# Appendix 1: Common and Scientific Names of Species Mentioned in the Text

| Mammals | |
|---|---|
| *Alces alces* | Moose |
| *Aplodontia rufa* | Mountain beaver |
| *Arborimus albipes* | White-footed vole |
| *Arborimus longicaudus* | Red tree vole |
| *Bettongia penicillata* | Woylie |
| *Bison bison* | Bison |
| *Blarina brevicauda* | Short-tailed shrew |
| *Clethrionomys gapperi* | Gapper's red-backed vole |
| *Canis latrans* | Coyote |
| *Canis lupus* | Wolf |
| *Castor canadensis* | Beaver |
| *Cervus elaphus* | Elk |
| *Clethrionomys californicus* | Western (California) red-backed vole |
| *Didelphis virginiana* | Virginia opossum |
| *Elephas maximus* | Asian elephant |
| *Erithrizon dorsatum* | Porcupine |
| *Felis concolor* | Florida panther, cougar |
| *Felis lynx* | Lynx |
| *Glaucomys sabrinus* | Northern flying squirrel |
| *Glaucomys volans* | Southern flying squirrel |
| *Gulo gulo* | Wolverine |
| *Lepus americanus* | Snowshoe hare |
| *Lepus* spp. | Hares |
| *Lontra canadensis* | River otter |
| *Marmota monax* | Woodchuck |
| *Martes americana* | American marten |
| *Martes pennanti* | Fisher |
| *Mephitis mephitis* | Striped skunk |
| *Microtus oregoni* | Creeping vole |
| *Microtus* spp. | Voles |
| *Mustela vison* | Mink |
| *Myotis* spp. | Myotis bats |
| *Myotis volans* | Long-legged bat |
| *Neotoma* spp. | Woodrats |
| *Odocoileus hemionus* | Mule deer |
| *Odocoileus hemionus sitkensis* | Sitka black-tailed deer |
| *Odocoileus* spp. | Deer |
| *Odocoileus virginianus* | White-tailed deer |
| *Ondatra zibethicus* | Muskrat |

| | |
|---|---|
| *Peromyscus leucopus* | White-footed mice |
| *Peromyscus maniculatus* | Deer mouse |
| *Procyon lotor* | Raccoon |
| *Rangifer tarandus* | Caribou |
| *Rattus norvegicus* | Norway rat |
| *S. trowbridgii* | Trowbridge's shrew |
| *Sciurus carolinensis* | Gray squirrel |
| *Sciurus niger* | Fox squirrel |
| *Sorex pacificus* | Pacific shrew |
| *Sorex palustris* | Water shrew |
| *Sorex vagrans* | Vagrant shrew |
| *Sus scrofa* | Domestic pig |
| *Sylvilagus floridanus* | Cottontail rabbit |
| *Tamias striatus* | Eastern chipmunk |
| *Tamiasciurus douglasii* | Douglas squirrel |
| *Thomomys* spp. | Pocket gophers |
| *Trichosurus vulpecula* | Brushtail possum |
| *Ursus americanus* | Black bear |
| *Ursus arctos horribilis* | Grizzly bear |
| *Ursus* spp. | Bears |
| *Vulpes vulpes* | Red fox |
| *Zapus* spp. | Jumping mice |
| *Zapus trinotatus* | Pacific jumping mouse |

**Birds**

| | |
|---|---|
| *Accipiter gentilis* | Northern goshawk |
| *Actitis macularia* | Spotted sandpiper |
| *Aimophila aestivalis* | Bachman's sparrow |
| *Aix sponsa* | Wood duck |
| *Amazona vittata* | Puerto Rican parrot |
| *Anas rubripes* | American black duck |
| *Ardea herodias* | Great blue heron |
| *Athene cunicularia* | Burrowing owl |
| *Bonasa umbellus* | Ruffed grouse |
| *Brachyramphus marmoratus* | Marbled murrelet |
| *Bubo virgianus* | Great horned owl |
| *Bucephala clangula* | Common goldeneye |
| *Buteo jamaicensis* | Red-tailed hawk |
| *Buteo swainsoni* | Swainson's hawk |
| *Campephilus principalis* | Ivory-billed woodpecker |
| *Catharus bicknelli* | Bicknell's thrush |
| *Catharus guttatus* | Hermit thrush |
| *Catharus ustulatus* | Swainson's thrush |
| *Certhia americana* | Brown creeper |
| *Ceryle alcyon* | Belted kingfisher |
| *Chaetura* spp. | Swifts |
| *Charadrius vociferous* | Killdeer |
| *Chaetura pelagica* | Chimney swift |
| *Chaetura vauxi* | Vaux's swift |
| *Ciconia ciconia* | White stork |
| *Cinclus mexicanus* | American dipper |
| *Coccyzus americanus* | Yellow-billed cuckoo |
| *Colaptes auratus* | Common flicker |

| | |
|---|---|
| *Colinus virginianus* | Bobwhite quail |
| *Columba fasciata* | Band-tailed pigeon |
| *Columba livia* | Rock dove |
| *Contopus cooperi* | Olive-sided flycatcher |
| *Corvus corax* | Common raven |
| *Dolichonyx oryzivorus* | Bobolink |
| *Dryocopus pileatus* | Pileated woodpecker |
| *Ectopistes migratorius* | Passenger pigeon |
| *Empidonax hammondii* | Hammond's flycatcher |
| *Falcipennis canadensis* | Spruce grouse |
| *Falco peregrinus* | Peregrine falcon |
| *Gavia immer* | Common loon |
| *Haliaeetus leucocephalus* | Bald eagle |
| *Histrionicus histrionicus* | Harlequin duck |
| *Hylocichla mustelina* | Wood thrush |
| *Ixoreus naevius* | Varied thrush |
| *Junco hyemalis* | Dark-eyed junco |
| *Melanerpes formicivorus* | Acorn woodpecker |
| *Mniotilta varia* | Black-and-white warbler |
| *Myiopsitta monachus* | Monk parakeet |
| *Parus bicolor* | Tufted titmouse |
| *Passer domesticus* | House sparrow |
| *Phasianus colchicus* | Ring-necked pheasant |
| *Picoides borealis* | Red-cockaded woodpecker |
| *Poecile atricapilla* | Black-capped chickadee |
| *Scolopax minor* | Woodcock |
| *Seiurus aurocapillus* | Ovenbird |
| *Setophaga discolor* | Prairie warbler |
| *Setophaga pensylvanica* | Chestnut-sided warbler |
| *Setophaga petechia* | Yellow warbler |
| *Setophaga pinus* | Pine warbler |
| *Setophaga virens* | Black-throated green warbler |
| *Sialia sialis* | Eastern bluebird |
| *Sitta pusilla* | Brown-headed nuthatch |
| *Spinus tristis* | American goldfinch |
| *Strix occidentalis caurina* | Northern spotted owl |
| *Strix varia* | Barred owl |
| *Sturnella magna* | Eastern meadowlark |
| *Sturnus vulgaris* | European starling |
| *Thryothorus ludovicianus* | Carolina wren |
| *Troglodytes aedon* | House wren |
| *Troglodytes troglodytes* | Winter wren |
| *Turdus migratorius* | American robin |
| *Vermivora celata* | Orange-crowned warbler |
| *Vireo olivaceus* | Red-eyed vireo |
| *Wilsonia canadensis* | Canada warbler |

**Amphibians**

| | |
|---|---|
| *Ambystoma maculatum* | Spotted salamander |
| *Ambystoma opacum* | Marbled salamander |
| *Aneides ferreus* | Clouded salamander |
| *Ascaphus truei* | Tailed frog |
| *Dicamptodon tenebrosus* | Pacific giant salamander |

| | |
|---|---|
| *Ensatina eschscholtzii* | Ensatina salamander |
| *Gyrinophilus porphyriticus* | Spring salamander |
| *Hyla sp.* | Tree frog |
| *Ochlerotatus triseriatus* | Tree hole mosquito |
| *Plethodon cinereus* | Red-back salamander |
| *Plethodon dunni* | Dunn's salamander |
| *Plethodon* spp. | Slimy salamander |
| *Plethodon stormi* | Siskiyou Mountains salamander |
| *Plethodon welleri* | Weller's salamander |
| *Rana aurora draytonii* | California red-legged frog |
| *Rana cascadae* | Cascades frog |
| *Rana catesbeiana* | Bullfrog |
| *Rana septentrionalis* | Mink frog |
| *Rana sylvatica* | Wood frog |
| *Rhyacotriton variegatus* | Southern torrent salamander |
| *Taricha granulosa* | Rough-skinned newts |
| *Zenaida macroura* | Mourning dove |

### Reptiles

| | |
|---|---|
| *Agkistrodon contortrix* | Northern copperhead |
| *Chelydra serpentina* | Snapping turtle |
| *Clemmys marmorata* | Western pond turtle |
| *Crotalus* spp. | Rattlesnake |
| *Crotalus viridis* | Prairie rattlesnake |
| *Elaphe obsoleta* | Rat snake |
| *Gopherus polyphemus* | Gopher tortoise |
| *Opheodrys aestivus* | Rough green snake |
| *Sceloporus occidentalis* | Western fence lizard |
| *Terrapene carolina* | Box turtle |

### Insects

| | |
|---|---|
| *Adelges tsugae* | Hemlock wooly adelgid |
| *Blattella* spp. | Cockroaches |
| *Camponotus* spp. | Carpenter ant |
| *Chrysomela confluens* | Leaf beetles |
| *Dendroctonus* spp. | Bark beetles |
| *Dendroctonus frontalis* | Southern pine beetle |
| *Lycaeides melissa samuelis* | Karner blue butterfly |
| *Lymantria dispar* | Gypsy moth |

### Fish

| | |
|---|---|
| *Carassi carassius* | Carp |
| *Oncorhynchus kisutch* | Coho salmon |
| *Oncorhynchus clarki* | Cutthroat trout |
| *Salmo* spp. | Trout |
| *Salvelinus fontinalis* | Brook trout |

### Plants

| | |
|---|---|
| *Abies balsamea* | Balsam fir |
| *Abies grandis* | Grand fir |
| *Acer macrophyllum* | Bigleaf maple |
| *Acer pensylvanicum* | Striped maple |
| *Acer platanoides* | Norway maple |
| *Acer rubrum* | Red maple |

| | |
|---|---|
| *Acer saccharum* | Sugar maple |
| *Acer saccharinum* | Silver maple |
| *Acer spicatum* | Mountain maple |
| *Acer* spp. | Maples |
| *Ailanthus altissima* | Tree of Heaven |
| *Alnus rubra* | Red alder |
| *Amelanchier* spp. | Serviceberries |
| *Arbutus menziesii* | Pacific madrone |
| *Berberis* spp. | Barberries |
| *Betula alleghaniensis* | Yellow birch |
| *Betula lenta* | Black birch |
| *Betula papyrifera* | White birch |
| *Betula populifolia* | Gray birch |
| *Betula* spp. | Birches |
| *Brachypodium sylvaticum* | False brome |
| *Carya ovata* | Shagbark hickory |
| *Carya* spp. | Hickories |
| *Castanea dentata* | American chestnut |
| *Cirsium* spp. | Thistles |
| *Chamaecyparis lawsoniana* | Port-Orford cedar |
| *Cornus florida* | Flowering dogwood |
| *Cornus* spp. | Dogwoods |
| *Corylus cornuta* | Hazlenut |
| *Crataegus* spp. | Hawthorns |
| *Cytisus scoparius* | Scotch broom |
| *Elaeagnus umbellata* | Autumn olive |
| *Endothia parasitica* | Chestnut blight fungus |
| *Fagus grandifolia* | American Beech |
| *Fomes pini* | Red heart disease |
| *Galium* spp. | Bedstraws |
| *Ilex* spp. | Hollies |
| *Ilex verticillata* | Winterberry |
| *Ilex vomitoria* | Yaupon |
| *Kalmia latifolia* | Mountain laurel |
| *Juglans* spp. | Walnuts |
| *Liquidambar styraciflua* | Sweetgum |
| *Liriodendron tulipifera* | Yellow-poplar |
| *Magnolia fraseri* | Fraser magnolia |
| *Melaleuca quinquenervia* | Australian paperbark tree |
| *Nyssa aquatica* | Water tupelo |
| *Nyssa sylvatica* | Blackgum |
| *Phaeocryptopus gaeumannii* | Swiss needle cast |
| *Phytophthora lateralis* | Root rot |
| *Picea glauca* | White spruce |
| *Picea mariana* | Black spruce |
| *Picea rubens* | Red spruce |
| *Picea sitchensis* | Sitka spruce |
| *Picea* spp. | Spruces |
| *Pinus banksiana* | Jack pine |
| *Pinus contorta* | Lodgepole pine |
| *Pinus echinata* | Shortleaf pine |
| *Pinus elliottii* | Slash pine |

| | |
|---|---|
| *Pinus jeffreyi* | Jeffrey pine |
| *Pinus palustris* | Longleaf pine |
| *Pinus ponderosa* | Ponderosa pine |
| *Pinus resinosa* | Red pine |
| *Pinus* spp. | Pines |
| *Pinus taeda* | Loblolly pine |
| *Populus deltoides* | Eastern cottonwood |
| *Populus trichocarpa* | Black cottonwood |
| *Populus* spp. | Cottonwoods |
| *Populus* spp. | Aspens |
| *Populus tremuloides* | Quaking aspen |
| *Prunus pensylvanica* | Pin cherry |
| *Prunus* spp. | Cherries |
| *Pseudotsuga menziesii* | Douglas-fir |
| *Quercus alba* | White oak |
| *Quercus garryana* | Oregon white oak |
| *Quercus nigra* | Water oak |
| *Quercus palustris* | Pin oak |
| *Quercus* spp. | Oaks |
| *Quercus velutina* | Black oaks |
| *Quercus alba* | White oak |
| *Quercus bicolor* | Swamp white oak |
| *Quercus coccinea* | Scarlet oak |
| *Quercus prinus* | Chestnut oak |
| *Quercus rubra* | Northern red oak |
| *Rosa multiflora* | Multiflora rose |
| *Rubus spectabilis* | Salmonberry |
| *Rubus* spp. | Brambles, raspberries, blackberries |
| *Salix* spp. | Willows |
| *Taxodium distichum* | Baldcypress |
| *Thuja plicata* | Western redcedar |
| *Tsuga canadensis* | Eastern hemlock |
| *Tsuga heterophylla* | Western hemlock |
| *Viburnum acerifolium* | Maple-leaf viburnum |
| *Viburnum alnifolium* | Hobblebush |
| *Viburnum* spp. | Viburnums |
| *Viburnum trilobum* | High-bush cranberry |

# Appendix 2: Glossary

**Active adaptive management:** Management is treated as a hypothesis to be tested using monitoring data

**Adaptive management:** A process of continual improvement in management using monitoring data to refine plans

**Advance regeneration:** Seedlings and saplings present in the stand prior to a disturbance that releases them

**Aerial photographs:** A capture of the reflectance of items on the Earth's surface on a photographic film

**Allele:** Expression of a gene

**Allochtonous material:** Leaves, needles, and plant parts that fall into a water body

**Alluvial:** Downstream movement of soils

**Artificial regeneration:** Planting seedlings or seeds usually at a particular spacing to establish a new stand

**Barrier:** An intervening patch type with a low probability of survival

**Basal area:** Cross-sectional area of all trees on a hectare or acre at 1.4 m above ground

**Broadcasting:** Extrapolating data to other units of space outside of the scope of inference

**Brood:** A cohort of young birds

**Brood parasite:** Birds that reproduce by laying their eggs in the nests of other birds

**Browse:** Herbivore consumption of woody plants

**Carrying capacity:** A point in population growth where births equal deaths and further population growth is limited

**Chain of custody:** A process that assures the consumer that wood products came from a certified forest

**Clearcut:** A regeneration method in which all or most trees are removed to allow establishment of a new cohort of trees

**Codominant:** Trees in an even-aged stand receiving full sunlight from above and comprising the main canopy layer

**Community:** An assemblages of populations over space and through time

**Composition:** The types or classes of features in an areas, such as species of plants and types of soils

**Connectivity:** The degree to which the landscape facilitates or impedes movement among habitat patches

**Context:** An area beyond the extent that we are not managing but it affects the function of our landscape

**Core:** The interior of a patch

**Corridor:** An intervening patch type with a high probability of survival

**Critical habitat:** Specific areas and habitat elements essential to the conservation of species listed under the U.S. Endangered Species Act

**Crown classes:** Differentiation of trees into classes in response to growth rates and competition in an even-aged stand

**Cutting cycle:** Period of time between harvests when some trees of all tree diameters in an uneven-aged stand are cut

**Decomposition pathway:** An energy web passing through decomposers

**Deferred rotation:** Also known as a clearcut with reserves; retains some trees through two rotations

**Demographic stochasticity:** The variability represented in vital rates owing to fluctuations in survival and reproduction

**Desired future condition:** A description of the structure and composition of a stand or landscape that you wish to achieve

**Diameter-limit cutting:** Cutting of all the trees above some minimum diameter during each cutting cycle in an uneven-aged stand

**Digestible energy:** That portion of food than can be used by an animal for energy and nutrients

**Dominant crown class:** Uppermost trees in an even-aged stand receiving sunlight from above and from the sides

**Dynamic carrying capacity:** Changing carrying capacity due to fluctuations in resource availability

**Dynamic corridor:** A corridor that "floats" across the landscape over time to provide connectivity at all times

**Ecological restoration:** Uses of practices of restoration ecology as well as human and natural sciences, politics, technologies, economic factors, and cultural dimensions

**Ecosystem management:** A management approach designed to increase the likelihood that it will be socially sustainable

**Ecosystem services:** Services provided by ecosystems to meet society's needs, including but not restricted to commodities

**Ectotherm:** A species that receives most of its body heat from the surrounding environment

**Edge associates:** Species that find the best quality habitat where there is access to required resources in two or more vegetation patch types

**Edge density:** Edge length per unit area

**Edge specialist:** A species likely to only occur where edges between two or more vegetative patch types exist

**Effect size:** The difference (or slope) that you could detect given your sample size, sampling error, and the probability of making an error when rejecting a null hypothesis

**Effectiveness monitoring:** Monitoring designed to determine whether habitat elements, populations, or processes are responding as expected and effectively achieving management goals

**Endotherm:** A species that generates its own body heat

**Environmental stochasticity:** Uncertain environmental events that influence population vital rates

**Establishment cut:** Second step in a shelterwood regeneration method to release trees to produce seeds and to provide growing space for regeneration

**Eutrophic system:** Nutrient-rich aquatic system

**Extent:** The outer bounds of the landscape over which we are managing resources

**Extinction vortex:** Accelerated population declines irreversibly leading to extinction

**Fecundity:** Number of young produced per female over a given time period

**Filter approach:** An approach to biodiversity conservation that employs coarse-, meso-, and fine-filter management strategies

**First-order selection:** Selection of a geographic range by a species

**Fledgling:** A bird that successfully leaves a the nest

**Forecasting:** Predicting trends into the future, based on past trends

**Forest interior species:** A species that avoid edges and use the core of a patch

**Forest structure:** The physical architecture of a forest in three dimensions

**Forest type:** Forest community dominated by representative tree species

**Founder effect:** Low genetic variation often seen in a newly established population

**Fourth-order selection:** Selection of specific food and cover resources acquired from the patches used by the individual within its home range

**Genetic bottleneck:** Marked decline in a population resulting in loss of alleles

**Genetic drift:** Some alleles may dominate in small populations by chance alone

**Grain:** The smallest unit of space in a landscape that we identify and use in an assessment or management plan

**Grazing:** Herbivore consumption of herbaceous plants

**Group selection:** Creation of small openings in a stand to establish patches of regeneration an uneven-aged stand
**Guild:** A group of species that share common nesting or feeding resources
**Habitat:** The set of resources necessary to support a population over space and through time
**Habitat conservation plan:** A plan designed to offset any harmful effects of a proposed activity on endangered or threatened species allowing issuance of an incidental take permit
**Habitat element:** Piece of a forest important to many species, such as vertical structure, dead wood, tree size, plant species, and forage
**Habitat fragmentation:** A process whereby a habitat for a species is progressively subdivided into smaller, geometrically more complex, and more isolated fragments
**Habitat generalist:** A species that can use a broad suite of food and cover resources
**Habitat selection:** A set of complex behaviors that each species has evolved to ensure fitness in a population
**Habitat specialist:** Species that use a narrow set of resources
**Habitat types:** Vegetation type or other discrete class of the environment that is associated with some species
**Hard mast:** Hard fruits such as nuts and acorns
**Harvesting systems:** The means of removing the trees from the site and to a landing during forest management
**Heuristic:** Use of models to teach us something about the system
**Home range:** Area that an individual (or pair of individuals) uses to acquire the resources that it needs to survive and reproduce
**Human commensal:** A species that typically is associated with humans
**Hyporheic zone:** Subsurface saturated sediments along the stream bottom
**Ideal despotic distribution:** A distribution of individuals reflecting high individual fitness in the highest quality patches at lower than expected densities caused by territoriality
**Ideal free distribution:** A distribution of individuals reflecting the freedom of each individual to choose the patch that will provide the greatest energy or other required resources
**Implementation monitoring:** Measurements that document compliance with a stand prescription or management plan
**Incidental take permit:** A permit issued by the USFWS to allow activities that might incidentally harm (or "take") species listed as endangered or threatened under the Endangered Species Act
**Indicator species:** Species that are assumed to be surrogates for other species having similar resource needs
**Individual tree selection:** Removal of one or a few trees from a location in the stand to create a canopy gap to allow tree regeneration to occur
**Induced edge:** Edge between two patch types of different successional condition
**Inherent edge:** Edge formed by differences in the floristic composition of two patches
**Intermediate crown class:** Trees in an even-aged stand receiving partial sunlight from above
**Intra-riparian gradients:** Continuum of conditions from the headwaters to the confluence with larger water bodies
**Intrinsic rate of natural increase:** Each species' potential for population increase
**Lambda:** The population parameter used to estimate population change
**Landscape:** A complex mosaic of interacting patches
**Logistic growth:** As resources become limiting, population growth becomes asymptotic
**Longevity:** The age at death of the average animal in a population
**Marsh:** Wetlands dominated by nonwoody vegetation
**Matrix:** The landscape patch type within which focal patches are embedded
**Matrix management:** Managing the matrix condition to be made more permeable to dispersing organisms

**Metapopulation:** A population distributed among smaller, interacting sub-populations that contribute to overall population persistence

**Mortality rate:** The number of animals that die per unit of time (usually 1 year) divided by the number of animals alive at the beginning of the time period

**Natality:** The number of young individuals born or hatched per unit of time

**Natural catastrophe:** Extreme case of environmental uncertainty such as hurricanes, fires, and epizootics that can cause massive changes in vital rates

**Natural cavity:** Tree hole resulting from fungal decay

**Natural regeneration:** Stand regeneration from seedling establishment or sprouting following the disturbance

**Neotropical migratory bird:** Birds that nest in the northern hemisphere but migrate to the tropics during the winter

**Oligotrophic:** Nutrient-poor aquatic systems

**Orographic effecs:** As air is moved over mountains, it increases in elevation, cools and moisture precipitates

**Orthophoto maps:** Aerial photos corrected for distortion and usually with topographic information superimposed

**Overwood removal:** Final step in a shelterwood regeneration method to release newly established regeneration

**Passive adaptive management:** The "best" management option is identified, implemented, and monitored

**Phreatophytic vegetation:** Vegetation associated with high soil moisture or free water

**Policy analysis:** An organized projection of how implementation of the policy over space and time might affect the resources valued by society

**Population:** Self-sustaining assemblages of individuals of a species over space and through time

**Population viability analysis:** A structured approach to examining population performance based on demographic characteristics and habitat quantity and quality

**Preparatory harvest:** First step in a shelterwood regeneration method to encourage seed production

**Prescriptions:** Silvicultural management plans for stands

**Primary cavity nester:** A species that excavates a cavity in living or dead wood

**Proximate cue:** An element of structure and/or composition that an individual uses to predict resource availability

**Q-factor:** The factor by which the number of trees in one diameter class is multiplied to get the number in the next smallest diameter class in an ueven-aged stand

**Refereed journal:** Scientific literature in which papers are reviewed and can be accepted or rejected based on review by peers

**Response variable:** Specific indicator or metric used to test a hypothesis

**Restoration ecology:** The suite of scientific practices that constitute an emergent subdiscipline of ecology designed to return functions to systems where they have been eliminated

**Riparian area:** The interface between the water and the land

**Riparian associate:** A species that tends to be found more commonly near water but does not require free water directly

**Riparian obligate:** A species that requires free water

**Risk analysis:** A structured way of analyzing the potential effects of decisions when outcomes are uncertain

**Rotation:** A complete growing cycle in an even-aged silvicultural system

**Rotation age:** The stand age when the stand is harvested and a new even-aged stand is regenerated

**Satellite imagery:** Reflectance values collected by satellites for discrete places on the Earth

**Scope of inference:** The space and time over which data can be used to assess changes in a response variable

**Secondary cavity user:** Species that use natural cavities or those created by primary cavity nesters

**Second-order selection:** Establishment of a home range
**Seedbank:** Seeds stored in the soil
**Seedbed:** Growing site for seedlings and sprouts
**Seed-tree regeneration method:** Natural regeneration is established by leaving some trees after harvest to provide a seed source
**Serpentine soil:** A soil enriched in toxic metals, including nickel, magnesium, barium, and chromium, and lacking in calcium
**Shade intolerant:** Plant species that do not survive under low light conditions, and grow well only under full sunlight
**Shade tolerant:** Plant species that can survive under low light conditions
**Shelterwood regeneration:** Natural regeneration needs protection from sun or frost so a light canopy cover is maintained after harvest
**Shifting gap phase:** Forests maintained by frequent small-scale gap disturbances
**Silviculture:** The art and practice of managing forest stands to achieve specific objectives
**Sink habitat:** Habitat patches in which populations are declining or are maintained by immigration
**Site fidelity:** A behavior in which an individual returns annually to the same location despite drastic changes in the habitat
**Site index:** Height of the dominant trees in an even-aged stand at a specified age
**Soft mast:** Soft fruits such as berries and drupes
**Source habitat:** Patches in which individuals are fit enough to support a stable or growing population
**Source patch:** During dispersal, the patch that a disperser is leaving from
**Stand initiation:** Early stage of stand development following a stand-replacement disturbance
**Stand:** Unit of homogeneous forest vegetation used as the basis for management
**Static corridors:** Maintaining connectivity in a fixed location
**Stepping stone:** Small patches of habitat close to one another to enhance connectivity between high-quality patches
**Stocking:** The degree to which a site is occupied by trees of various sizes
**Structure:** Physical features of the environment such as vegetation, soils, and topography
**Suppressed tree:** Trees in an even-aged stand occurring below the main canopy in the stand
**Survival:** The number of animals that live through a time period and is the converse of mortality
**Survivorship functions:** Types 1, 2, and 3 refer to high, medium, and low survival rates of juveniles, respectively
**Swamp:** A wetland dominated by woody vegetation
**Target patch:** During dispersal, the patch that a disperser is going to
**Target tree size:** The diameter class representing the largest harvestable trees in an uneven-aged stand
**Territory:** The space, usually around a nest, that an individual or pair defends from other individuals
**Thermal neutral zone:** The range of ambient temperatures where an animal has to expend the least amount of energy to maintain a constant body temperature
**Third-order selection:** Use of patches within a home range where resources are available to meet an individual's needs
**Trans-riparian gradients:** Changes in conditions as you move from the edge of the stream into upslope forests
**Trophic level:** The feeding position in a food web
**Ultimate resources:** Food, cover, and other resources needed for survival
**Validation monitoring:** Measurements that provide the basis for testing assumptions
**Vernal pools:** Isolated ponds and wetlands that hold water for only a part of the year
**Wolf trees:** Large and often deformed legacy trees from the previous stand

# Appendix 3: Measuring and Interpreting Habitat Elements

Basic to understanding current conditions and desired future conditions in stands and landscapes is measurement and interpretation of habitat elements. This field exercise introduces you to a few simple techniques for measuring the availability of key habitat elements. More comprehensive information on field sampling of habitat elements can be found in Bookhout (1994), James and Shugart (1970), Hays et al. (1981), and Noon (1981).

## METHODS

Some habitat elements are particularly important to many species depending on their size, distribution, and abundance. These include percent cover, height, density, and biomass of trees, shrubs, grasses, forbs, and dead wood. Other habitat elements are associated with only a few species, such as stream gradients (e.g., beaver; Allen 1983) and forest basal area (e.g., downy woodpecker; Schroeder 1982). Visit two areas with very different management histories such as a recent clearcut and an unmanaged forest. Then compare habitat elements between the two stand types and assess the relative habitat quality for a species between them using life history information, a habitat suitability index model, and a geographic information system.

## RANDOM SAMPLING

Probably, the most important part of sampling habitat is to sample randomly within the area of interest (stand, watershed, stream system, etc.). Systematic or subjective sampling can introduce bias into your estimates and lead to erroneous conclusions. In this example you will be sampling two stands. Within your stand you should collect a random sample of data describing the habitat elements. For the purposes of this exercise, you will collect data from three or more randomly located points in each stand.

1. Using a random numbers table (nearly all statistics books have these) first select a three-digit number that is a bearing (in degrees) that will lead you into the stand. If the number that you select does not lead you into your stand, then select another number until you have a bearing that will work.
2. Select another three-digit number that is a distance in meters. Using your compass to establish the bearing and either a 30 m tape measure or pacing, measure along the assigned bearing the randomly selected distance and establish a sample point. You will collect habitat data at this point. Once you have completed collecting data at this point, you repeat the process of random number selection three or more times in this stand and then three or more times in another stand.

## MEASURING DENSITY

One of the most common habitat elements that you will measure is density of items, usually trees, snags, logs, shrubs, or other plants. Density is simply a count of the elements over a specified area. When estimating the density of trees, you usually will count all the trees in a circular plot, usually 0.04 ha (0.1 acre) in size. Saplings and tall shrubs are usually measured in a 0.004 ha (0.01 acre) plot. Small shrubs and tree seedlings are usually measured in a 0.0004 ha (0.001 acre) plot.

1. From plot center, measure out in each cardinal direction (N, E, S, W) 11.3 m (37.2 ft) (the radius of a 0.04 ha [0.1 acre] plot). Mark these places with flagging.
2. Using a diameter tape or a Biltmore stick, measure the diameter at 1.3 m (4.5 ft) above ground of all live trees in the plot that are >15 cm (6 in) dbh (diameter at breast height) and record the species of each tree. Repeat this procedure for all dead trees >15 cm dbh. Expand this sample to 1 ha (or acre) estimate by multiplying the estimates by 25 to convert to a per hectare estimate (or multiply by 10 to get a per acre estimate). This procedure can be repeated for smaller plot sizes to estimate seedling numbers, and so on.

## ESTIMATING PERCENT COVER

Using your four 11.3 m (37.2 ft) radii as transects, walk along each stopping at five equidistant points along each transect. At each of these points, you will estimate canopy cover. There are a number of techniques available to estimate canopy cover, including moosehorns (Garrison 1949) and densiometers (Lemmon 1957). A simple approach to estimating cover is to estimate the presence or absence of vegetation using a sighting tube (a piece of PVC pipe with crosshairs) (James and Shugart 1970). At each of the 20 points on your transects, look directly up and see if the crosshairs intersect vegetation (if so record a “1”) or sky (if so, record a “0”). Repeat this at each of the five points on each of the four transects.

1. Tally the number of “1”s recorded from these points.
2. Divide by 20 to estimate percent cover.
3. How would you use this technique to measure understory herbaceous cover?

## ESTIMATING HEIGHT

Use a clinometer with a percent scale (look through the view finder and you should see two scales, with units given on them if you look straight up or straight down).

1. Measure 30 m (100 ft) from the base of the tree or other object that you wish to measure.
2. Looking through the view finder, align the horizontal line in the view finder with the top of the tree. Record the number on the percent scale (top).
3. Looking through the view finder, align the horizontal line in the view finder with the base of the tree. Record the number on the percent scale (bottom).
4. If the top number is positive and the bottom number is negative (<0) then add the absolute values of these two numbers together to estimate height in feet.
5. If the top number is positive and the bottom number is also positive (>0), then subtract the absolute value of the bottom number from the top number to estimate height in feet.

## ESTIMATING BASAL AREA

Basal area is the cross-sectional area of all woody stems at 1.3 m (4.5 ft) above ground. It is a measure of dominance of a site by trees. The higher the basal area, the greater the dominance by trees. There are two ways to estimate basal area. First, using your estimates of dbh from your sample of trees (see the section on Measuring density, given earlier), you can calculate the area of each stem ($A = 3.1416*r^2$, where $r = dbh/2$). By summing the areas on a 0.04 ha (0.1 acre) plot and then multiplying the total by 25, you can get an estimate of basal area per hectare (multiply by 10 to estimate basal area per acre).

Alternatively, you can use a wedge prism (Figure A3.1). Holding the prism over plot center, look at a tree through the prism. If the image that you see through the prism is connected to the image of the tree outside the prism, then tally the tree and record its species. If the image that you see through the prism is disconnected from the image outside the prism, then do not record the tree. Moving in a circle around the prism that you continue to hold over plot center record all trees that have the prism

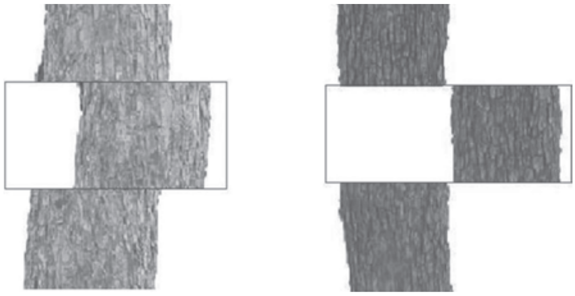


**FIGURE A3.1** When using a wedge prism you have two images to compare—the one you see through the prism and the one above or below the prism. If they overlap you count the tree as an "in" tree. If the images do not overlap then the tree is not counted. (Image from Jesse Caputo. With permission.)

image connected to the image outside of the prism regardless of whether they fall in the 0.1 acre plot or not. Tally up the number of trees that were recorded. Generally you will use a 10-factor prism, that is, each tallied trees represents 10 other trees per acre. Multiply the number of trees tallied by 10 and this estimates the basal area in square feet per acre for this site.

## ESTIMATING BIOMASS

Biomass of vegetation is usually estimated to provide information on food available for herbivores, typically in the winter when browse resources are essential to supporting herbivores (deer, moose, or hares). Herbivores usually will only eat woody growth resulting from the most recent growing season, and during winter, which includes the twigs and buds, but not leaves (which will have fallen off).

Within a 1.1 m (3.7 ft) radius plot, using clippers, clip all of the twigs within the plot that have resulted from the most recent growing season. Remove and discard the leaves and place the twigs in a bag. Return to the lab and weigh the bag with the twigs. Remove the twigs and weigh the empty bag. Subtract the bag weight from the bag + twigs weight to estimate biomass per 0.0004 ha (0.001 acre) plot. Multiply this number by 2500 (or 1000 in acres) to estimate biomass (kilogram) per hectare.

## USING ESTIMATES OF HABITAT ELEMENTS TO ASSESS HABITAT PRESENCE

If you refer to Table A3.1 as an example (you will have your own numbers from your field samples), consider how you would interpret these data for a species of your choice, in this case downy

**TABLE A3.1**
**Comparison of Average and Range of Habitat Elements between Clearcut (with a Legacy of Living and Dead Trees) and Uncut Forests, Cadwell Forest, Pelham, MA**

| | Clearcut | Mature Forest |
|---|---|---|
| Trees >15 cm/ha | 3 (0–6) | 308 (234–412) |
| Snags >15 cm/ha | 1 (0–2) | 22 (4–43) |
| Basal area/ha | 2.4 (0–3) | 16 (12–18) |
| Canopy cover (%) | 4 (0–7) | 95 (90–100) |
| Canopy height (m) | 23 (18–34) | 27 (23–33) |
| Browse (kg/ha) | 1234 (554–2600) | 387(122–788) |

woodpeckers. DeGraaf and Yamasaki (2001, p. 161) describe habitat for downy woodpeckers as: "… woodlands with living and dead trees from 25–60 cm dbh; some dead or living trees must be greater than 15 cm dbh for nesting." Although both sites contain trees and snags of sufficient size, the canopy cover data in Table A3.1 would suggest that the clearcut is not functioning as a woodland and so we would probably not consider it a suitable habitat for downy woodpeckers though they certainly do use snags in openings at times.

## USING ESTIMATES OF HABITAT ELEMENTS TO ASSESS HABITAT SUITABILITY

In addition to using your data to understand if a site might be used by a species, habitat suitability index models have been developed to understand whether some sites might provide more suitable habitat than others (e.g., Schroeder 1982). Very few of these models have been validated especially not using fitness as a response variable. Nonetheless they do represent hypotheses based on the assumption that there is a positive relationship between the index and habitat carrying capacity. If we take the example of the downy woodpecker then its habitat suitability is based on two indices: tree basal area (Figure A3.2) and density of snags >15 cm dbh (Figure A3.3). Considering first the uncut stand, note that there is an average of 16 $m^2$/ha of basal area and 22 snags/ha (8.8/0.4 ha). The corresponding suitability index score for each variable is 1.0 and the overall habitat suitability is calculated (in this case) as the minimum of the two values. Hence, this should be a very good habitat for downy woodpeckers. In the recent clearcut, however, the suitability index for snags is approximately 0.1 and for basal area is approximately 0.2. Hence, the overall suitability in the recent clearcut for this species is 0.1; not very good and certainly less than in the uncut stand. And in this case, snag density is the factor most limiting habitat quality for downy woodpeckers in the recent clearcut. The best way to use these sorts of models is in a relative sense, to compare one site to another. If we were to use this technique for snowshoe hares habitat assessment, then we might find the recent clearcut to be much better habitat.

## ASSESSING THE DISTRIBUTION OF HABITAT ACROSS A LANDSCAPE

It is often as important to know whether stands are a suitable habitat for a species and how they are arranged on a landscape. In Figure A3.4, a 490 ha forest has been broken into habitat types based

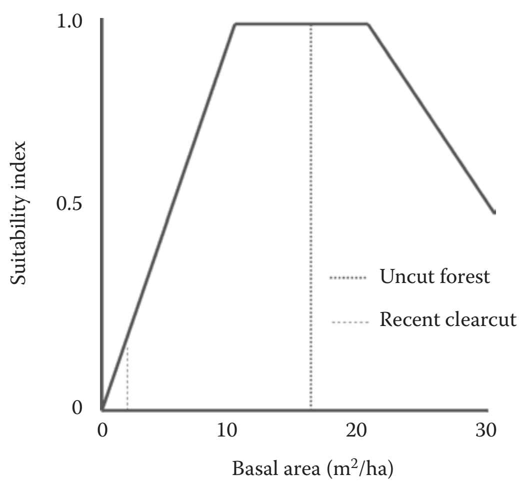


**FIGURE A3.2** Habitat suitability relationship for downy woodpeckers for one of two suitability indices: basal area. (Redrafted from Schroeder, R.L. 1982. *Habitat Suitability Index Models: Downy Woodpecker*. US Fish and Wildl. Serv. FWS/OBS-82/10.38.)

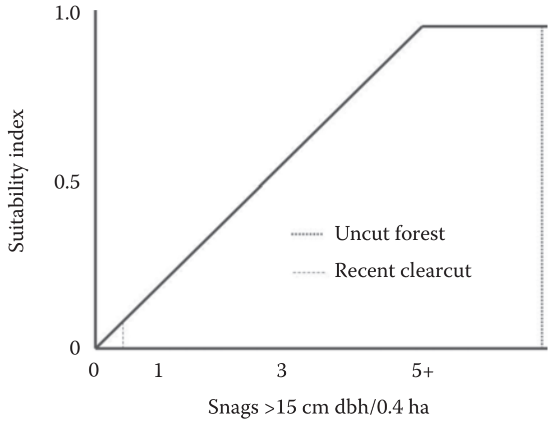


**FIGURE A3.3** Habitat suitability relationship for downy woodpeckers for one of two suitability indices: snag density. (Redrafted from Schroeder, R.L. 1982. *Habitat Suitability Index Models: Downy Woodpecker*. US Fish and Wildl. Serv. FWS/OBS-82/10.38.)

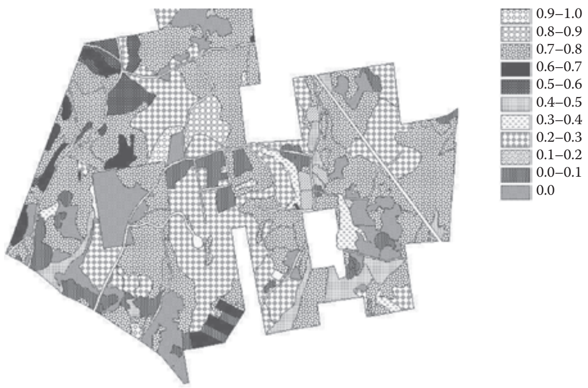


**FIGURE A3.4** An example of a mosaic of habitat patches of varying suitability based on extrapolation of ground inventory data to digitized patches in Cadwell Memorial Forest, Pelham, Massachusetts.

on overstory cover and stand structure. Field samples were taken at 117 points distributed across the forest and habitat elements were sampled at each point. Habitat suitability index values are then calculated at each point and extrapolated to the habitat types as portrayed in this figure to illustrate how habitat availability for a species can be displayed over a landscape. A different pattern would emerge for other species using this same approach, and these would have to be overlain on stands used as the basis for management. In addition, these types of maps can guide harvest planning in order to achieve habitat patterns leading to a desired future condition for the landscape.

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# Appendix 4: Wildlife–Habitat Relationships Models

Since the 1970s, scientists and managers have developed tools that allow them to relate the possible occurrence of a species to a habitat type as the basis for assessing the potential of a unit of land to support populations or communities. A species–habitat-type matrix has long been at the heart of wildlife–habitat relationships (WHR) models such as these, which have been developed for New England, the Blue Mountains, Colorado, the southwestern United States, California, and the Pacific Northwest. These models provide a quick and easy, though not always entirely accurate, ability to relate a species to a habitat type, given knowledge about the structural stage of the habitat type and its location. Each of these models has greater or lesser levels of detail when developing lists of species that could be found in a habitat type or habitat types that a species could be found in. I use a simple hypothetical example of a WHR to illustrate how they are structured and can be used.

## THE CENTRAL HARDWOODS EXAMPLE

I use a subset of habitat types and a subset of species to illustrate how a WHR might be developed and used. In this simplified example, consider three habitat types:

Grasslands—areas dominated by herbaceous vegetation, including grasses, sedges, and forbs
Mixed mesophytic hardwoods—upland hardwoods often with 20 or more species represented per acre
Upland coniferous forest—forests dominated by pines and hemlock

Within the two forested habitat types, we can define four structural states of stand development:

Seedling shrub—woody vegetation <2 m tall
Sapling/pole—woody vegetation >2 m tall but <20 cm in dbh (diameter at breast height)
Sawtimber—woody vegetation 20–50 cm dbh
Old-growth—woody vegetation representing a range of tree sizes with some trees per hectare >50 cm dbh

I then created a matrix of these conditions and whether or not each of the following species was likely to be found in that habitat-type–structural-condition combination: American goldfinch, Chestnut-sided warbler, Pileated woodpecker, Pine warbler, eastern meadowlark, wood thrush, and black bear. Within this simplified system, we can see that we would expect three of these species to occur in grasslands and four to occur in old-growth conifer forests, and that they would be a different set of species (Table A4.1). So if we applied this model to a forest in southern Indiana, then we would be outside the geographic breeding range of Chestnut-sided warblers and pine warblers might be uncommon (Figures A4.1 and A4.2). So although the model can generate a list of species, the user must assess whether the site being assessed is within the geographic range for the species. However, we can also add value to this simplified assessment of potential occurrence of a species by asking how each habitat type might be used by a species. For instance, a black bear might use a seedling stage of forest for feeding, but an old-growth stage for denning. By designating use of each type-condition combination with an “F” or a “D” rather than an X we know more about how the species could use the habitat type. Some models have further refined this attribution

**TABLE A4.1**

**Simplified WHR Model for a Few Habitat Types and a Few Species from the Central Hardwoods Region**

| *Habitat Type* | Grassland | Hardwood | Hardwood | Hardwood | Hardwood | Conifer | Conifer | Conifer | Conifer |
|---|---|---|---|---|---|---|---|---|---|
| *Structural Stage* | Grassland | Seedling | Sapling | Sawtimber | Old-growth | Seedling | Sapling | Sawtimber | Old-growth |
| *Species* | | | | | | | | | |
| Rough green snake | x | x | | | | x | | | |
| American goldfinch | x | x | | | | x | | | |
| Chestnut-sided warbler | | | x | | | | x | | |
| Pileated woodpecker | | | | x | x | | | x | x |
| Pine warbler | | | | | | | | x | x |
| Eastern meadowlark | x | | | | | | | x | x |
| Wood thrush | | | | | | | | | |
| Black bear | | x | x | x | x | x | x | x | x |
| Total species | 3 | 3 | 2 | 2 | 2 | 3 | 2 | 4 | 4 |

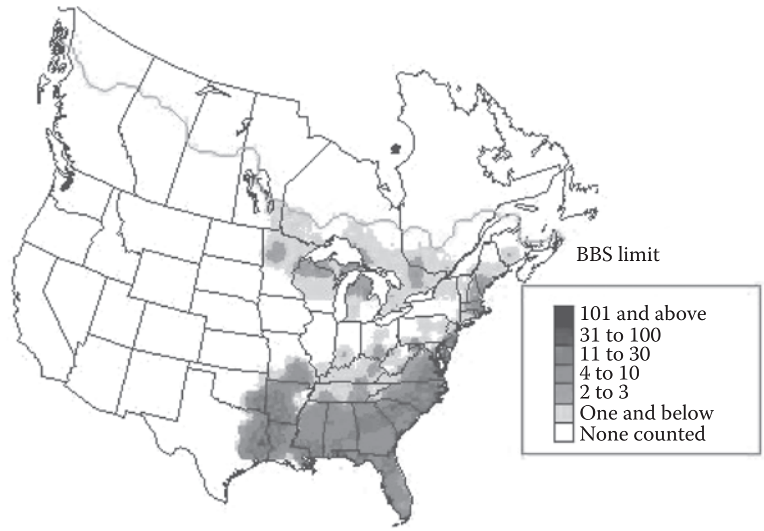


**FIGURE A4.1** Geographic distribution of pine warblers in the summer. (From Sauer, J.R. et al. 2012. *The North American Breeding Bird Survey, Results and Analysis 1966–2011.* Version 07.03.2013 USGS Patuxent Wildlife Research Center, Laurel, MD.)

to identify primary and secondary habitat types, where grasslands may be a primary type for goldfinches and seedling stage forests may be secondary, or less commonly used. It might also be important to know whether certain habitat elements are present, such as snags. If we knew that the conifer-sawtimber condition did not have snags >40 cm dbh, then we might conclude that although the habitat type is adequate for feeding pileated woodpeckers, they would be unlikely to nest there. Some WHR models add considerable detail with regard to habitat elements (e.g., Johnson and O'Neil 2001), while others recognize the importance of habitat elements but do not include some of them explicitly within the model (DeGraaf and Yamasaki 2001).

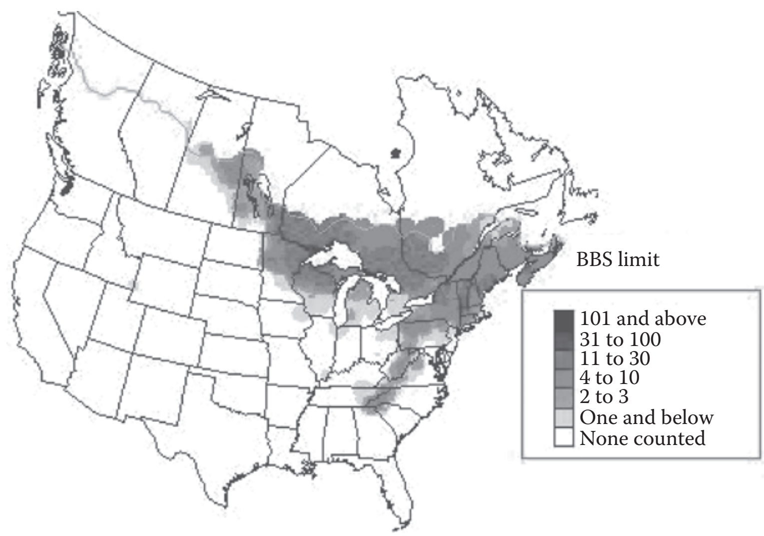


**FIGURE A4.2** Summer geographic range for chestnut-sided warblers. (From Sauer, J.R. et al. 2012. *The North American Breeding Bird Survey, Results and Analysis 1966–2011.* Version 07.03.2013 USGS Patuxent Wildlife Research Center, Laurel, MD.)

## VALUES AND CAUTIONS OF USING WHR MODELS

Given the fact that each species has its own niche and habitat requirements, how well can an approach like this represent habitat for a suite of species? As a first-level assessment of the potential for a site to support species x, y, or z, it may be useful to identify focal spcies that may need greater attention in a fine filter analysis. Further, if you know that your management actions are likely to shift a stand from one structural stage to another, then the model can be used to provide an estimate of the potential impacts on species found in that area. For instance, in our simple example, if we clearcut a hardwood sawtimber stand, we likely would lose pileated woodpeckers, gain goldfinches and rough green snakes, and black bears would continue to use the site (although for different reasons). What this does not tell us is that goldfinches would be most likely to use the clearcut if thistles (a source of food) were present in the clearcut and that black bears may use the site if it is not too close to people. A WHR model is not a substitute for an approach that identifies the habitat elements important to a species and describes habitat based on the collection of habitat elements needed to support the species. But WHR models can be a first step toward developing more species-specific habitat models.

Because WHR models do not necessarily include all of the habitat elements important to each species that tests of WHR models document errors of omission (species predicted to occur on a site but were not found there) and commission (species were not predicted to occur on a site but were found there). Edwards et al. (1996) reported error rates of 0%–33% among eight national parks in Utah, while Block et al. (1994) reported error rates from 6% to 42% in California. Errors of commission are usually unknown unless independent field verification such as the study conducted by Block et al. (1994). Although WHR models may be useful for large-scale conservation planning, their use for site-specific planning is limited due to these high error rates in some situations and because geographic ranges and detailed habitat elements are not included in some WHR models (the California WHR models now interface with GIS for more accurate representation of species geographic ranges however). Hence, WHR models should be used with caution and the species lists that are derived from them should be assessed carefully to minimize errors of omission.

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# Appendix 5: Projecting Habitat Elements through Time

Once a manager has defined a desired future condition (DFC), then it is important to know whether it is possible to achieve that condition given the mix of plant species on the site and their capacity for growth. If achievement of the DFC is possible, then the manager will need to know what actions will likely be needed and when to achieve the goal and what costs and incomes might be accrued along the way. The U.S. Forest Service developed the forest vegetation simulator (FVS) as a decision support tool for forest managers to use as part of stand and forest plan development (Crookston and Dixon 2005). Because the model has tree growth and mortality functions for most common tree species and because growth varies regionally, FVS has variants designed to simulate the growth of forests in regions across the United States. FVS is a single tree growth and mortality model, meaning that the growth simulations are based on field measurements of a sample of individual trees in a stand.

The model is widely used by public agencies and NGOs and some industries because it is adaptable to a variety of conditions and its ability to use some of the output of the model to understand economics, habitat elements, fuels, and carbon sequestration, among other values associated with forests. Snag dynamics have also been incorporated into some variants of FVS. Further, recent advances have allowed the simulated stand characteristics to be visualized as idealized cartoons of stand structure and composition so that stakeholders can envision what the future conditions might look like, offering a valuable tool for stakeholder input during forest planning.

Although FVS is commonly used to simulate growth of a stand, using FVS to simulate growth of multiple stands simultaneously across a landscape is also possible. The landscape management system (LMS) incorporates FVS (as well as several other growth models) into an overall forest simulation decision support system (Oliver et al. 2012). When landscape visualization is overlain on a topographic map displayed in three dimensions using a digital elevation model, then stakeholders can not only view stands but also landscape change through time from any point in three-dimensional space (Oliver et al. 2012). In this overview of forest stand projection, I first introduce you to simulating stand changes over time and then discuss how these are integrated over landscapes.

## INPUTS

In order to simulate growth of a stand, we need information about the stand and about the trees in the stand. Characteristics of the stand include its location, site index (height of the dominant trees at 50 years of age), stand age (for even-aged stands), slope, aspect, elevation and size (ha), as well as the year that the data were collected to represent current conditions in the stand. In addition, a random sample of trees from the stand must be measured to represent as much as possible all other trees in the stand. See Appendix 3 in this book for examples of how these data can be collected or refer to a text book of forest measurements (e.g., West 2009). For each tree, you record the species, dbh (diameter at breast height), height, and crown ratio (proportion of the tree with living branches), as well as the expansion factor or the number of trees per hectare that each sampled tree represents (e.g., samples from a 0.1 ha plot would have an expansion factor of 10). These data allow the model to represent the current condition of the stand as the basis for all simulations of future conditions.

## PROJECTIONS

Usually the first simulation is simply to grow the stand without any management and assess the changes in conditions over time. I use an example from a stand on the Oregon State University Forests as an example (Figure A5.1) that is two-story stand with a large 20-year-old cohort and scattered 100-year-old trees. Note that the model allows the user to visualize the stand as well as the diameter and height distributions. In addition to the visualization, tables are available to understand basal area, carbon sequestration, vertical structure, fire risk, habitat suitability for selected high interest species, tree species composition, volume tables, and wind hazard assessment for live trees and for dead trees (e.g., snags per acre by size class). Simulating growth of the stand for 50 years results in a different stand structure (Figure A5.2) and the resulting tables tell us that the basal area has increased from 140 to 313 $ft^2$/acre during that time, and the average tree has increased diameter from 12 to 22 in dbh. The number of trees per acre has dropped from 119 to 90, with 29 snags per acre produced during that time. Note that the model does not simulate growth of shrubs or herbs. At this point in the simulation the planner/manager should be asking, "Does this simulation seem realistic?" If so, then additional simulations with management actions can be attempted to understand achievement of a DFC. If not, then the underlying parameters in the model may need to be adjusted to more accurately represent conditions on your site.

## TREATMENTS TO ACHIEVE A DFC

Let us assume that we define a DFC as a stand with three age cohorts of trees, the oldest of which is 200 years of age, and with both hardwoods and conifers represented in the stand, and with five snags >20 in dbh. One first treatment would be to thin the 20-year-old trees to a level to which

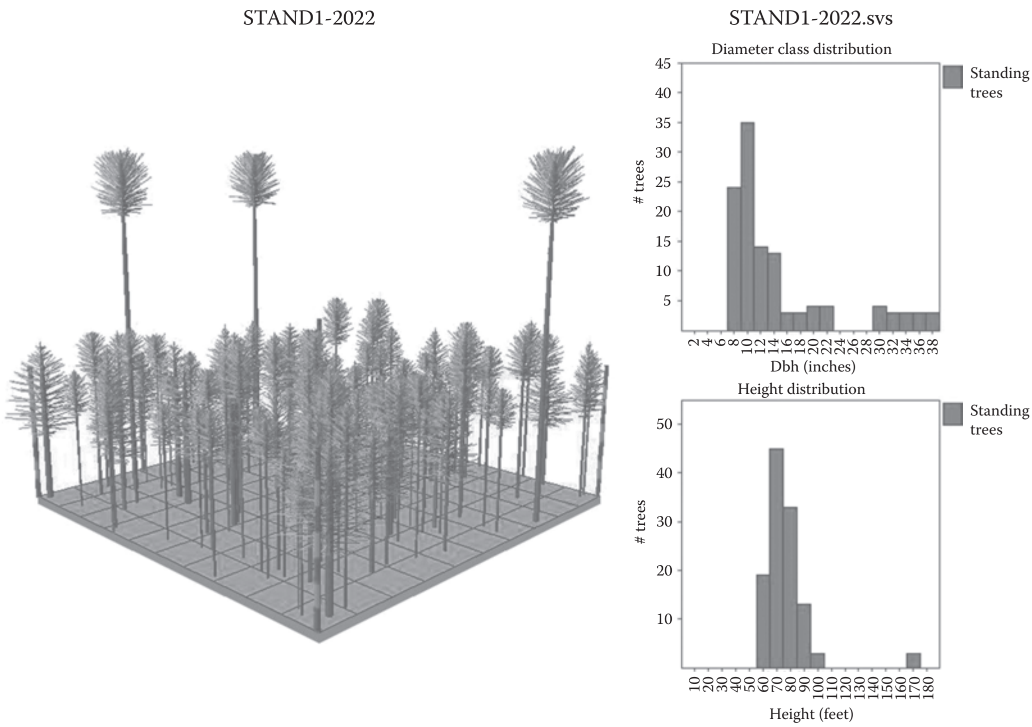


**FIGURE A5.1** Example of a two-story stand 20 years after establishment on McDonald Forest, Corvallis, Oregon, and projected using stand inventory data. (Based on simulations from the Landscape Management System; McCarter, J.M. et al. 1998. *Journal of Forestry* 96(6):17–23.)

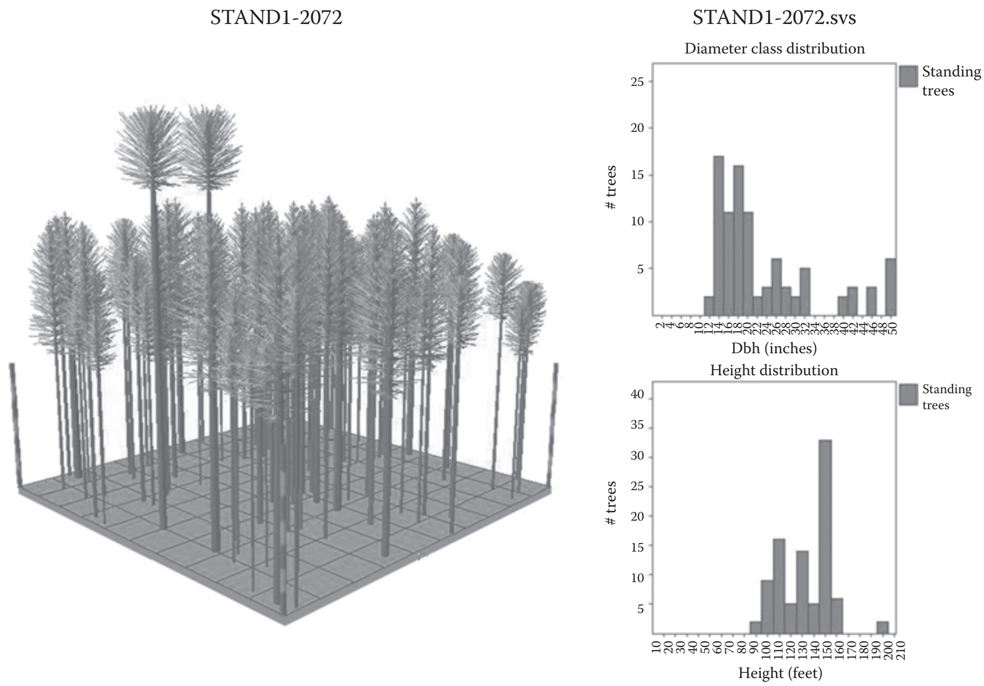


**FIGURE A5.2** Example of the stand illustrated in Figure A5.1 projected 50 years into the future. (Based on simulations from the Landscape Management System; McCarter, J.M. et al. 1998. *Journal of Forestry* 96(6):17–23.)

regeneration would become established and receive enough sunlight to grow. I simulated a thin to 30 trees/acre and then planted or relied on natural regeneration of red alder and bigleaf maple (Figure A5.3), which leaves the stand looking very sparse, but allowed removal of 93 thousand board feet of Douglas-fir, which, if sold for \$500/ thousand board feet, would generate \$46,500 based on the harvested volume tables provided by the model. Projecting the stand 50 years into the future, we see a three-storied stand with the lower story consisting largely of hardwoods (Figure A5.4). If there were insufficient snags >20 in dbh, then there are 13 live trees per acre >20 in dbh available to create snags if needed. In fact, the DFC would have been met within 30 years following the harvest. The question then is, how long would this condition persist? Projecting stand growth another 50 years suggests that the stand complexity would persist and potentially increase over the 100 years following the initial harvest, and at that time, there would be 88 thousand board feet per acre, 160 trees/acre, with Douglas-firs as large as 70 in dbh and red alders as large as 18 in dbh.

## COMPARISONS

Of course the approach that I took to achieve the DFC is not the only way to get there and may not even be acceptable to some stakeholders. Repeated lighter thinning may be preferable to one heavy thin. Or a different species mix of regeneration may be desired. Or more income may be required. By simulating different types of treatments at different times, comparisons can be made among multiple approaches to achieve the DFC and then the approach acceptable to stakeholders can be used as the basis for developing a stand management plan.

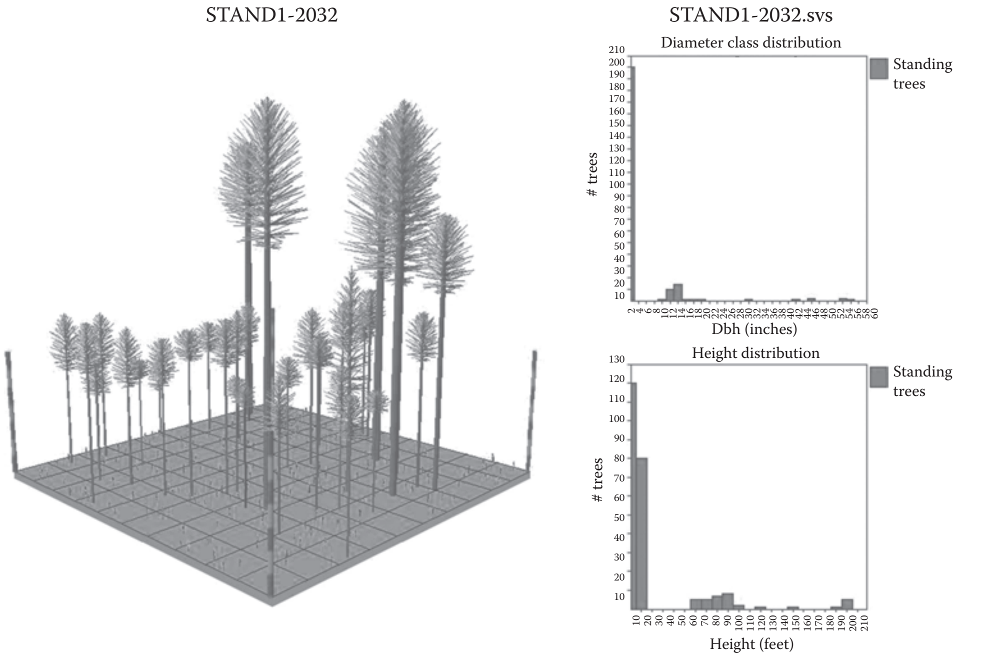


**FIGURE A5.3** Example of the stand illustrated in Figure A5.1 thinned and planted to establish a third cohort of trees. (Based on simulations from the Landscape Management System; McCarter, J.M. et al. 1998. *Journal of Forestry* 96(6):17–23.)

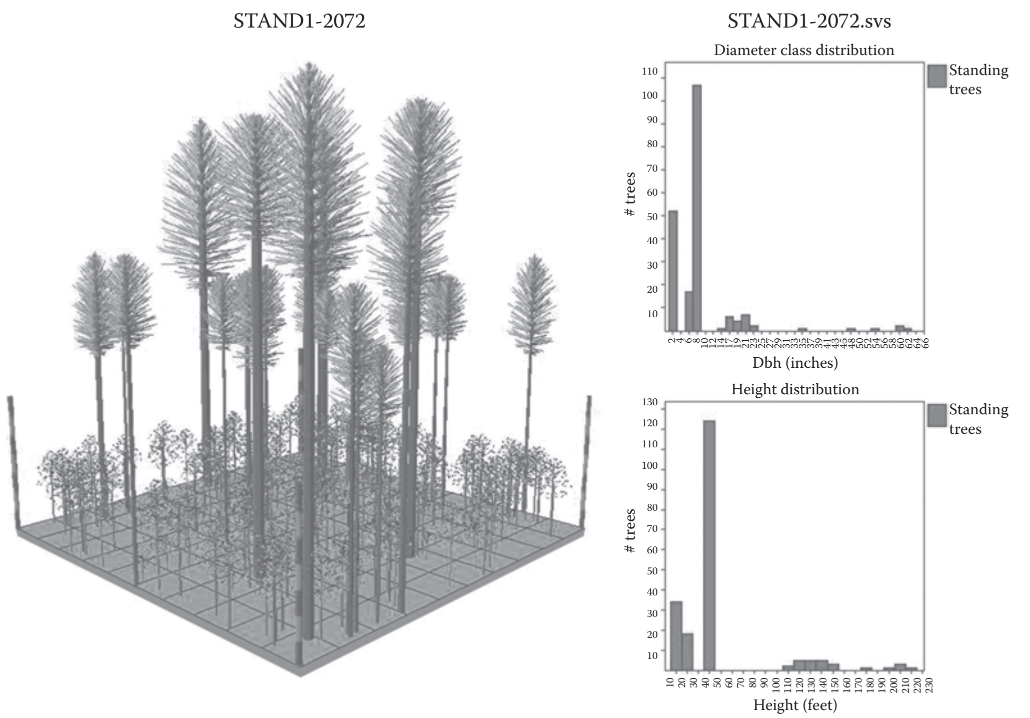


**FIGURE A5.4** Example of the stand illustrated in Figure A5.3 thinned projected 50 years into the future. (Based on simulations from the Landscape Management System; McCarter, J.M. et al. 1998. *Journal of Forestry* 96(6):17–23.)

## INTERPRETATION OF HABITAT ELEMENTS

Although some habitat elements such as tree species, tree size, snag abundance and size, and fallen log accumulation can be estimated directly from the tabulated output from the model, other elements must be inferred. For instance, canopy cover can be estimated from the model and used as a surrogate for the potential of the stand to support shrubs and herbs. As the canopy closes, it is likely that shrubs and herbs will decline. As more large and old trees persist in the stand, there is a greater likelihood that some will contain rot and be more likely to form tree cavities as den sites. Hence the ability to fully understand that a DFC might develop is limited using these models, but knowledge of stand dynamics is useful in making inferences.

## STOCHASTIC PROCESSES AND UNCERTAINTIES

Most growth models such as FVS do not explicitly include effects of stochastic processes such as wind, fire, defoliating insects, droughts, floods, and similar events as processes affecting stand development. But clearly these events do occur; so the simulations of stand development are merely representation in the absence of coarse scale disturbances that would cause tree mortality significantly greater than might be found from inter-tree competition mortality. Consequently, it is important to remember that the farther into the future you simulate stand development the more likely one of these stochastic events is to occur, which could significantly affect your ability to achieve a DFC. Simulations such as these are useful to develop plans and modify plans as stands develop but managers realize that unexpected disturbances may cause them to have to plan again following a disturbance.

## PROJECTING LANDSCAPES

Projecting landscape change using LMS is largely a function of simulating the dynamics of many stands simultaneously, something that LMS is designed to do as a part of a planning process. Additional information is needed to describe the location, shape, and position of each stand on the landscape and that information is imported from a Geographic Information System such as ArcGIS. By exporting the digital elevation model and the shape files for each stand, the visualization for each stand is overlain on the landscape (Figure A5.5). By adjusting your position in Envision (the

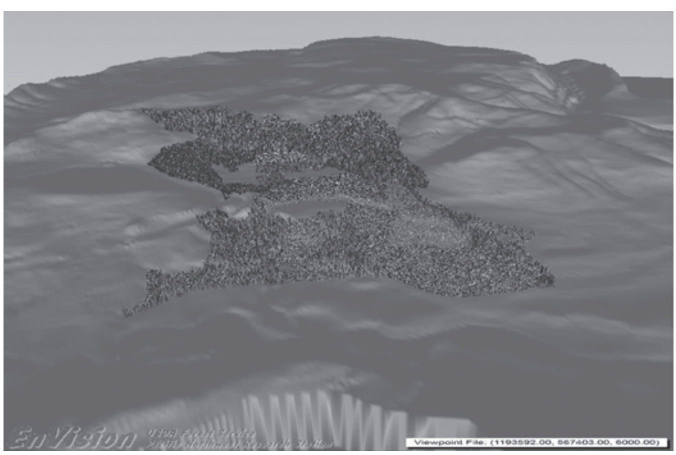


**FIGURE A5.5** Example of multiple stands simulated across a landscape. (Based on simulations from the Landscape Management System; McCarter, J.M. et al. 1998. *Journal of Forestry* 96(6):17–23.)

visioning tool created by the U.S. Forest Service), you can look at the landscape from different points around it and above it to understand what stakeholders might see. Further tabular data allow a comprehensive landscape level understanding of the availability of habitat elements over the planning area over time.

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