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See also FORESTY, HISTORY OF; LANDSCAPE ECOLOGY; OLD GROWTH FORESTS

Forest Fragmentation and Bird Habitats

Fragmentation of forests by human or natural causes decreases forest-interior habitats or "core areas" (i.e., forest areas over 100 meters from an edge) and increases forest edge. The size, shape, and age of a forest fragment, as well as the forest structure all affect the amount of core area available for forest-interior birds. Increasing forest fragmentation on breeding grounds generally leads to reduced population abundance, reduced pairing and nesting success of forest-interior birds, and increased abundance of forest-edge species. Although larger forest fragments may harbor a high abundance of forest-interior birds, nesting success is often significantly lower than that of birds in continuous forests.

Forest-interior species are often absent in small forest patches, despite the presence of forest areas large enough for many territories. The biogeography model of true islands is often invoked to explain the low abundance of such species in isolated forest patches. When species extinctions—through emigration and mortality—are not sufficiently counterbalanced by immigration or reproduction species abundance in isolated forest patches declines. Rates of immigration can be affected by distance from continuous forest and the amount of forest habitat available nearby. In contrast the abundance of forest-edge species appears more closely tied to vegetation complexity than to forest size.

Neotropical migrants appear particularly vulnerable to forest fragmentation on their North American breeding grounds. Many of these species nest on or near the ground and use open-cup rather than cavity nests. Open-cup nests are especially prone to nest predation and brood parasitism. Brood parasitism, the practice of birds laying their eggs in the nests of other birds, is a significant threat in some regions of North America, as cowbird species expand their ranges. Predator and parasite numbers often are higher near forest edges, resulting in increased nest losses for forest birds near edges. Because they migrate earlier and arrive later than residents and short-distance migrants, neotropical migrants are less apt to renest and, therefore, less able to recover from nest losses. Return rates of territorial adults to smaller forests are often lower than those in contiguous forests. Although minimum forest size for species presence has been estimated for many species little is known about minimum forest size necessary to maintain self-sustaining populations. Moreover minimum size may vary with habitat quality and landscape attributes.

Nearly half of all neotropical migrants breeding in North American forests winter in tropical forests. Fragmentation on the wintering grounds also reduces abundance and survivorship for such forest specialists. Tropical and subtropical forests harbor many forest-specialist species. Forest endemics such as the harpy eagle, resplendent quetzal, woodcreepers, and tropical antbirds are particularly vulnerable to deforestation. Frugivorous species may require an extensive continuous forest to locate ephemeral food. Some species are restricted to forest of a certain altitude, such as the blue bird of paradise of New Guinea. As tropical forests are converted to agriculture, harvested, and developed populations of both wintering migrants and resident tropical forest species decline. Although second-growth forest patches and hedgerows provide habitat for some forest-specialists in many regions forest habitat is scarce.

Fragmentation may diminish the overall habitat quality compared to similar areas in larger forests. Changes in microclimate, sunlight, and vegetation may intensify seasonal and annual weather cycles, reduce insect abundance, and affect the food availability for insectivorous birds. This, in turn, may result in larger forest bird territories in small forests. Edge species are often more aggressive and may compete with interior species for limited resources.

Composition of the surrounding habitat influences the type and extent of fragmentation effects on forest-interior birds. Suburban and agricultural edges, for example, attract different predator communities. The distance of the fragment from a contiguous forest and the degree of isolation from other woodlots is known to affect colonization and impact mating success and abundance. A higher proportion of forested to open area surrounding a fragment can mod-

erate the detrimental consequences of reduced forest size. Similarly forest patches interconnected to each other can increase the abundance of forest-interior species and enhance the possibility of successful reproduction. Some forest specialists require specific types or ages of forest (e.g., northern spotted owl).

Resident and short-distance migrants that dwell in forest-interior habitats are also measurably influenced by fragmentation. Some species, particularly raptors and other large birds, are found only in large, contiguous forests. For some species (e.g., northern goshawk, barred owl, pileated woodpecker) even small openings in the contiguous forest allow new competitors or predators to invade and diminish the usable habitat. Other forest species benefit from the increased food supply found in forest openings yet are only found in large extensive forests (e.g., ruffed grouse, sharp-shinned hawk). Little is known about the minimum forest size needed to maintain healthy self-sustaining populations of these species.

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See also CLEARCUT; HABITAT FRAGMENTATION, PATCHES, AND CORRIDORS; LANDSCAPE ECOLOGY; NEW FORESTRY; OLD GROWTH FORESTS; TROPICAL DEFORESTATION

Forest Regeneration/Reforestation

Forests are the world's most widespread vegetation type and, with the exception of human food production systems, the most important. They play a major role in regulating atmospheric concentrations of the greenhouse gas CO_2, in the global hydrological cycle, and in the global radiation budget. Forests create critical habitat for the majority of the world's terrestrial animals and microbial species. They regulate soil development and erosion, water quality and stream flow, and provide raw materials, wealth, employment, recreational opportunities, and spiritual values for humans. It is little wonder, therefore, that people are concerned when natural disturbances or timber harvesting remove forest cover from significant portions of a landscape. The prompt regeneration of the forest—the reforestation of the landscape—after such a disturbance is one of the most fundamental objectives of forest management.

There are five main approaches to the reforestation of a recently denuded area. Three of these involve "natural" regeneration. The other two methods are planting and direct seeding. Natural regeneration has many advantages. It ensures that the local genetic varieties of the local tree species reforest the area, and it is often much cheaper than "artificial" regeneration methods because nature provides the seed and seedlings free. However, successful natural regeneration sometimes requires special harvesting regimes and soil preparation activities, so it is not always "free." It may require more skill than "artificial" regeneration, and is often less predictable. Natural regeneration is normally the method by which partially harvested forests are regenerated. Planting can be the most reliable method of regenerating a particular type of forest quickly, but may be more expensive than natural regeneration. If not done with respect for the seedlings' physiology and ecology, it can result in costly regeneration failures. Planting is most commonly associated with clearcutting. The five main approaches to regeneration are advance regeneration, natural seeding regeneration, vegetative regeneration, planting, and direct seeding.

Advance Regeneration

As a forest matures, the canopy often opens up letting in sufficient light to allow a population of seedlings to become established. These seedlings usually grow slowly. They are suppressed by competition for light, moisture, and nutrients, and may remain less than one or two meters in height for more than a century. Many of these seedlings survive when the overstory is removed by wind, insects, or logging, and, after a period of physiological adjustment to the new microclimate, grow to create a new forest. A drawback of advance regeneration is that it is usually limited to seedlings of shade-tolerant species, whereas the forest that is being replaced may have consisted of more light-demanding species. If the advance regeneration is old, it may be parasitized or diseased, or may not respond to increased availability of light.

Natural Seeding Regeneration

Natural seeding regeneration occurs when seeds are blown by wind or are distributed by animals

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See also COMMON PROPERTY RESOURCE MANAGEMENT; MALTHUS, ROBERT THOMAS; POPULATION CONTROL; TRAGEDY OF THE COMMONS

Hawk Shooting

Like many predatory animals—eagles, falcons, owls, and other raptorial birds—hawks have long been persecuted by humans, chiefly because of alleged or actual injury to game or livestock. Others have been shot simply for sport, or for their trophy value. Systematic efforts to eliminate raptors date from the seventeenth century, when the British aristocracy placed bounties on all predatory birds. Earlier in this century raptors were unprotected in most of North America, and bounties were offered on many species. With a few notable exceptions, turn-of-the-century bird protectionists generally held raptors in low regard, in large part because several species, including the sharp-shinned hawk (*Accipiter striatus*), Cooper's hawk (*Accipiter cooperii*), and northern goshawk (*Accipiter gentilis*) were known to feed principally on wild birds. Hawk shooting was rarely mentioned as a conservation issue at the time and, when it was, raptors were often classified as "good" or "bad" depending upon their diets. As a result, hawk shooting—chiefly for sport but at some sites for bounty profit as well—flourished in North America. This was especially true during fall migration when the large numbers of birds converged in massive flights along established migratory corridors.

In an effort to reverse this trend in 1934 New York conservationist Rosalie Edge purchased a 1,400-acre parcel of land in the central Appalachian mountains of eastern Pennsylvania and converted it from a shooting gallery for hawks into Hawk Mountain Sanctuary, the world's first refuge for predatory birds and a preeminent birding attraction. Persistent lobbying on the part of Edge and others eventually resulted in the passage of the Model Hawk Law in Pennsylvania in 1970, which for the first time afforded hawks year-round protection in that state. Two years later the Migratory Bird Treaty Act between the United States and Canada was amended to protect all migratory hawks in North America.

Hawks continue to be persecuted elsewhere in the world for a number of reasons. In Malta, Italy, and other locations in the Mediterranean, tens of thousands of migrating raptors are shot annually, mainly for recreation, as well as for their value as taxidermy specimens. In the Andes of Colombia, South America, migrating raptors are shot each spring because local villagers believe that fat rendered from the birds' bodies has medicinal benefits, and that shooting the birds hastens the passage of Lent. Although most countries currently have laws protecting raptors enforcement is often lax or nonexistent. The impact of shooting on species populations remains unclear.

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See also BALD EAGLE; BIRDING; NATIONAL AUDUBON SOCIETY; PEREGRINE FALCON

Hayes, Denis

See EARTH DAY; SOLAR ENERGY RESEARCH INSTITUTE

Hazardous Waste Treatment Facility Siting

The siting of hazardous waste treatment facilities has become one of the most controversial environmental issues to have emerged in recent years. Many nations now face the realization that, whether proposed by governmental agencies or private waste management firms, the selection of a community or communities to host a hazardous waste incinerator, landfill, or treatment facility consistently triggers local public outrage. In most instances the siting proposal is withdrawn or rejected, making it increasingly difficult to open new facilities and introduce new waste treatment technologies.

This phenomenon is most commonly known as the Not-In-My-Back-Yard (or NIMBY) Syndrome. It is also increasingly evident in other areas of facility siting, including those intended for radioactive, biomedical, and solid wastes, as well as controversial facilities such as prisons, drug and alcohol rehabilitation centers, and airports. In all such cases any benefits to be derived from facility siting are likely

senger pigeon resembled the mourning dove (*Zenaida macroura*) but was larger (about sixteen inches or 40 centimeters) with a longer pointed tail and a blue-gray head. The underparts were pinkish in the male and gray in the female. The pigeon's diet consisted of various invertebrates, seeds, berries, and nuts, especially beechnuts. The flocks sometimes devastated newly planted grain fields but otherwise did little damage to crops.

Flocks of pigeons in search for food roamed in almost incredible numbers and could literally darken the skies for hours. Mark Catesby, Pehr Kalm, Alexander Wilson, and John James Audubon observed flocks that possibly contained over a billion birds. The pigeons bred in equally impressive colonies, and a typical nesting site could cover thousands of acres. The pigeons laid their single egg in a flimsy nest of twigs, and often more than 100 pairs occupied the same tree. From the 1870s on the species' decline was dramatic: the last great nestings took place during that decade, and the last wild birds were encountered at the turn of the century. A few individuals still survived in captivity, and the last passenger pigeon, the famous Martha, died on September 1, 1914, at the Cincinnati zoo.

A variety of explanations have been offered for the species' rapid decline, such as imported avian disease, destruction of the bird's food supply by forest clearance, and ruthless slaughter for human consumption. Year after year hundreds of thousands of birds were killed and shipped by railway carloads for sale in the markets of eastern cities, the hunting pressure easing up only after the great nesting colonies were gone and the commercial attraction lost.

Mikko Saikku

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See also AUDUBON, JOHN JAMES; BIODIVERSITY; CAROLINA PARAKEET; HAWK SHOOTING; NATIONAL AUDUBON SOCIETY

PCBs

See PERSISTENT ORGANOCHLORINE COMPOUNDS

Peregrine Falcon

The peregrine falcon (*Falco peregrinus*), formerly known as the duck hawk in North America, is by common consent the quintessential falcon. Indeed, the species has long been used in falconry. The practically cosmopolitan, 600- to 1,000-gram (approximately crow-sized) raptor feeds chiefly on birds, including waterfowl and shorebirds among others, aerially pursuing its prey at high speeds in a variety of expansive landscapes on six continents and numerous oceanic islands. Peregrine falcons are open-habitat raptors at all times of the year. The species is both territorial and traditional in nest-site use, with records of continual occupation at several specific breeding locations dating from the thirteenth century through the present. Restricted in breeding-sites by its limited ability to construct a nest, the species tends to breed on natural (cliff) and artificial (building and bridge) ledges, frequently at great heights, and often overlooking water. If the cliff is a small one and nestlings are crowded one or more young may fall from it. Peregrine is Latin for "wanderer" or "migrant," and many northern-latitude populations are highly migratory; many others, however, are mainly resident.

Rarely common, even in the centers of its range (the world population in 1982 was estimated at less than 20,000 breeding pairs) North American and European populations of peregrine falcons greatly declined in the 1950s and 1960s as a result of organochlorine contamination. DDT and its metabolites induced eggshell thinning by inhibiting calcium movements within female peregrines, which, in turn, decreased reproductive success when thin-shelled eggs were crushed by incubating adults. At the same time, cyclodiene insecticides (aldrin, dieldrin, etc.) and their metabolites increased adult mortality. As a result, the species was extirpated from several portions of its historic European and North American range.

Over the past twenty years many depleted peregrine falcon populations have increased substantially, both because of more limited use of organochlorine pesticides, and because of successful captive-rearing and release programs. In North America many captive-reared birds were released into urban environments, where the species is now breeding in large numbers. Populations in Great Britain have increased to the point that many pigeon fanciers have called for the removal of some birds from the British population. As of late 1993 the species remains on the U.S. Endangered Species List.

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See also PESTICIDES

Permaculture

See AGROFORESTRY; SUSTAINABLE AGRICULTURE

Permafrost

Permafrost is soil, sub-soil, or bedrock that is frozen continuously for more than two consecutive years in alpine or Arctic areas. While the concept appears rather static the reality is a complex and dynamic phenomenon with very clear environmental implications. On the surface there may be an active layer of soil six to thirty inches deep which melts each summer and freezes again each fall. This active zone includes an organic mat on the surface which is critical for all vegetative growth and the ponding so frequent in tundra areas. The active layer also acts as insulation preserving the stability of the permafrost below. In some areas the permafrost may contain a significant percentage of ice crystals or even large chunks of ice. Stability of land forms requires that the ice remain permanently frozen. In North America permafrost may vary from a few feet at 60 degrees north latitude to several thousand feet thick in the high Arctic islands. It is a product of the interaction between the cooling effect of the surface weather and the heat emanating from the earth's core. As a result there may be scattered patches of permafrost in the southern Arctic (due to vegetation or north facing slopes); then discontinuous permafrost (unfrozen areas under lakes and rivers); and finally continuous permafrost as one proceeds north.

From a geophysical and an environmental point of view it is essential to keep permafrost areas permanently frozen since these areas provide the foundation for all that occurs above. Permafrost was once described as ice cream composed of soil and water. If the active layer is disturbed by human activity then settlement begins to erode the permafrost below and, where ice content is high, there can be collapsing land forms and demolished buildings. When the Alaska Highway was constructed during World War II, engineers did not fully comprehend the problems of permafrost and sections of the highway disappeared. In the decades following World War II extensive scientific and technical research led to the development of mitigative construction techniques for roads, airstrips, buildings, and pipelines. For instance, in the construction of the Trans-Alaskan Oil Pipeline (Alyeska), long stretches of pipeline had to be elevated at great expense to keep the hot oil from melting the surrounding permafrost. Gravel pads with refrigeration coils were also used where caribou had to cross the right of way. These innovative designs helped to escalate the capital cost of the pipeline from $900 million to $8.5 billion. Permafrost has added a whole new dimension to the challenges of engineering and construction. Also the future stability of permafrost may be seriously eroded if global climate change impacts the Arctic as some predict. Thus this phenomenon presents a series of environmental challenges for the future.

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See also ALASKA: PARK, WILDERNESS, AND RESOURCE ISSUES; ARCTIC; BERGER INQUIRY; CLIMATE WARMING; SNOW AS HABITAT

Persistent Organochlorine Compounds

Organochlorine (halogenated aromatic) compounds have been used in the open environment as pesticides (DDT) and in industry in many applications such as heat transfer fluids, dielectric fluids, plasticizers, flame retardants and diluents (PCBs). They are produced as byproducts of industrial processes (polychlorinated dibenzo-p-dioxins [PCDD], and polychlorinated dibenzofurans [PCDF]). They can be found throughout the environment in all compartments. They persist because they resist degradation by acids, bases, heat, or hydrolysis, and they are incorporated into and are concentrated in the food chain. The frequently identified and studied compounds include DDT and its degradation products and congeners (DDE), PCB and its congeners, as well as the PCDDs and PCDFs. Others in the group used

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