Virgin Forests and Endangered Species, Northern Spotted Owl and Mt. Graham Red Squirrel

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The dwindling supply of virgin forests in the United States has endangered many species dependent on old-forest conditions. Most of the remaining virgin forests are in western states and are highly fragmented by timber harvesting. The controversies surrounding the Mt. Graham red squirrel and the northern spotted owl illustrate the synergetic development of our scientific, social, and legal responses to species conservation. A cluster of telescope observatories has been built within the red squirrel's mountaintop habitat after a congressional exemption abbreviated regulatory review. In the Pacific Northwest, an involved legal and political controversy over the spotted owl has halted most logging and has prompted the development of a regional ecosystem management plan. The two cases exemplify how difficult it is to achieve effective conservation or public consensus if the debate is narrowed by the legal procedures of the Endangered Species Act to a single species issue. The move from species to ecosystem management in the spotted owl controversy provides a model for more effective conservation of our forests and their endangered wildlife.

I. INTRODUCTION

> "[Man] fells the forests and drains the marshes. . . The wilds become villages, and the villages towns. The American, the daily witness of such wonders, does not see anything astonishing in all this. This incredible destruction, this even more surprising growth, seem to him the usual progress of things in this world. He gets accustomed to it as to the unalterable order of nature."
>
> Alexis de Tocqueville (1831)

Virgin forests, which covered about 385 million ha, or 50% of the contiguous United States before the arrival of Europeans, were viewed by early settlers as both an inexhaustible bounty of timber and an obstacle to civilized settlement and agriculture. The cutting and clearing of the American landscape has since occurred with every increasing energy. Most of the remaining virgin forests in the lower 48 states are found in three regions that were among the last areas to be settled as Europeans migrated west: northern California and western

Oregon and Washington. By one estimate made in 1991, these remnant virgin forests total just 1.53 million ha, or less than 0.4% of the original forest cover.

A. Virgin Forests

Virgin forests, by definition, are forest stands that have not been disturbed by human activity, in particular timber harvesting. In areas with good growing conditions, several centuries of undisturbed growth produce the large trees, snags, and down logs called old growth. Virgin forests, however, also include forests that never develop old-growth characteristics because they grow at high elevation, in nutrient-poor soil, or in an area frequently disturbed by fire, wind, insects, or pathogens. [*See* FOREST PATHOLOGY.]

To a historical observer the cutting of virgin forests may not appear so dramatic because many areas of virgin forest have been reforested. While urban and suburban growth have diminished forests in some areas, other regions, such as rural New England and the Southeast, have increased forest cover on abandoned agricultural lands. What has changed is the structure, composition, and function of these forests, the attributes that distinguish virgin from second-growth forests. [*See* FOREST STAND REGENERATION, NATURAL AND ARTIFICIAL.]

Regardless of tree size, the stand structure of virgin forests differs from second growth by having more foliage layers, more dead wood, and gaps in the canopy cover where trees have died (Fig. 1). The composition of most virgin forests has a greater diversity of tree and understory species, much more variety in the size of woody structures, and higher spatial heterogeneity than second growth. A key functional difference between the two forest types is that virgin forests provide dead wood that is important for nutrient cycling, soil and fungal processes, and provide habitat for many birds, small mammals, amphibians, and insects. [*See* NUTRIENT CYCLING IN FORESTS.]

In contrast, the structure, composition, and function of second-growth forests are managed more for economical than ecological products. To this end, the ecosystem is simplified to increase wood production. In its extreme form, second-growth forests become even-aged, single-species plantations. Forest succession is truncated into repeat rotations of young, fast-growing trees. Most timber plantations are cut when the trees are between 40 and 90 years old, as they approach the peak of their mean annual increment in wood volume. These forests never develop the large, tall trees, complex canopies, or accumulation of dead woody material common in old forests. Land owners cannot afford to manage forests for the long-growing period needed to produce large-diameter trees, snags, and down logs. For these reasons, the cutting of virgin forests is not the harvest of a renewable resource, it is the replacement of one kind of forest ecosystem with another of very different character.

Although it is not considered profitable to create old-forest conditions, existing virgin forests are highly prized by the timber industry. Such forests typically contain a higher volume of wood per hectare than second growth and much of it is of very high quality. Futhermore, there are no management costs and stands are ready to harvest. America's large logging companies have migrated from New England to the West Coast in step with a retreating line of virgin forests.

As the forests were cut in the eastern and central states, animals that threatened livestock and those dependent on virgin forest conditions were gradually extirpated. By 1855, Henry David Thoreau described New England as an "emasculated country" where "the nobler animals have been exterminated." While Thoreau's lament was written more than a century ago, forest species extinction has become a general public concern only recently when most of the remnant virgin forest is pressed into a sliver of land against the Pacific Ocean.

B. Species Endangerment

The cutting of virgin forests is not detrimental to all forest wildlife. In fact, species that prefer open or brushy areas, such as some songbirds, may increase as old forests are cut. Other "edge" species, such as deer (*Odocoileus* spp.) and elk (*Cervus* spp.), thrive in forests that have a combination of young and old stands for browsing and bedding down.

FIGURE 1 Sunlight from a gap in a virgin forest illuminates a stand with large trees, high understory species diversity, and a complex canopy structure.

The species threatened by the cutting of virgin forests are those dependent on interior, old-forest conditions. These are often rarely seen, nongame animals that have developed specialized niches associated with virgin forests. Other species are dependent on virgin forests simply because they require forest habitat free of human disturbance. For example, in the Pacific Northwest, Roosevelt elk (*C. elaphus*) populations have increased on the Olympic Peninsula as clearcuts adjacent to the Olympic National Park have created more edge habitat. In the same area, populations of the Olympic Torrent salamander (*Rhyacotriton olympicus*) are believed to have fallen sharply because of stream siltation and warmer water temperatures related to logging of headwater streams.

Two laws constitute the principal legal protection provided threatened species. The Endangered Species Act (ESA) of 1973 charges the U.S. Fish and Wildlife Service (FWS) with evaluating species for listing using only biological considerations in its review. If a species is listed, all actions that might jeopardize the species or its habitat must be reviewed. The National Forest Management Act (NFMA), passed in 1976, charges the U.S. Forest Service to manage habitat "to maintain viable populations of existing native and desired non-native vertebrate species." The ESA applies to all species, including plants and invertebrates. Language in sections of the NFMA implies that plant diversity and invertebrate communities should be considered, but there is no consensus on this interpretation. [*See* WILDLIFE MANAGEMENT.]

The ecology and politics of species endangered by the loss of virgin forests are as different as the individual animals involved (Table I). While the biology and management of each species are unique, a common pattern in all of the controversies is the strain of conflicting public demands and wildlife needs on an increasingly rare ecosystem, virgin forests.

The most common causes of virgin forest clearing are development and timber harvesting. Two different cases illustrate each of these pressures on virgin forests: The Mt. Graham red squirrel (*Tamiasciurus hudsonicus grahamensis*) in the Pinaleno Mountains of Arizona and the northern spotted owl (*Strix occidentalis caurina*) in the Pacific Northwest.

The red squirrel conflict is an interesting example of development in the singular, isolated habitat of

TABLE I

A Sample of Species Associated with Virgin Forests That Have Been Listed as Threatened or Endangered by the U.S. Fish and Wildlife Service[a]

Scientific name	Common name	Habitat
Campephilus principalis	Ivory-billed woodpecker	Bottomland hardwoods and old-growth long-leaf pine
Dendroica chrysopaira	Golden-cheeked warbler	Mature mixed forests of oak and Ashe juniper in Texas
Felis concolor coryi	Florida panther	Undisturbed dense, subtropical forests of Florida
Felis concolor couguar	Eastern cougar (possibly extinct)	Undisturbed forests of North Carolina and the Virginias
Glaucomys sabrinus coloratus and *fuscus*	Carolina and Virginia northern flying squirrel	Old-growth transition zone between conifer and hardwood forests
Phaeognathus hubrichti	Red hills salamander	Ravine slopes in mature hardwood forests of Alabama
Picoides borealis	Red-cockaded woodpecker	Old-growth pine stands in southeastern states
Plethodon nettingi	Cheat Mountain salamander	Spruce/birch forests of West Virginia
Rangifer tarandus caribou	Woodland caribou	In winter, old-growth cedar/hemlock forests of northern Washington– Idaho border into Canada
Sciurus niger cinereus	Delmarva Peninsula fox squirrel	Undisturbed forest/shrub ecotone in Maryland and Delaware
Strix occidentalis lucida	Mexican spotted owl	Old-growth forests of Southern Utah and Colorado, Arizona, New Mexico, and northern Mexico

[a] Many more species on the candidate list await the agency's review.

a species with a small population. If the scale and economics involved are smaller than those of the spotted owl controversy, the issue highlights the limits of current regulations for protecting species when the impacts of development are unknown. In contrast, few have questioned the effects of logging on spotted owls. Instead the issue shows how conflict over the scale, cost, and methods of conserving a species can escalate to a debate over the fundamental management of a region's forest ecosystems. The stories of these two species point out the limits of our ability to conserve species and possible remedies to improve conservation efforts in the future.

II. THE MT. GRAHAM RED SQUIRREL AND ITS ISLAND FOREST HABITAT

At the end of the last ice age, about 12,000 years ago, the Sonoran Desert advanced into the Arizona lowlands and mountaintops became a refugium for the spruce/fir forests that once covered the surrounding valleys. In these mountaintop islands of Pleistocene forest, a number of plants and animals evolved into distinct subspecies. The Mt. Graham red squirrel, a subspecies of the red squirrel common throughout North America, is endemic to a small subalpine zone in the Pinaleno Mountains of southeastern Arizona. Mt. Graham also contains the southern extreme of the Engelman spruce/ corkbark fir (*Picea engelmanii*/ *Abies lasiocarpa* var. *arizonica*) association, as well as the northern extreme of several rare plants and reptiles from Mexico's Sierra Madre Occidental.

A. Habitat and Population

The Mt. Graham red squirrel is a small grayish-brown arboreal rodent that weighs about 230 g (Fig. 2). The squirrel's main diet is conifer cone seeds and fungal fruiting bodies (both "mushrooms" and "truffles"). Squirrels show a strong preference for the stand structure, microclimate, and species diversity found in the old-growth spruce/fir and Douglas-fir (*Pseudotsuga menziesii*) forests above 2800 m elevation. The high elevation forests have closed canopies that keep the understory cool, damp, and dark. These conditions may increase fungal productivity and prevent cones stored in squirrel middens from drying out and losing their seeds. The closed canopy may also

FIGURE 2 A Mt. Graham red squirrel. [Photograph courtesy of Bob Miles, Arizona Game & Fish Department. Used with permission.]

afford overhead protection from raptors and a network of connected branches for safe movement through the forest. Large snags common in the spruce/fir forest provide nesting spots and additional cone storage areas. Logs are used by the squirrel as safe runways and subnevean cone storage sites. The high conifer diversity in the combined Douglas-fir and spruce/fir zone may be particularly important because a poor cone crop is unlikely to occur in all species in the same year. These conditions are only found in the isolated, mountaintop virgin forests. Few red squirrels have been found in lower-elevation Ponderosa pine (*Pinus ponderosa*) forests where canopy cover is low and conditions are drier and warmer.

The Mt. Graham red squirrel is susceptible to extreme population swings and extinction because it occupies a single, isolated habitat. Before the arrival of Europeans, the population may have numbered about 1000 individuals. In the spring of 1990 the population dipped to 132 squirrels, but by the fall of 1993, a census of middens estimated 375 squirrels. Scientists believe that most of the year-to-year fluctuation is due to the abundance of the annual cone crop. The concentration of the squirrel in a small area also makes it susceptible to any habitat changes. For example, a fire in the mid-1970s on Mt. Graham's west peak may have caused the extirpation of the local squirrel population by isolating the subpopulation and destroying available habitat. Given these conditions, some biologists suggest that management should not focus on achieving a stable squirrel population but instead try to actively keep the squirrel's population as high as possible. Estimates suggest that the current habitat, under optimal conditions, could support up to 650 squirrels.

B. Telescopes and Politics

Mt. Graham is in the Coronado National Forest, managed by the U.S. Forest Service. The four peaks that make up Mt. Graham have approximately 4750 ha of potential squirrel habitat, of which only 830 ha is given a good to excellent habitat rating. The threat to the red squirrel's habitat is an astrophysics project sponsored by the University of Arizona. The university wants to build seven telescopes on the mountain top because it has little light pollution and ideal dry air conditions for nonvisible wavelength telescopes. The initial proposal called for buildings to be constructed on about 3 ha of land, improving an existing road, and restricting public access to an area around the observatories.

The university first proposed the telescope project in 1980. Although the university had expected to begin building by 1982, construction was delayed while the U.S. Forest Service prepared a draft environmental impact statement and solicited public input. In June of 1987 the U.S. Fish and Wildlife Service (FWS) listed the Mt. Graham red squirrel as an endangered species. In the following year the FWS issued a "statement of jeopardy" for the squirrel and suggested three "reasonable and prudent" alternatives. The Forest Service selected a recommended alternative which allowed three telescopes to be built on Emerald Peak about 2 km west of High Peak, the site originally proposed. The three observatories would occupy 3 ha within a 49-ha preserve. This alternative also provided an option for building four more telescopes in the future if red squirrel populations are observed to be unaffected by the first three telescopes.

The Forest Service, noting that the selected alternative would force closure of some areas to the public, informed the university that a final decision could not be made until more public comment was considered. The university, eager to begin construction, persuaded the Arizona congressional delegation to attach an amendment to the Arizona–Idaho Conservation Act of 1988 exempting the observatories from continued evaluation. Construction began shortly after passage of the act and in September of 1993 two of the first three telescopes were dedicated. In August of 1994, a court injunction halted construction of the third telescope after the university moved the building site approximately 300 m to another peak on the mountaintop. Eighteen environmental organizations filed the lawsuit, claiming the relocation site is outside the area exempted in the 1988 Congressional Act.

To date, any construction impacts on the squirrel have not been observed. The squirrel population has increased, in large part, biologists believe, because cone crops have been high in the last few years. Construction of the four additional telescopes will require several years of high squirrel populations and then a full NEPA evaluation.

In the early stages of the red squirrel conflict public reaction was limited to a few highly interested groups such as hunters, hikers, environmental organizations, and the university. The FWS final recovery plan received only 21 written comments. The muted response may reflect the small size of the affected area and the uncertainty about how observatory construction would impact the squirrel population. These factors made it possible for the university to politically shorten a regulatory process it found cumbersome and slow. The recent court injunction, however, indicates political and public support is building for red squirrel protection.

When the FWS lists a species as "endangered" or "threatened," only biological considerations are supposed to influence a species' management plan. Investigations by Congress and the U.S. General Accounting Office, however, found that the selection of Emerald Peak was based on nonscientific considerations. It is clear that without a broad base of public and political support, species conservation can be strongly influenced by economic and political forces as well as by biological concerns. The conflict of all these forces has been dramatically played out in the largest and most costly endangered species conflict since passage of the Endangered Species Act.

III. THE NORTHERN SPOTTED OWL AND OLD-GROWTH FORESTS

The controversy in the Pacific Northwest over old-growth forests and the northern spotted owl has involved science, economics, politics, and public response on a regional, if not national, scale. Much of the debate illustrates how the management and perception of endangered species have changed in the last 20 years since the ESA was passed. Although there are many factors that have molded the spotted owl/old-growth controversy, four influences are particularly important: research on the spotted owl, ecological studies of old-growth forests, changes in the timber industry, and a change in society's perception of forests.

A. Spotted Owl Research

Three subspecies of the spotted owl are recognized. The Mexican spotted owl (*Strix occidentalis lucida*), genetically distinct from the other subspecies, resides in northern Mexico, Arizona, New Mexico, and southern Utah and Colorado. Similar in its habitat requirements to the northern subspecies, it was listed as a threatened species by the FWS in 1993. The California spotted owl (*Strix occidentalis occidentalis*), found in coastal forests south of San Francisco and in the Sierra Nevada south of the Pit River, is considered distinct from the northern subspecies because of morphological, not genetic, differences. The northern spotted owl (*Strix occidentalis caurina*) ranges from northern California into southern British Columbia in the Cascade Mountains and westside forests. It is the best studied of the three subspecies, and plans developed for its management may provide a framework for managing the other two subspecies.

Although the first written report of a spotted owl was made in 1860, the rarely observed bird (Fig. 3) was not scientifically studied until the 1970s by Eric Forsman. In those preliminary studies, Forsman, an Oregon State University graduate student, immediately noted two characteristics of the owl that would eventually generate most of the debate surrounding the species: spotted owls are found predominantly in old-growth forests, and they have large home ranges.

Scientists have since refined the first observation, emphasizing that the spotted owl is closely associated with specific forest stand structures rather than an age class of forest. Two important forest structures for the owl, multilayer canopies and large snags, however, are often found only in old growth. These features may facilitate prey capture and provide cavities for one of the owl's staple prey species, the northern flying squirrel (*Glaucomys sabrinus*) (Fig. 4). Some old-growth forests also have a greater abundance and diversity of "truffles" than second-growth forests. Truffles are an important food source for many small mammals, and may influence the local abundance of several of the owl's prey species.

FIGURE 3 An adult northern spotted owl.

FIGURE 4 A northern flying squirrel with a truffle, which comprises 90% of the squirrel's diet. The abundance of truffles in old growth may attract flying squirrels, which in turn may improve owl foraging success.

In the course of the spotted owl controversy, reports have circulated that owls have been found in young forests. In general, these reports result from three situations: (1) Spotted owls have been found using younger forests that have old-growth remnant patches in the core activity area, (2) juvenile owls have been located in young forests as they search for unoccupied habitat territory (see the following discussion), and (3) in northern California, spotted owls will use redwood (*Sequoia sempervirens*) forests as young as 60 years old. These forests, however, because of favorable growing conditions, may produce large trees with some old-growth attributes within 50 to 60 years of being logged.

Changes in forest type and the owl's diet are believed to influence home range size. One contro-

versial theory is that as the number, biomass, and availability of prey decreases, owls need larger home ranges. For instance, in the mixed conifer forests of northern California and southern Oregon, the owl feeds mostly on bushy-tailed and dusky-footed woodrats (*Neotoma cinera* and *N. fuscipes*) and on northern flying squirrels. The combined weight and density of the three species give an average available biomass of 388 g per ha. The owl's median home range size in this region varies from 400 to 3000 ha. In the western hemlock (*Tsuga heterophylla*), Douglas-fir forests of Washington's Olympic Peninsula and North Cascades, the owl's prey is mainly flying squirrels with an available average biomass of 61 g per ha. The home range size in Washington varies from 2500 to 12,000 ha. Other scientists who disagree with the preybase theory note that some studies have found high densities of woodrats and flying squirrels in young forests. They argue that forest structure and foraging success are also an important influence on home range size and the owl's preference for old-growth forests.

Spotted owls, which may live for 12 years or more, reach sexual maturity by their second year. Mating usually occurs in March and the two eggs hatch in May. Owlets remain in the nest for about 35 days after hatching. By September the adult owls stop feeding their young and the juveniles disperse to search for their own territory. Before dispersal, about one-third of the owlets die; starvation is frequently the cause. Survival is further jeopardized as juveniles search for old-growth stands unoccupied by other owls. In the Pacific Northwest most timber has been harvested on public land in dispersed 8–16 ha (20–40 acre) clearcuts (Fig. 5). The resulting landscape pattern forces juveniles to cross open areas where they are especially susceptible to predation by the great horned owl (*Bubo virginianus*).

The importance of juvenile dispersal and territory establishment prompted scientists to think of owl conservation using metapopulation models. The whole nothern spotted owl population was analyzed as a dynamic set of subpopulations where local extinction and recolonization depend on successful juvenile dispersal and adult migration. Owl conservation studies applied the principles of island biogeography to landscape ecology. Owl activity centers were viewed as islands surrounded by a forest matrix. The matrix could help or hinder juvenile dispersal depending on how many clearcuts perforated the forest and the stand structure of the intact forest cover.

A diminishing supply of old-growth forests makes it more difficult for juveniles to find suitable unoccupied territory. Biologists have speculated that this lack of old growth may explain why owls sometimes occupy young forests or crowd at high densities in fragmented old-growth stands. This crowding of birds into remaining habitat, referred to as "packing," may reduce local prey availability and decrease the reproductive success of both "floater" birds and the resident owl pair. Scientists realized that measures of owl density may not be a good indicator of population health or habitat quality.

As timber sales were halted, scientists were pressured to provide information on the spotted owl. Thousands of individuals have been located by "calling surveys" and more than 100 owls were fitted with radio telemetry packages so their habitat preference, home range size, and dispersal patterns could be mapped. As data accumulated, biologists noted that few juveniles survived their search for new habitat. Although scientists were gaining an unprecedented understanding of a species' complex biology, it was clear they were also witnessing a declining spotted owl population.

B. Old-Growth Ecology

Owl biologists, however, were not the only scientists exploring the old-growth forests. In fact, much of the debate surrounding the owl is really an expression of concern for the old-growth ecosystem. Certainly much of the growing public concern over old growth developed in response to scientific studies of how old-growth forests differ from young-managed plantations. As recently as the early 1970s old growth was viewed as overmature, decadent timber, a "biological desert" shunned by most animals. Beginning in the late 1960s, however, funding from the International

FIGURE 5 A pattern of small, scattered clear-cuts in the Pacific Northwest exposes dispersing owls to predation and fragments the remaining old-growth habitat.

Biological Program and other sources enabled more extensive studies of old growth. The resulting research changed some of the most fundamental thinking about forest ecosystems.

Typically, managed forests eliminate the development of large woody structures by confining forest succession to early seral stages. Large, old trees provide a more complex canopy structure for modifying the microclimate, reduce the flood potential of rain-on-snow runoff, and increase ephiphyte and invertebrate diversity. In particular, studies started to focus on the functional role of snags, dead wood, and decomposing processes (Fig. 6). Although forest management had concentrated on young tree growth and fiber production, researchers now realized that perhaps only half of a tree's ecological functions occur while it is alive. Snags provide insects for wood-boring birds and cavities for many birds and arboreal mammals. Down logs are important habitat for woodland salamanders and most detritivores, and function as nutrient and moisture reservoirs. Old growth also provides high understory plant diversity, an important source of logs for stabilizing stream beds, a conservative nutrient cycle, and unique above- and below-ground conditions for canopy invertebrates and soil microfauna.

C. The Timber Industry

A growing awareness of old-growth ecosystems and the spotted owl's imperiled status were not the only factors that provoked the owl/old-growth debate. Fundamental changes in the region's timber industry were underway, squeezing timber workers, rural communities, and the markets on which both depend.

The western half of Oregon and Washington have some of the world's most productive timber land. Early settlers marveled at Douglas-fir trees more than 3 m in diameter and up to 90 m tall. The supply of timber seemed inexhaustible. In 1865, on the shores of Washington State's Puget Sound, the newly arrived A.S. Mercer claimed, "The supply of logs for lumber will only be exhausted when the mountains and valleys surrounding the Sound are destroyed by some great calamity of nature."

Early settlers began harvesting the timber that could be easily floated to market. In the 1890s, when the last of the virgin pine stands were ex-

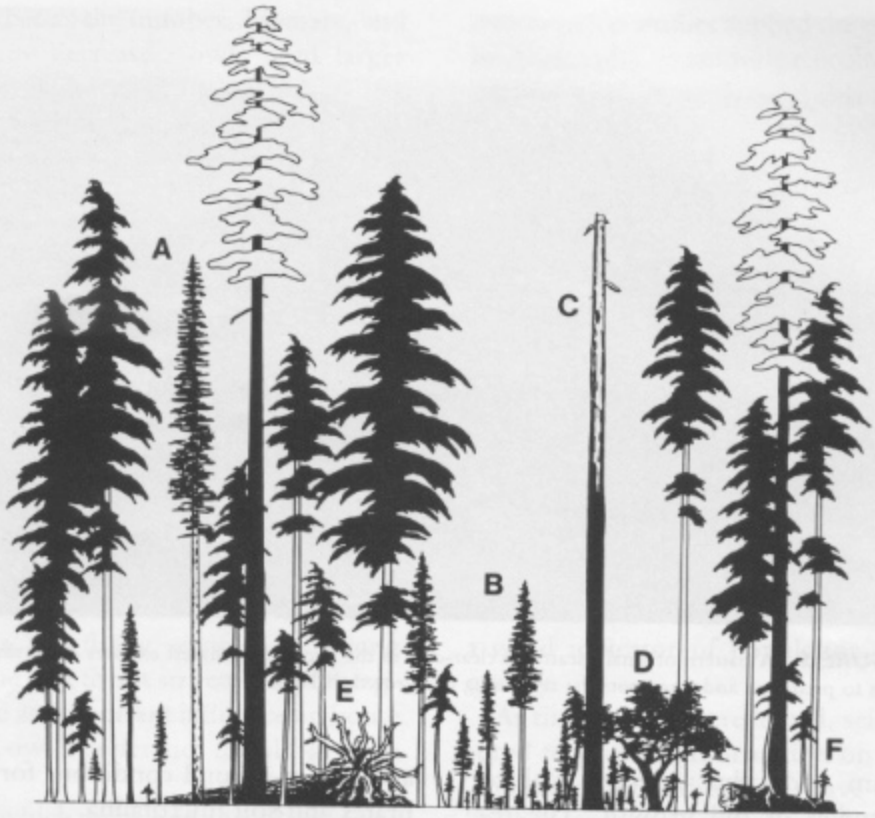

FIGURE 6 An illustration of an old-growth Douglas-fir and western hemlock forest near Stephenson, Washington. This stand displays many of the characteristics of old-growth forests such as (A) a complex, multilayered canopy; (B) a gap with regenerating trees created when an overstory tree died; (C) a large snag with a cavity; (D) an understory of shade-tolerant trees including western yew (*Taxus brevifolia*); (E) a tipup mound and large, windthrown log; and (F) trees growing on a "nurse" log. [Illustration by Robert Van Pelt.]

hausted in the upper Midwest, many large timber companies moved to the Pacific Northwest. Logging changed from a frontier economy that anyone with an axe and pair of oxen could pursue, to an organized industry with company-owned towns and overseas exports. In the 1950s, privately owned, old-growth timber began to run out and federal land managers increased their annual harvest to sustain the local lumber economies. Forest Service managers were directed to set annual harvest at a sustainable yield, the level at which the forest would regenerate timber at the rate it was being cut. Harvest rates on many forests, however, were not sustainable because optimistic growth and yield projections were used, and the congressionally dictated sale quantity increased each year. In the 1960s and 1970s, rural logging economies boomed in the Pacific Northwest, as fully half of the total National Forest Service timber harvest came from western Oregon and Washington alone. Timber supply experts began to point out that old-growth timber would run out before most maturing second-growth stands would reach a merchantable size.

While the timber supply condition was becoming ominous, changes in technology and world markets were concurrently impacting logging economies. Improvements in milling mechanization reduced the number of workers needed in lumber manufacturing. Only mills that modernized their equipment could afford to stay competitive and many small milling operations closed. For the mills that did mechanize, timber was still scarce because Asian markets were paying higher prices for raw

logs than were U.S. mills. All of these changes pushed to shrink the logging economy at the time when the issue of the spotted owl was taking hold.

In the Pacific Northwest, logging is not only a means of making a living, it is also a part of the rural community's cultural heritage. Many loggers felt the economic slowdown was an assault on both their livelihood and on their way of life. As timber sales slowed and the controversy became increasingly portrayed in the media as "jobs versus owls," the timber communities vented their frustration on the spotted owl and environmentalists. One reason the controversy has become so polarized and difficult to resolve is that forest mismanagement, changes in timber markets, and threats to a way of life have all been simplified to a single visceral symbol, the spotted owl.

D. Society's Perception of Forests

If the spotted owl became a simplified symbol for change in many timber communities, the same could be said of many urbanite's response to the issue. As America has changed from a rural, resource-dependent economy to a service and information-based society, forests are less a source of money and food than an escape from urban work and stress. This demographic shift from rural to urban has been accompanied by a perceptual shift in the utility of forests. Forests, once viewed as stands of timber for working and hunting, are now understood as complex ecosystems with some attributes and wildlife species that may be renewable only after many centuries. Much of this shift can be explained by the percolation of spotted owl and old-growth scientific research into the public's understanding of forest ecosystems. In this context, forests were best left as undisturbed environments for wildlife and nonconsumptive recreation. The new aesthetic might best be summed by the popular Sierra Club adage, "Take only pictures, leave only footprints."

Forests also embody more than the sum of their biological parts. Vast woodlands are part of the unique American landscape that was woven into the cultural heritage distinguishing early Americans from their European roots. The French writer Chateaubriand noted this heritage when he remarked, "There is nothing old in America excepting the woods . . . they are certainly the equivalent for monuments and ancestors." This sense of forests as an historical legacy fueled some of the passionate debate in the spotted owl controversy. Cutting old growth was described as the destruction of nature's cathedral and the loss of a future generation's rightful heritage. In this scenario, loggers were cast as a selfish lot, bent on profiting from the final decimation of an American treasure.

E. Political and Legal Actions

For environmentalists concerned with preserving old growth, the best political tool was neither a spiritual appeal nor lobbying for the recreational value of the forest. Since its passage in 1973, the Endangered Species Act has proven most effective for reserving land because economic and social impacts of protecting an endangered species are not supposed to be weighed in determining whether or not a species is listed. As one environmentalist put it, "If the spotted owl hadn't come along, it would have been necessary to invent it."

Spotted owl and old-growth research, changes in the timber industry, and society's perception of forests all contributed to push the spotted owl/old-growth debate into the political and legal arena. As early as 1981 the Portland Regional Office of the FWS described the owl as "vulnerable," but concluded the species did not qualify for listing at the time. In the mid 1980s the Bureau of Land Management (BLM) and the Forest Service developed and revised spotted owl management plans which in turn were challenged by conservation groups. In 1987 the FWS was again petitioned to list the spotted owl as endangered. Their decision not to list the owl was appealed by conservation groups in 1988. The U.S. Federal Court in Seattle ruled that the decision against listing was not based on biological studies and it ordered the FWS to reexamine the owl for listing.

By 1988, Washington and Oregon state agencies had listed the spotted owl as endangered and threat-

ened, respectively. In 1989 an agreement among the Bureau of Land Management, the Forest Service, the Fish and Wildlife Service, and the National Park Service established an Interagency Spotted Owl Scientific Committee. The committee produced a spotted owl management plan in May 1990, commonly referred to as the Thomas report after the Committee's chairman Jack Ward Thomas. The report proved to be a landmark in species conservation plans by taking a landscape-level approach to managing northern spotted owl populations. The committee developed a region-wide plan calling for 5.8 million acres to be set aside for owl habitat and outlined a management guideline for the connecting areas between reserves to provide for owl dispersal. The so-called "50–11–40" rule called for 50% of the land base between owl reserves to be maintained in stands with an average tree diameter of 11 inches and at least 40% canopy cover.

In the summer of 1990 the U.S. Fish and Wildlife Service listed the northern spotted owl as a threatened species. With this listing, federal land management agencies were required to develop new spotted owl environmental impact statements. In the interim most timber sales on federal lands were halted. In the summer of 1992 the marbled murrelet (*Brachyramphus marmoratus*) was listed by the FWS as a threatened species, further restricting all timber sales in a 50-mile-wide band along the ocean coast where the sea bird nests. Environmentalists were also pressing the Forest Service under the 1976 National Forest Management Act to include viability assessments of other old-growth associated species in their plans. There was also mounting public concern about logging impacts on the headwater streams of several salmon runs that were in critical condition.

The resulting legal challenges polarized the environmentalists and timber industry until issue discussion and compromise became impossible. The newly elected Clinton administration convened a timber summit in April of 1993 in an attempt to break the deadlock and hear all sides of the issue. Following the summit, a team of scientists was directed to develop an array of alternatives for managing the region's forests that would provide for the viability of all species associated with old forests. The resulting set of 10 alternatives, including the selected option 9, was open to public comment and more than 100,000 responses were received. The timber industry objected to the plan because the region's annual federal timber sale was reduced from 4.5 to 1.2 billion board feet (a board foot is equal to a 1-inch thick board measuring 1 foot by 1 foot). Environmental groups oppose the plan because it allows some continued logging of old growth and some salvage logging in owl habitat. Federal agencies jointly developed plans to implement the option 9 recommendations on the lands under their jurisdiction. In the fall of 1994 a federal court reviewed the joint plan and decided it satisfied the requirements of NFMA and ESA. In the absence of congressional action the federal court decision will be the final arbiter in the spotted owl controversy.

What started with an effort to slow old-growth harvests and give the spotted owl federal protection has developed into a legal tangle about the region's forests and NFMA's requirement to provide for the viability of all vertebrate species threatened by the loss of old growth. Certainly the regulations, legal reviews, and political maneuverings are costly, slow, and often shrill. Yet for all the inefficiency and possible inequities, the controversy has focused research effort and public scrutiny on the old-growth ecosystem. Initially, scientists and environmentalists concentrated on the spotted owl. However, with closer scrutiny, the diversity and complexity of old forests became clear. It is not just the spotted owl that is threatened by the disappearance of old growth. Other species include the fischer (*Martes pennanti*), Vaux's swift (*Chaetura vauxi*), Northwestern salamander (*Ambystoma gracile*), and hooded lancetooth snail (*Ancotrema voyanum*) to name but a few of the estimated 1098 terrestrial species (excluding arthropods) at risk (Table II). Cutting old-growth forests does not simply eliminate big trees, but also complex canopies, large snags with cavities, big down logs, and diverse understory plants. The dwindling supply of old growth also means the loss of a refuge from urban stress, an environment where the human imprint has not yet been stamped. Clearcuts are

TABLE II

Estimates of the Number of Species Closely Associated with Old-Growth Forests in the Pacific Northwest (PNW)[a]

Group	Number of species associated with old growth	Comments
Fungi	527	One hundred and nine species are endemic to the PNW.
Lichens	157	Many of these species have been extirpated or are in decline in Europe and eastern North America.
Bryophytes	106	Thirty-two species are endemic to the PNW.
Vascular plants	124	Many of these species are poor dispersers, needing large rotting nurse logs or specific fungi.
Mollusks	102	Many rare land and freshwater snails with high endemism. Eight species proposed for federal listing.
Amphibians	18	Mostly salamanders that require large logs or undisturbed riparian areas.
Birds	38	Many cavity nesters that use large snags.
Mammals (excluding bats)	15	Most species are in the Rodentia order. The marten, fisher, and red tree vole are the most threatened.
Bats	11	Seven are *Myotis* spp. Roost sites in crevices, old tree hollows, and under bark are important habitats.
Arthropods	7000+	An estimate since little is known about most species and only approximately 75% of regional species have been described.

[a] These estimates were made by the Forest Ecosystem Management Assessment Team (FEMAT), a scientific report developed following the timber summit.

replanted and will regenerate, but second-growth forests are not managed to provide old-growth attributes.

IV. CONSERVING VIRGIN FORESTS AND ENDANGERED SPECIES

Although the Endangered Species Act has been a powerful legal means of protecting wildlife, it has directed conservation efforts into a species-by-species approach. When the ESA was passed in 1973, immediate legal protection was needed for such species as the peregrine falcon (*Falco peregrinus annatum*) endangered by exposure to the pesticide DDT. This approach was essential triage for the hemorrhaging of a long-neglected environment. However, scientific studies of species have always emphasized the connectivity between all species and the structure, function, and composition of their habitat. The spotted owl controversy is a good example of how ecological research can help expand the debate beyond a single species approach.

The plan that evolved from the timber summit's team of scientists was appropriately called forest ecosystem management, emphasizing that species viability is best ensured by managing for ecosystem integrity within a connected landscape. What is threatened is the old-growth ecosystem of which the spotted owl is but one component. The plan makes another important distinction by stressing that low-elevation, old-growth ecosystems are the most threatened. Ecosystem management at a regional scale can evaluate whether existing reserve areas provide a representative sample of the natural range of ecosystems. For example, most U.S. Park and Wilderness areas protect scenic, high-elevation ecosystems, while species-rich lowlands are underrepresented. By changing the currency of conservation from the species to the ecosystem, management will preserve more diverse habitats and their associated wildlife.

Another important contribution of the spotted owl debate is the development of a species conservation plan at a regional scale. The large habitat size and dispersal needs of the spotted owl required management planning over a landscape. The Thomas and FEMAT reports are the first large-scale application of theories from the new fields of conservation biology and landscape ecology. The effective con-

servation of many species requires planning for species dispersal and movement, and the influence of a landscape's matrix on habitat reserves.

The spotted owl debate has also accelerated changes in forest management. All of the agency plans submitted for court consideration adopted "new forestry" practices. These practices emphasize that forests should be managed to minimize the logging impacts on ecosystem processes and wildlife habitat. On harvest sites, large live trees, snags, and logs will be left to increase the structural diversity and habitat potential of the regenerating forest. This practice more closely mimics the effects of wildfire and windstorm disturbances on a forest than clearcutting. Scientists are working to identify the density, arrangement, and kinds of woody structures essential to threatened species. When a forest is harvested, managers focus on what is to be left on site instead of simply calculating the timber volume that can be clearcut and extracted.

At the landscape level, "new forestry" may aggregate harvest areas to minimize forest fragmentation and retain habitat connectivity. Management plans examine logging impacts on watersheds, the effects of road construction on erosion and fragmentation, and cumulative changes on the landscape matrix.

The politics and public debate surrounding the Mt. Graham red squirrel and the northern spotted owl are a telling narrative of our fledgling struggle to conserve endangered species when there is little time or room for error. In both instances, a reactive approach to an endangered species framed each conflict as one of immediate economic loss against the uncertain future loss of a species. In the absence of broad-based public support, the politics and economics of the moment strongly influence how an endangered species debate is resolved. In the spotted owl controversy, however, the scope of the debate kept expanding as regulations and legal challenges prevented an expedient resolution. The evolving controversy eventually spawned the nation's first attempt at regional ecosystem management. To stay ahead of the species extinction curve, this example of ecosystem management may be a promising proactive model for conserving what remains of our virgin forests and their endangered species.

Glossary

Ecosystem management A strategy to manage ecosystems for all associated species instead of a species-by-species approach to conservation.

Forest fragmentation Splitting a continuous old-forest landscape into a mosaic with younger-age stands.

Landscape matrix Dominant cover type in the landscape that binds smaller, different types together.

Metapopulation A species population made up of subset populations linked through migration. A habitat unoccupied following a local extinction can be recolonized by immigration from another subpopulation.

New forestry Forest management that minimizes the impact of timber harvesting on ecosystem integrity and landscape connectivity.

Old growth Virgin forest that has been free of disturbance long enough to develop large, woody structures and senescent mortality.

Packing Crowding of species into a dwindling supply of habitat that can depress prey abundance and successful reproduction.

Sustainable yield A timber harvest rate at which a region's forest regenerates the same volume of wood that is cut each year.

Succession Progressive change in forest composition and structure with age; broadly defined by four seral or successive stages: stand initiation (the forest regenerates), stem exclusion (self-thinning), understory reinitiation (dying trees produce canopy gaps and light for establishing trees), and old growth (tree growth balances mortality losses).

Virgin forest Forest of any age that has not been altered by human activity.

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