead, retaining large pines and conifer patches (Gillihan 2006, Gaines et al. 2010). In piñon–juniper stands specifically, woodland birds have been shown to benefit both by preserving relatively high piñon density and also retaining abundant juniper (Balda and Masters 1980, Pavlacky and Anderson 2001, Francis et al. 2011, Gallo and Pejchar 2017). Higher piñon pine density correlates with presence of specialist woodland species that glean insects from bark and foliage or that use cavities as nest sites (Masters 1979; Pavlacky and Anderson 2001, 2004); juniper provides vital canopy nesting substrate for many species (Francis et al. 2011). The thinning levels in masticated units in our study reduced mean canopy cover from 36% in controls to 5% in treatments (Coop et al. 2017). Our results suggest that this level of tree canopy reduction may be below a required threshold for several piñon–juniper specialists and conifer obligates. For example, Parrish et al. (2002) determined that the Black-throated Gray Warbler requires a minimum of 15% canopy cover for nesting habitat.

The duration of tree-removal treatment effects on piñon–juniper bird communities was beyond the scope of our research, but we anticipate they will be extended. Given sparse tree regeneration in treatments, reductions in piñon–juniper canopy cover, density, and basal area within our study area are expected to persist for many decades (Coop et al. 2017). Within 2 yr of treatments in northwestern Colorado, no birds responded positively to small clearcuts and woodland species rarely used treated sites (Bombaci et al. 2017). By contrast, our estimates of avian occupancy occurred over a 1–11 yr post-treatment timeframe. Four decades after chaining treatments, woodlands had lower bird species richness with shrubland species dominating, compared to reference sites where woodland species had higher richness and dominated in abundance (Gallo and Pejchar 2017).

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 Avian Community Composition and Diversity in Pinon-Juniper Woodlands.

We observed 77 bird species during this study, confirming the reportedly high avian diversity of piñon–juniper woodlands (Balda and Masters 1980, Paulin et al. 1999, Bombaci et al. 2017). The most abundant bird species detected matched those recorded in other studies; however, the species richness was higher than that documented in piñon–juniper systems elsewhere across the range of this ecosystem (Balda and Masters 1980, Bombaci et al. 2017, Gallo and Pejchar 2017). The Arkansas River corridor spans a relatively large and geographically complex region including piñon–juniper woodlands of diverse structural and taxonomic characteristics which may have accounted for the high number of species recorded in our study. Alternatively, the piñon–juniper bird community in our study area may reflect a regional hot spot of avian biodiversity.

Study Design and Appropriate Metrics

Resource managers require a clear understanding of how birds and other species respond to management interventions such as woodland tree removal (Kroll et al. 2014). Occupancy measures presence or absence and is relatively easy to quantify compared to abundance (distance sampling or mark/recapture) or avian productivity or performance metrics (nest success, survival). However, occupancy is a relatively coarse metric and can remain unchanged while substantial increases or decreases in abundance take place. Small or null changes in occupancy may mask relatively large and important changes in abundance, survival, or nest success. Therefore, our analysis should be viewed as a conservative means of detecting bird responses, and as such, suggests that thinning treatments may have other impacts on the avian community beyond what we measured in this study. For ubiquitous species, limitations of relying on occupancy to assess treatment effects may be accentuated. For example, occupancy estimates of 4 of the most frequently encountered species in the study—Spotted Towhee (n = 2,595), Black-throated Gray Warbler (n = 1,022), Woodhouse's Scrub-Jay (n = 834), and Chipping Sparrow (n = 806)—were functionally 1.0, yet for Black-throated Gray Warbler and Chipping Sparrow, naive counts of the number of detections indicated that abundance may have been substantially different between treatments and controls, a result that was masked by the coarse nature of occupancy estimation.

Management Implications

Land managers are increasingly conducting tree removal projects in piñon–juniper woodlands to improve habitat for target wildlife species, reduce fire risk, and increase livestock forage production. However, these treatments may catalyze numerous unintended consequences for biodiversity (Holmes et al. 2017). Given that avian assemblages generally encompass a diverse suite of habitat preferences, diets and foraging adaptations, and life histories, any specific management action would not be expected to produce uniform effects across all bird species within a community (Hurteau et al. 2008, Crow and van Riper 2010, Gaines et al. 2010). Our results and those of other studies (Bombaci and Pejchar 2016, Bombaci et al. 2017) demonstrate that conifer removal negatively impacts piñon–juniper specialists and other woodland birds that are vulnerable to habitat loss and fragmentation. Among the most vulnerable are 2 listed as Species of Greatest Conservation Need by Colorado Parks and Wildlife (2015): Virginia's Warbler and Pinyon Jay. Both of these species are experiencing survey-wide, long-term population declines (Sauer et al. 2017a, 2017b), and both responded negatively to piñon–juniper thinning in this study.

In thinned piñon–juniper forests, woodland-obligate birds are most likely to decline, whereas species of open or edge habitats are likely to benefit. To reduce risk to priority conservation woodland birds and piñon–juniper specialists, canopy reduction should only occur when social and/or ecological benefits of treatment outweigh the loss of functional woodland habitat.

Piñon–juniper thinning prescriptions may vary by thinning method and extent of woodland canopy reduction. In our study, managers used 2 thinning treatments, mastication and hand-thinning. We did not detect differences in occupancy between methods. Similarly, other researchers have shown birds do not respond differentially to tree removal methods (rollerchop, mastication, chaining) in piñon–juniper woodlands (Bombaci et al. 2017) or ponderosa pine dry forests where thinning and burning were employed (Hurteau et al. 2008, Gaines et al. 2010). Regardless of the method, to sustain habitat use by forest-obligate birds, thinning should retain more trees. We also encourage managers to explore alternate means to achieve the goals in thinning prescriptions. For example, reductions of surface and ladder fuels may facilitate the retention of larger piñon pines and junipers, at higher densities and with greater canopy cover, that benefit forest-dependent species and still meet fire mitigation objectives.

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A range of disturbances projected to increase under future climates (e.g., Williams et al. 2013), may also fully negate the need for thinning and tree removal in some settings. Strong evidence points to major piñon–juniper woodland losses in some areas, driven by climate-mediated drought, fire, and insect impacts (Breshears et al. 2005, Romme et al. 2009, Clifford et al. 2013, Meddens et al. 2015). Additional information is needed to effectively design and implement treatments in a balanced way to sustain avian biodiversity and achieve other objectives such as fuels reduction

Particularly. Application of thinning treatments, are complex. Decisions Should consider the importance of ecological integrity and conservation of habitat-obligate species

The Salt Lake Tribune

The juniper mystery: Why is a tree that's supposed to withstand drought suddenly dying in southern Utah?

(Courtesy photo | Kate Magargal, University of Utah) Scientists and federal land managers are scrambling to investigate widespread juniper mortality in southeast Utah. Researchers shot this photo last month on Cedar Mesa, where junipers started dying in droves in September after the driest and warmest year on record. Foresters are stumped because juniper is seen as a drought-tolerant species.

By Brian Maffly • Published: November 18
Updated: November 20, 2018

The Utah juniper is considered the West's most drought-tolerant and resilient conifer, withstanding even the worst dry spells while nearby pinyon and ponderosa drop their needles and die.

So it was with some alarm for Kay Shumway, a retired science educator from Blanding, when he noticed yellowing among the juniper on southeastern Utah's Moki Dugway last spring, a time of year when these trees' needles should carry a vivid shade of green as they ramp up their photosynthetic capacity.

"During summer, the dying junipers were such a bright yellow color. It was easy to see. You could look out over the landscape and see thousands of those dying trees. Now a lot have dropped their needles and are becoming a skeleton," said Shumway, a former botanist who has kept himself busy as a nature photographer since retiring from the College of Eastern Utah 20 years ago. "They are dying. They are not going to come back [even if they get] some moisture."

He frequents the Moki Dugway on the southern tip of Cedar Mesa, which provides photogenic views of the buttes and canyons falling toward the San Juan River in what was initially part of Bears Ears National Monument. Shumway has since documented dying juniper in other parts of San Juan County, which is in the midst of a severe drought.

"My first reaction was the drought was causing it. The interesting thing is the pine trees, which are the most susceptible to drought, aren't affected. They are still green and healthy," Shumway said. "There were more and more of [the juniper] turning yellow. By July, I went all over the county, like Mustang Mesa and Alkali Ridge [east of Blanding]. Lo and behold, it was happening there, too."

Shumway has shared his photos and drone footage with academic scientists and forestry officials, who are now scrambling to determine the extent and causes of Utah's latest round of tree mortality.

The Colorado Plateau just experienced its driest year on record. Bluff saw barely 2 inches of precipitation in the water year that ended Sept. 30, about a fourth of normal, according to a National Weather Service database.

But juniper should be able handle a dry year.

"You can't look at the weather data for one year. Often the stress from drought is lagged," said entomologist Liz Hebertson. "We would have to look at conditions back three years, six years, 10 years. When a tipping point occurs might be different between species and even individual trees."

Other factors, working in combination with climate change, are probably at play, according to Hebertson, who works with the U.S. Forest Service's Forest Health Protection program in Ogden.

"It could be the perfect storm of other factors," Hebertson said. "Right now, we have a lot of questions."

Like what is the extent of the mortality? What are the elevation profiles, soil conditions and other environmental characteristics of the affected areas? Are there signs of beetle infestation? Is the wood discolored? Are other tree species showing signs of distress?

Utah is no stranger to conifer die-offs. Dixie National Forest outside Cedar City is ground zero in a beetle epidemic that wiped out spruce, while lodgepole pines are falling victim to beetles in the Uinta Mountains. Ghost forests stretch across basins and plateaus for miles around the West.

Hebertson and her colleagues have been preoccupied this year with a new infestation afflicting forests in northern Utah, where a nonnative beetle, the balsam woolly adelgid, is decimating subalpine fir. This tree mortality is just as troubling as the one unfolding in San Juan County.

In search of clues in the juniper deaths, Hebertson is leading numerous scientists on a tour near Blanding later this month, along with Shumway, who wishes the group came earlier while the yellowed foliage was still hanging from the juniper branches.

"I'm thrilled to know there is some work being done on it," Shumway said. "I'm going to have this group get up close and personal with these trees, though it won't be as easy to see. You can still see there are dying trees all over the place."

Since retiring from CEU (now part of Utah State University), where he served as dean of instruction after helping to establish the Blanding campus in 1977, Shumway has explored Bears Ears country with cameras in tow. While stressed junipers have been documented across the state line in Colorado since last year, Shumway was the first to systematically record the phenomenon in Utah.

Almost more a shrub than a tree, Utah junipers crowd valley bottoms and mesa tops all over the Beehive State. They often mistakenly were called cedars in pioneer times; hence the appearance of the word "cedar" in so many Utah place names.

Junipers, along with the pinyons they usually grow with, are the subject of vegetation-removal operations in the name of habitat improvement. But these trees play a vital ecological role, stitching landscapes together and providing habitat for countless animals.

Widespread loss of junipers would have far-reaching consequences for southern Utah's fragile desert environments.

Among those taking a keen interest is University of Utah biology professor Bill Anderegg, who studies the impact of climate change on forest ecosystems.

"What we see is worrying and it's mind-boggling because juniper has weathered drought. In the drought of 2002, they were not affected," Anderegg said. "To see juniper die on a landscape scale is pretty disturbing. The pinyon don't seem to be dying at the same rate."

A possible factor is the Western cedar borer or cedar bark beetle, insects known to attack juniper. Shumway has pulled bark off dead trees to find larvae munching on the phloem, the critical tree tissues that conduct the fruits of photosynthesis to the root system.

But the presence of beetle larvae is just a clue, not a complete causal picture.

Last year was not only the driest on record for Utah, but it also was the second warmest. Could warm weather be compromising the trees' health, undermining their ability to repel beetle attacks? Or could it be enabling populations of hungry beetles to explode?

"We want to know how bad is the mortality event, how prevalent it is across the Four Corners, pin down the drivers," Anderegg said. "What are the thresholds that push junipers over the edge, and why are those thresholds being crossed now?"

Anderegg has applied for a Forest Service grant to explore such questions. At this stage, however, the extent of juniper mortality has yet to be established, much less why it might be happening, although few doubt climate change is playing some role.

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ORIGINAL RESEARCH
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The Unseen Effects of Deforestation: Biophysical Effects on Climate

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Climate policy has thus far focused solely on carbon stocks and sequestration to evaluate the potential of forests to mitigate global warming. These factors are used to assess the impacts of different drivers of deforestation and forest degradation as well as alternative forest management. However, when forest cover, structure and composition change, shifts in biophysical processes (the water and energy balances) may enhance or diminish the climate effects of carbon released from forest aboveground biomass. The net climate impact of carbon effects and biophysical effects determines outcomes for forest and agricultural species as well as the humans who depend on them. Evaluating the net impact is complicated by the disparate spatio-temporal scales at which they operate. Here we review the biophysical mechanisms by which forests influence climate and synthesize recent work on the biophysical climate forcing of forests across latitudes. We then combine published data on the biophysical effects of deforestation on climate by latitude with a new analysis of the climate impact of the CO_2 in forest aboveground biomass by latitude to quantitatively assess how these processes combine to shape local and global climate. We find that tropical deforestation leads to strong net global warming as a result of both CO_2 and biophysical effects. From the tropics to a point between 30°N and 40°N, biophysical cooling by standing forests is both local and global, adding to the global cooling effect of CO_2 sequestered by forests. In the mid-latitudes up to 50°N, deforestation leads to modest net global warming as warming from released forest carbon outweighs a small opposing biophysical cooling. Beyond 50°N large scale deforestation leads to a net global cooling due to the dominance of biophysical processes (particularly increased albedo) over warming from CO_2 released. Locally at all latitudes, forest biophysical impacts far outweigh CO_2 effects, promoting local climate stability by reducing extreme temperatures in all seasons and times of day. The importance of forests for both global climate change mitigation and local adaptation by human and non-human species is not adequately captured by current carbon-centric metrics, particularly in the context of future climate warming.

Keywords: forest, biophysical effects, temperature, climate policy, deforestation/afforestation

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deforestation and all emitted CO_2 would have had an effect in a given band, but the point of the analysis was to isolate the temperature change caused by forests in a given latitude. We determined the latitudinal sensitivity to warming in response to added CO_2 from a re-analysis of global 2 m temperature data (CERA-20C) obtained from the European Centre for Medium-Range Weather https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/cera-20c. We compared average temperatures from 1901 to 1910 and 2001–2010, by latitude on land only (inadequate land only data for 50–60S and 80–90N; for those, we do not report a locally felt CO_2 effect). Then we divided the temperature change for each latitude band by the change in global temperature over the same period. We scaled the effect of CO_2 emitted by a given 10° latitude band by this sensitivity to represent the influence of non-linear responses such as polar amplification (see **Supplementary Information 1** and **Supplementary Table 2**).

RESULTS

Biophysical Effects of Deforestation on Local Climate: A Broader Context

Our analysis is the first to compare regional scale biophysical and CO_2 impacts from regional scale deforestation but the literature is replete with data on local biophysical impacts. The results for local biophysical effects (100s of m to 100s of km) agree with our results at the regional scale (below). **Figures 2, 3** synthesize local biophysically-driven temperature responses to deforestation, as indicated by forest/no-forest comparisons or forest change over time, from the scientific literature. Satellite and flux tower data indicate that surface temperatures in tropical forests are significantly lower than in cleared areas nearby. On an annual basis, local surface cooling of 0.2–2.4°C has been observed (mean 0.96°C, **Figure 2** and **Supplementary Information 2**). In the temperate zone, satellite studies of land surface temperature (which is more sensitive than the temperature of the air at 2 m) have shown biophysical cooling from forest cover, or biophysical warming from deforestation (0.02–1.0°C, mean of 0.4°C; see **Figure 2** and **Supplementary Information 2**). Both *in situ* and satellite data generally indicate an average annual cooling of under 1°C from boreal deforestation (**Figure 2**). Across latitudinal zones, warming from deforestation is generally greater during the day, and during the dry (hot) season (**Figure 3**).

CO_2-Induced Warming Versus Biophysical Effects on Regional (Local) Temperature From Deforestation by 10° Latitude Band

As expected, the regionally felt effect of regionally (10° band) produced CO_2 is very small compared to any individual biophysical effect or the sum of all non-CO_2 effects (**Figure 4**). These results indicate that the net impact of all non-CO_2 effects is negligible between 20 and 30N. Beyond 30N the local biophysical response to deforestation is cooling. In the broader literature, this latitude of net zero biophysical effect on local temperature is generally between 30 and 40N (**Figure 1**).

Biophysical Effects on Global Temperature From Deforestation by 10° Latitude Band

For most latitudinal bands, the strongest biophysical effect of deforestation is cooling from albedo changes. In the tropics, however, the warming effect of lost roughness is comparable to or greater than the albedo effect (**Figure 5A**). Adding the warming from lost evapotranspiration, the net biophysical effect from tropical deforestation is global warming, as much as 0.1°C contributed each by latitudes 0°–10°S and 0°–10°N. The net biophysical effect of intact tropical forest, therefore, is global cooling; slightly more cooling if BVOCs are also considered (see **Figure 5B**). Roughness effects are generally greater than evapotranspiration effects across latitudes providing a strong counterbalance to albedo effects (Davin and de Noblet-Ducoudré, 2010; Burakowski et al., 2018; Winckler et al., 2019b; **Figure 5A**). Albedo almost balances the combined effect of roughness, evapotranspiration, BVOC and non-linear effects between 20 and 30°N resulting in close to zero net biophysical effect on global temperature (**Figure 5B**). From 30–40°N and northward, albedo dominates, and the net biophysical effect of deforestation is cooling.

CO_2-Induced Warming Versus Biophysical Effects on Global Temperature From Deforestation by 10° Latitude Band

From 30°S to 30°N, the biophysical effect of deforesting a given 10° latitudinal band is about half as great and in the same direction as the CO_2 effect: global warming. Biophysical warming is around 60% as great as warming from released CO_2 in the outer tropics (20°S–10°S and 10°N–20°N) and about 35% as great in the heart of the tropics (10°S–10°N). Biophysical cooling due to deforestation from 30°N to 40°N offsets about 40% of the warming associated with carbon loss from deforestation; from 40°N to 50°N biophysical effects offset 85% of CO_2 effects (**Figure 5B**). Above 50°N, biophysical global cooling is 3–6 times as great as CO_2 induced global warming. The net impact of deforestation (effects of CO_2, biophysical processes and BVOC combined) is warming at all latitudes up to 50N (**Figure 5C**). Thus, from 50S to 50N, an area that encompasses approximately 65% of global forests (FAO, 2020), deforestation results in global warming (**Figure 5C**).

DISCUSSION

All Forests Provide Local Climate Benefits Through Biophysical Effects

Ignoring biophysical effects on local climate means casting aside a powerful inducement to promote global climate goals and advance forest conservation: local self-interest. The

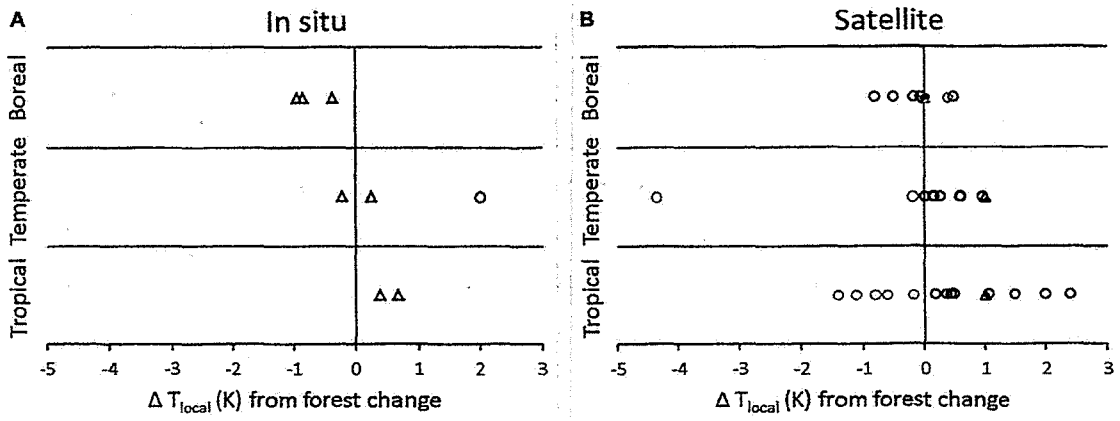

FIGURE 2 | Local average annual temperature change in response to deforestation (black symbols) or afforestation (green symbols) as determined by comparing neighboring forested and open land (space for time approach) or measuring forest change over time in the tropics, temperate and boreal zones, by **(A)** *in situ* or **(B)** satellite based land surface temperature measurements (0 m, triangles) or air temperature measurements (2 m, circles). See **Supplementary Information 2** for data sources.

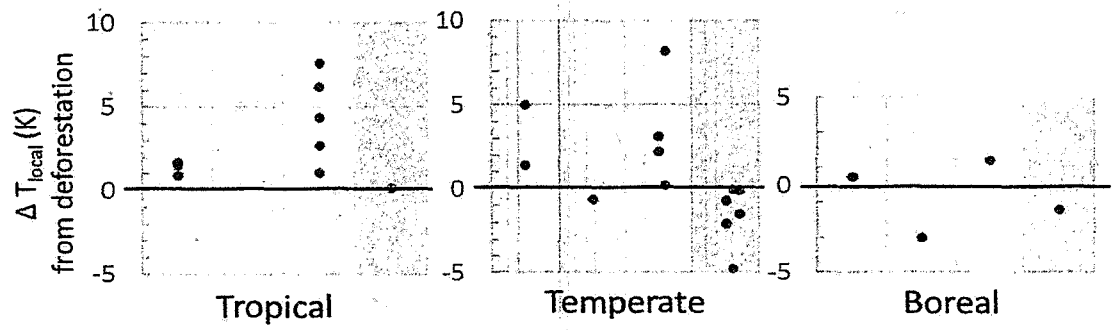

FIGURE 3 | Local temperature change in response to deforestation by season and time of day in the various climate zones as determined by comparing neighboring forested and open land (space for time approach) or measuring forest change over time. Warm/dry season response, averaged over the entire diurnal cycle, in red shading and cold/wet season response in blue shading. Daytime response, averaged over the entire annual cycle, in yellow shading and nighttime response in gray shading. See **Supplementary Information 3** for data sources.

biogeochemical effect of forests tends to dominate the biophysical effect at the global scale because physical effects in one region can cancel out effects in another. Nevertheless, biophysical effects are very important, and can be very large, at the local scale (e.g., Anderson-Teixeira et al., 2012; Bright et al., 2015; Jiao et al., 2017; **Figures 2–4**). The role of forests in maintaining critical habitat for biodiversity is well known, but new research on extinction confirms the role of forests in maintaining critical climates to support biodiversity. Changes in maximum temperature are driving extinction, not changes in average temperature (Román-Palacios and Wiens, 2020). Deforestation is associated with an increase in the maximum daily temperature throughout the year in the tropics and during the summer in higher latitudes (Lee et al., 2011; Zhang et al., 2014). Of course deforestation also increases average daytime temperatures in boreal, mid-latitude and tropical forests (**Figure 3**). The biophysical effects of forests also moderate local and regional temperature extremes such that extremely hot days are significantly more common following deforestation even in the mid- and high latitudes (Vogel et al., 2017; Stoy, 2018). Historical deforestation explains ~1/3 of the present day increase in the intensity of the hottest days of the year at a given location (Lejeune et al., 2018). It has also increased the frequency and intensity of hot dry summers two to four fold (Findell et al., 2017). Local increases in extreme temperatures due to forest loss are of comparable magnitude to changes caused by 0.5°C of global warming (Seneviratne et al., 2018). Forests provide local cooling during the hottest times of the year anywhere on the planet, improving the resilience of cities, agriculture, and conservation areas. Forests are critical for adapting to a warmer world.

Forests also minimize risks due to drought associated with heat extremes. Deep roots, high water use efficiency, and high surface roughness allow trees to continue transpiring during drought conditions and thus to dissipate heat and convey moisture to the atmosphere. In addition to this direct cooling, forest ET can influence cloud formation (Stoy, 2018), enhancing albedo and potentially promoting rainfall. The production of BVOCs and organic aerosols by forests accelerates with

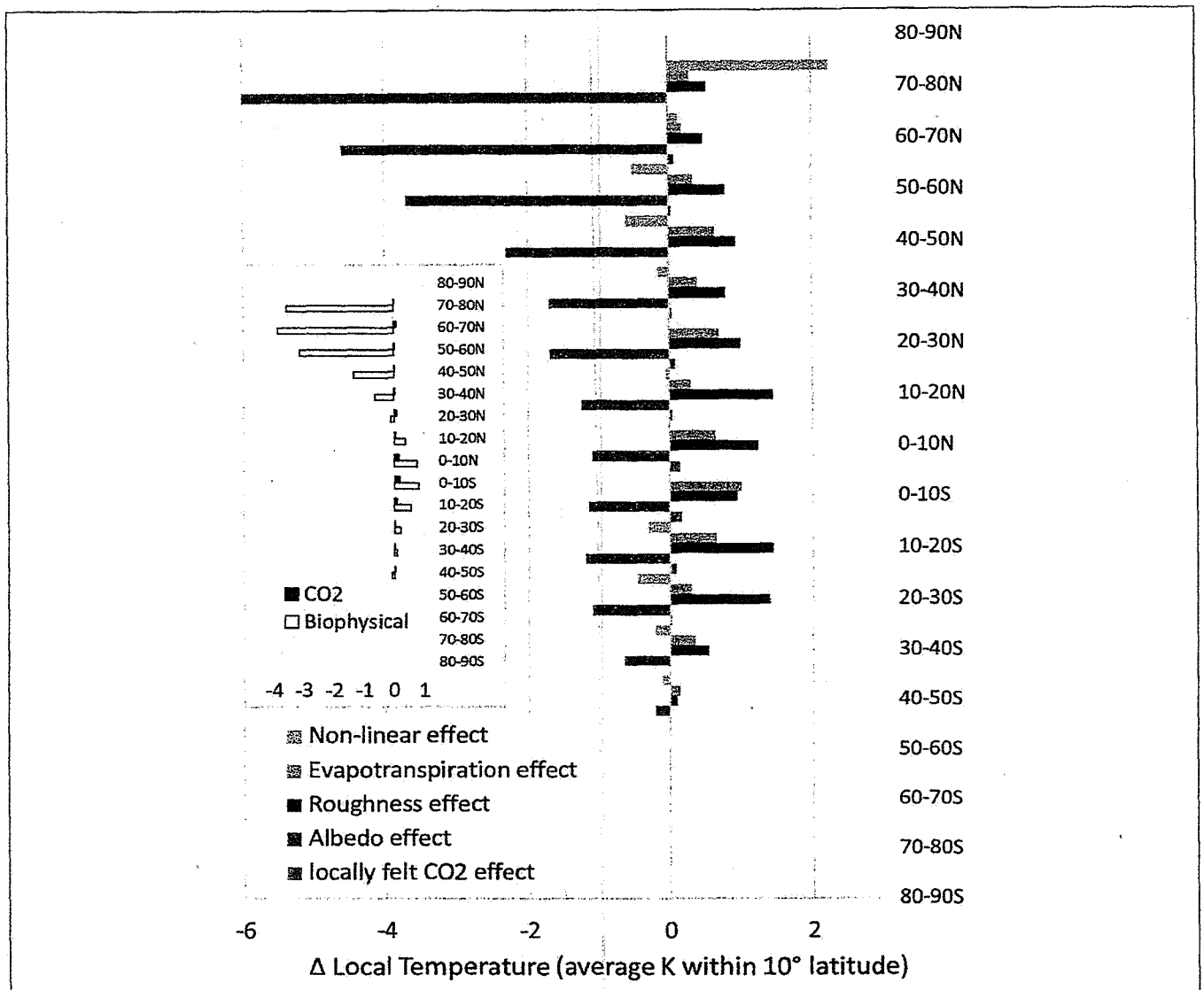

FIGURE 4 | Effect of complete deforestation on local annual temperature by climate factor, averaged across the land surface within a 10° latitudinal band. Complete deforestation was implemented globally and analyzed by 10° latitudinal bands (Davin and de Noblet-Ducoudré, 2010). The CO_2 effect was determined from total aboveground biomass in each 10° band after Walker et al. (2020) and scaled by CERA-derived sensitivity by latitude. Inset distinguishes the sum of all local biophysical effects from local CO_2 effects.

increasing temperatures, enhancing direct or indirect (cloud formation) albedo effects. This negative feedback on temperature has been observed to counter anomalous heat events in the mid-latitudes (Paasonen et al., 2013).

Some Forests Provide Global Climate Benefits Through Biophysical Effects

Disregarding the biophysical effects of specific forests on global climate means under-selling some forest actions and over-selling others. The response to local forest change is not equivalent for similar sized areas in different latitudes. According to Arora and Montenegro (2011) warming reductions per unit reforested area are three times greater in the tropics than in the boreal and northern temperate zone due to a faster carbon sequestration rate magnified by year-round biophysical cooling. Thus, considering biophysical effects significantly enhances both the local and global climate benefits of land-based mitigation projects in the tropics (see **Figures 4, 5**).

Constraints on Forest Climate Benefits in the Future

Climate change is likely to alter the biophysical effect of forests in a variety of ways. Deforestation in a future (warmer) climate could warm the tropical surface 25% more than deforestation

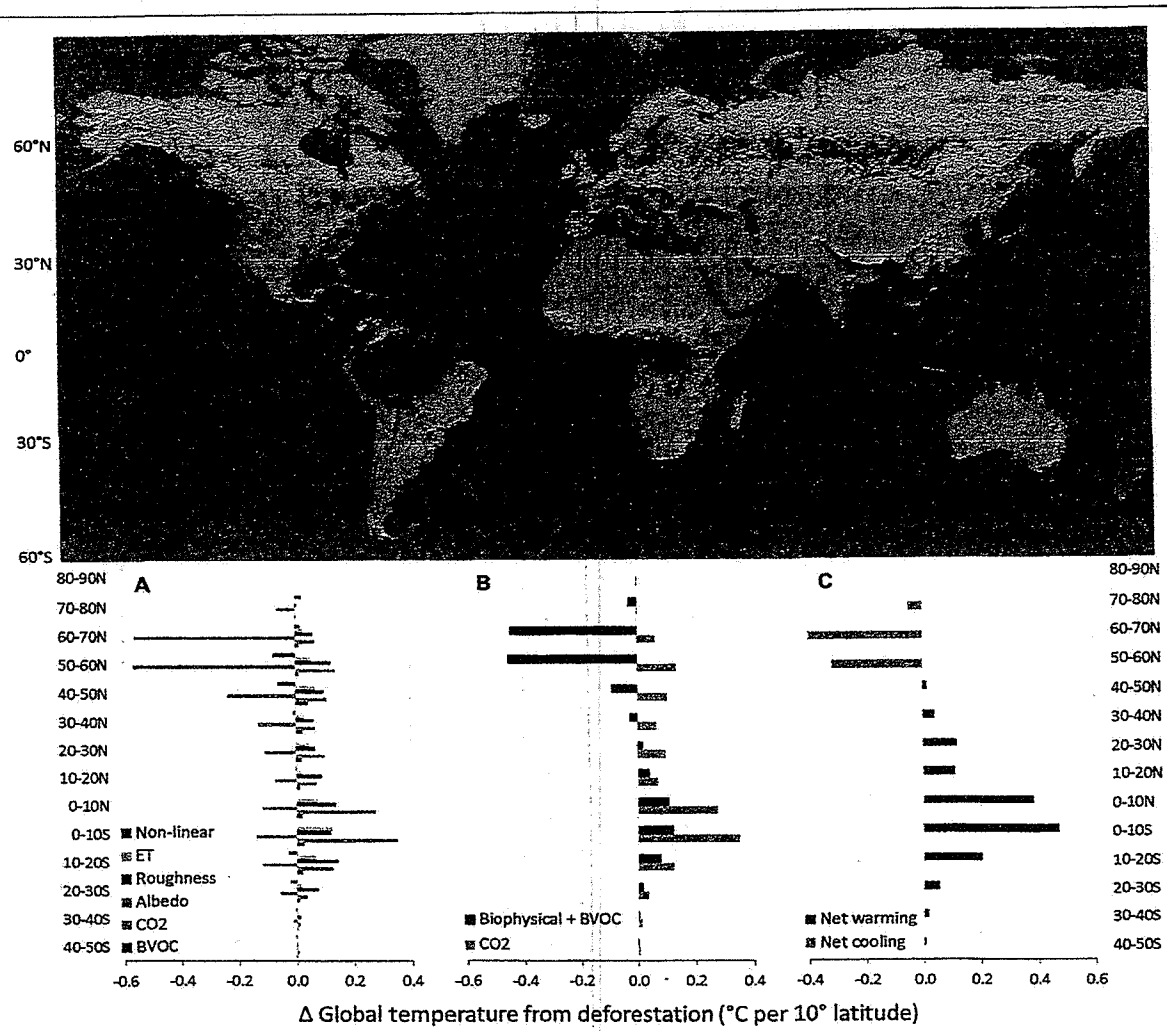

FIGURE 5 | Effect of complete deforestation on global temperature by 10° band of latitude. **(A)** Contribution to global temperature change by climate forcing factor. Biophysical factors are from Davin and de Noblet-Ducoudré. 2010, area-weighted. BVOC effects are estimated relative to albedo effects based on Scott et al., 2018. CO_2 effect is based on aboveground live biomass for each 10° latitudinal band following Baccini et al., 2017 and Walker et al., 2020. **(B)** Net biophysical and BVOC effect versus CO_2 effect. **(C)** Cooling or warming effects of deforestation by 10° latitudinal band (BVOC included). "Forests as mountains" map of aboveground biomass carbon in woody vegetation ca. 2016 courtesy of Woodwell Climate Research Center and shaded to indicate where deforestation results in net global warming. See **Supplementary Information 1** for details.

in a present-day climate due to stronger decreases in turbulent heat fluxes (Winckler et al., 2017b). In a warmer climate, reduced snow cover in the temperate and boreal regions will lead to a smaller albedo effect and thus less biophysical cooling with high latitude deforestation. In addition to snow cover change, future rainfall regimes will affect the response of climate to changes in forest cover (Pitman et al., 2011) as rainfall limits the supply of moisture available for evaporative cooling. Increases in water use efficiency due to increasing atmospheric CO_2 may reduce evapotranspiration (Keenan et al., 2013), potentially reducing the local cooling effect of forests and altering atmospheric moisture content and dynamics at local to global scales. Future BVOC production may increase due to warming and simultaneously decline due to CO_2 suppression (Lathière et al., 2010; Unger, 2014; Hantson et al., 2017). The physiological and ecological responses of forests to warming, rising atmospheric CO_2 and changing precipitation contribute to uncertainty in the biophysical effect of future forests on climate.

Forest persistence is essential for maintaining the global benefits of carbon removals from the atmosphere and the local and global benefits of the physical processes described above. Changing disturbance regimes may limit forest growth and regrowth in many parts of the world. Dynamic global vegetation models currently show an increasing terrestrial carbon sink in the future. This sink is thought to be due to the effects of fertilization by rising atmospheric CO_2 and N deposition on plant growth as well as the effects of climate change lengthening the growing season in northern temperate and boreal areas (Le Quéré et al.,

2018). Free-air carbon dioxide enrichment (FACE) experiments often show increases in biomass accumulation under high CO_2 but results are highly variable due to nutrient limitations and climatic factors (Feng et al., 2015; Paschalis et al., 2017; Terrer et al., 2018). Climate change effects on the frequency and intensity of pest outbreaks are poorly studied, but are likely to be significant, particularly at the margins of host ranges. Warmer springs and winters are already increasing insect-related tree mortality in boreal forests through increased stress on the tree hosts and direct effects on insect populations (Volney and Fleming, 2000; Price et al., 2013).

Climate also affects fire regimes. In the tropics, fire regimes often follow El Niño cycles (van der Werf et al., 2017). As temperatures increase, however, fire and rainfall are decoupled as the flammability of forests increases even in normal rainfall years (Fernandes et al., 2017; Brando et al., 2019). Fire frequency is also increasing in some temperate and boreal forests, with a discernable climate change signal (Abatzoglou and Williams, 2016). Modeling exercises indicate that this trend is expected to continue with increasing damage to forests as temperatures rise and fire intensity increases (De Groot et al., 2013).

In addition to changes induced by warming, continued deforestation could severely stress remaining forests by warming and drying local and regional climates (Lawrence and Vandecar, 2015; Costa et al., 2019; Gatti et al., 2021). In the tropics, a tipping point may occur, potentially resulting in a shift to shorter, more savannah-like vegetation and altering the impact of vast, previously forested areas on global climate (Nobre et al., 2016; Brando et al., 2019). Some of these processes are included in climate models and some are not. The gaps leave considerable uncertainty. Nevertheless, a combination of observations, models, and theory gives us a solid understanding of the biophysical effects of forests on climate at local, regional and global scales. We can use that knowledge to plan forest-based climate mitigation and adaptation.

Mitigation Potential of Forests: Byond the Carbon/Biophysical Divide

If instead of focusing on the contrast between biophysical and biochemical impacts of forests and forest loss, we focus on the potential of forests to cool the planet through both pathways, another picture emerges. By our conservative estimate, through the combined effects on CO_2, BVOC, roughness and evapotranspiration, forests up to 50°N provide a net global cooling that is enough to offset warming associated with their low albedo. Given the most realistic pathways of forest change in the future (not complete deforestation of a 10° latitudinal band, or an entire biome), global climate stabilization benefits likely extend beyond 50°N. For the 29% of the global land surface that lies beyond 50°N, forests may warm the planet, but only as inferred from assessing the effects of complete zonal deforestation with all the associated, and powerful, land-ocean feedbacks spawned by largescale forest change in the boreal zone. Forests above 50°N, like forests everywhere, provide essential local climate stabilization benefits by reducing surface temperatures during the warm season as well as periods of extreme heat or drought. Indeed, they also reduce extreme cold.

Creating a fair and effective global arena for market-based solutions to climate change requires attention to all the ways that forests affect climate, including the biophysical effects. Future metrics of forest climate impacts should consider the effects of deforestation beyond CO_2. Only recently have modelers begun to include BVOC. Doing so means that the albedo of intact forests (or the atmosphere above them) is higher due to the creation of SOA and subsequent cloud formation. Modeled deforestation thus results in less of a change in albedo, reducing the biophysical cooling effect. Similarly, accounting for the ozone and methane effects of BVOC reduces the biogeochemical warming from deforestation (Scott et al., 2018). In addition, especially in the tropics, deforestation reduces the strength of the soil CH_4 sink (Dutaur and Verchot, 2007). While a small change relative to the atmospheric pool of CH_4 (the second most important greenhouse gas), the loss of this sink is equivalent to approximately 13% of the current rate of increase in atmospheric CH_4 (Saunois et al., 2016). We already have the data (**Figure 5**) to begin conceptualizing measures to coarsely scale CO_2 impacts of forest change by latitude. Finer resolution of latitude, background climate (current and future) and forest type would improve any such new, qualifying metric for the climate mitigation value of forests.

The role of forests in addressing climate change extends beyond the traditional concept of CO_2 mitigation which neglects the local climate regulation services they provide. The biophysical effects of forest cover can contribute significantly to solving local adaptation challenges, such as extreme heat and flooding, at any latitude. The carbon benefits of forests at any latitude contribute meaningfully to global climate mitigation. In the tropics, however, where forest carbon stocks and sequestration rates are highest, the biophysical effects of forests amplify the carbon benefits, thus underscoring the critical importance of protecting, expanding, and improving the management of tropical forests. Perhaps it is time to think more broadly about what constitutes global climate mitigation. If climate mitigation means limiting global warming, then clearly the biophysical effects of deforestation must be considered in addition to its effects on atmospheric CO_2. We may further consider whether mitigation is too narrow a scope for considering the climate benefits provided by forests. Climate policy often separates mitigation from adaptation, but the benefits of forests clearly extend into both realms.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

DL conceived the presented idea. All authors helped perform the computations, discussed the results, and contributed to the final manuscript.

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Cover photos
Blue-gray Gnatcatcher (top)—Tony Leukering, RMBO
Landscape—Glenn Giroir, RMBO
Black-chinned Hummingbird (bottom)—© Brian Small / www.briansmallphoto.com

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Sharing the Land with Pinyon-Juniper Birds

Other Pinyon-Juniper Birds

Western Scrub-Jay ✓

This species inhabits shrubby habitats, especially oaks, but is also found regularly in pinyon-juniper woodlands. It is nonmigratory, but individuals may wander widely in winter. It adapts well to suburbia and is not very sensitive to human disturbance. Like other jays, this species is omnivorous, eating invertebrates, small vertebrates, small fruits, acorns, and pine nuts (Curry et al. 2003).
What you can do: Preserve oak stands, especially mature mast-producing stands.

Bushtit

The Bushtit is a resident of open habitats with conifers, including pinyon-juniper woodlands. It is comfortable in suburban settings. It builds a pendulous, gourd-shaped nest of spider webs and plant material. It gleans insects and spiders from plant foliage, especially from pinyons (Sloan 2001).
What you can do: Reduce or eliminate the use of insecticides.

Bewick's Wren ✓

This species prefers dense shrubs mixed with open woodland such as pinyon-juniper. It picks invertebrates from vegetation or the ground. It is a cavity-nester, and will accept artificial nest boxes (Kennedy and White 1997).
What you can do: Preserve mature stands, especially junipers, which tend to have more cavities. Reduce or eliminate the use of insecticides. Install nest boxes with floor dimensions of 4" x 4" and an entrance hole of 1.25" diameter, 4-6" above the floor; mount 5-10' high on a tree. Note: nest boxes may not be successful where House Wrens are present, as they may usurp Bewick's Wrens.

Blue-gray Gnatcatcher ✓

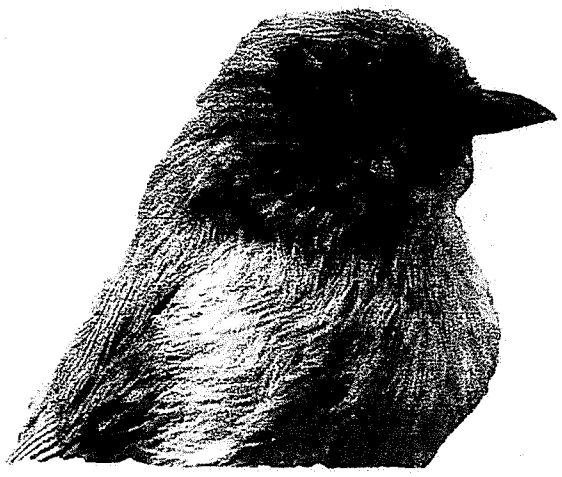
This species inhabits pinyon-juniper woodlands and shrublands. It eats small invertebrates gleaned from vegetation. Its open cup nest leaves it susceptible to brood parasitism by the Brown-headed Cowbird; in some areas the rate is quite high (Ellison 1992).
What you can do: Take steps to reduce Brown-headed Cowbird parasitism (see page 10). Reduce or eliminate the use of insecticides.

Mountain Bluebird

The Mountain Bluebird prefers open woodlands and forest edges. It consumes insects, spiders, and small fruits. A cavity-nester, it will use artificial nest boxes (Power and Lombardo 1996).
What you can do: Preserve trees with cavities, especially at forest or woodland edges or in open woodlands. Preserve standing dead trees as foraging perches. Reduce or eliminate the use of insecticides. Retain fruiting shrubs such as currants or elderberries. Install nest boxes to encourage nesting (see nest box dimensions for Western Bluebird on page 29); place nest boxes at least 1/4 mile (400 m) from buildings to discourage House Sparrows.

Chipping Sparrow

This species inhabits coniferous forests, including pinyon-juniper woodlands. In particular, it prefers open woodlands with little or no shrub cover, and often places its flimsy cup nest in trees or shrubs at the edge of a woodland. It feeds on insects and small seeds, which it collects from the ground. This is a frequent host to the Brown-headed Cowbird (Middleton 1998).
What you can do: Take steps to reduce Brown-headed Cowbird brood parasitism (see page 10).



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Female Bushtit