Chapter 13: Monitoring

Monitoring is an important element in any properly conducted restoration project. Too often, however, restoration projects are put in place and monitored poorly if at all. Failure to follow up on a project obviously results in a lack of information on how well the project is succeeding in meeting its objectives. Success criteria (as discussed in Chapter 2) can only be evaluated through a program of monitoring. The lack of monitoring also eliminates the chance for promptly carrying out post-planting corrective measures (midcourse corrections) that may save a project. Furthermore, the failure to monitor projects may result in repeating mistakes in future projects.

Monitoring does not always have to be sophisticated and expensive to be effective. Simply walking through a restoration site may be enough to spot some problem that needs to be remedied, such as excessive weed competition, damage to a fence, herbivory problems, or a malfunctioning water control structure. To be most effective, this type of monitoring should be done frequently at first (at least monthly), especially if extensive earthmoving or hydrologic modifications were done, or the site is an area subject to human disturbance.

When designing a monitoring program involving the collection of quantitative information, five things should be considered carefully: (1) what is the purpose of the monitoring program? (goals which are tied directly to success criteria should be specified), (2) what are the most appropriate methods for achieving the goals? (3) how should the data be handled and analyzed? (4) how will the data be interpreted (and who will do the interpretation)? and (5) when will the monitoring program achieve its goals and be terminated? Two guiding principles should be to keep the program as simple as possible and to collect data only if it meets a specific need and addresses a specific success criterion. It should also be kept in mind that because of the relatively long-term nature of many monitoring projects, personnel will change over time. Good records should therefore be kept on all aspects of the program, including sampling protocols, plot locations, and information on how and where data are stored.

Vegetation Monitoring

A wide range of techniques developed by plant ecologists and foresters is available for use in vegetation monitoring. Most of these techniques are based on the sampling of vegetation along transects and/or in plots. Some of the most commonly used measures of vegetation abundance or plant performance are summarized in table 13.1. In general, an effective monitoring program will use a combination of absolute measures of abundance and selected measures of performance.

If transects or plots are used, they should be permanently marked because remeasuring the same area each time will provide information on trends in survival and plant performance. Sections of PVC pipe placed at either end of transects or in plot centers works well in most cases, especially where vandalism is not a major problem. Plots and transects should also be located in a truly random or systematic fashion, not selected subjectively.

One example of a simple, inexpensive, and yet appropriate monitoring system is that used by the Louisiana Department of Wildlife and Fisheries to evaluate the survival of their direct-seeded reforestation sites. They establish 50-ft (15.2 m) transects along every third row at the time of planting. The transects are marked with five flags; some of the flags are tagged in such a way that the exact position of the transect can be relocated if one or more flags are lost. The transects are established so they stretch out either diagonally across the field (fig. 13.1) or in another arrangement that captures the variability of topography within the field. In late summer and again 2 or 3 months later, at the end of the first growing season, the seedlings along these transects are counted. If the average number of seedlings per transect is below the target of three, then the field may be replanted. Since the only stated goal of these restoration projects is reestablishment of the hard mast producing species that were actually planted, there is no need for more extensive monitoring. The decision to replant a site should only be made after consideration of the fact that many seedlings may be difficult to see (hidden by herbaceous vegetation, delayed germination of direct-seeded acorns, clipped by rodents but retaining living roots, etc.). It is usually advisable to wait until at least 3 to 5 years post planting before evaluating seedling survival and stocking rates.

An example of a somewhat more complicated and expensive vegetation monitoring system is that used by Agrico Chemical Company on their Morrow Swamp restoration site in central Florida. They established a system of 12 permanent belt transects (elongated quadrats) that are 29.5 ft (9 m) in width and from 300 to 900 ft (90-275 m) in length (fig. 13.2). All trees were measured for height and crown diameter and classified into one of seven categories based on the tree's condition (live, stressed, tip dieback, basal sprouts, apparently dead, dead, and missing). The transects are measured annually, and the data are summarized in a series of tables and graphs (fig. 13.3).

Where reference wetlands have been used as a guide for designing the restoration project, various indices can be employed to compare the reference and restoration

Table 13.1. Measures of vegetation abundance and plant performance that can be used for monitoring.

Abundance measures	**Description**
Presence or absence of vegetation	This is a simple list of what species are present without more specific information on abundance.
Presence or absence of vegetation combined with frequency estimates	In addition to listing species present, an estimate of frequency (e.g., common, occasional, rare) is made. Simple, but relatively imprecise.
Absolute measures	
Density	Number of individuals per unit area. Easy to use with trees but difficult with herbaceous plants.
Cover	Proportion of ground covered by a species (should be envisioned as a vertical projection of the species to the ground). Often estimated by eye, although this can be inaccurate, and results will vary from worker to worker.
Biomass/yield	Usually involves destructive sampling of plots to obtain dry weight estimates for each species. Cannot be recommended for restoration projects unless samples are small or biomass/yield can be accurately estimated from variables such as plant height and diameter.
Basal area	Cross-sectional area of each species per unit area (e.g., ft^2/acre). Widely used for tree and shrub species.
Nonabsolute measure	
Frequency	The proportion of plots containing a particular species. Simple, but results may vary with plot size and sampling intensity.
Measures of plant performance	
Growth	Most commonly defined as height or diameter growth.
Mast/seed production	Could include proportion of individuals producing seed and/or a quantitative measure of seed production (i.e., yield).
Indicators of plant health or damage	Possible indicators include evidence of branch dieback, defoliation, nutrient stress, and fire or browsing damage.

sites. These include simple tallies of the number of species on each site (species richness) and more complex diversity and similarity indices. Index values should be evaluated with caution, however. High species richness or diversity, for example, may be due to the presence of weeds and undesirable exotic species. It is therefore advisable to limit some index comparisons to those preferred species that are typical of mature, undisturbed forest. Also, such indices are of limited use for most restoration projects because of the large differences that naturally occur between forests in early successional stages (the project site) and mature forests (the reference sites).

Hydrologic Monitoring

On restoration sites with minimal disturbance, qualitative monitoring of hydrology may be adequate. Hydrologic monitoring could involve visiting the site during seasons when flooding or saturated soils are expected to occur, or inspecting the site at other times for evidence that the hydrology is adequate (e.g., drift lines, sediment deposited on leaves, water lines on trees).

The use of quantitative monitoring techniques is worthwhile for projects on heavily disturbed sites. Staff gages, piezometers, and shallow monitoring wells (fig. 13.4) can be used for measuring water table levels and/or groundwater flow directions. Staff gages provide a measure of standing water above the soil surface. They are inexpensive, easy to install, and easy to read. Piezometers, which are screened for water entry (and sediment exclusion) only near their bottom end, are used to measure the potentiometric surface, which is not necessarily the same as water table level. These data are used to determine groundwater flow directions and water levels (pressures) below a confining layer in the soil. Piezometers are especially useful for monitoring contaminant movement (Freeze and Cherry, 1979). Shallow monitoring wells are screened along most of their length and are useful for measuring the water table depth in soils without a confining layer. Great care must be exercised

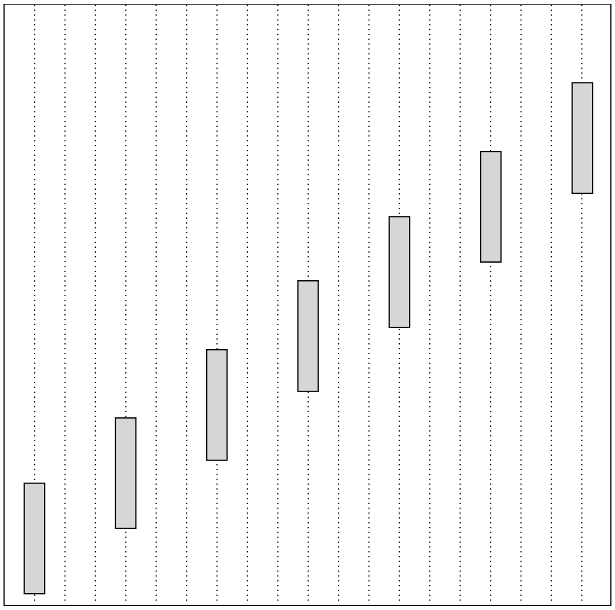

Figure 13.1. Diagonal layout of sample transects across a direct-seeded field.

in the installation of monitoring wells (Sprecher, 1993). If a well is installed through a confining layer, such as a clay layer, water may be able to flow through the well casing from a perched aquifer above the confining layer into a lower layer below the clay, resulting in bad data and possible damage to the local wetland.

Staff gages, piezometers, and monitoring wells should be distributed to cover the range of hydrologic variability within the restoration site. As an example, figure 13.5 shows the placement of piezometers and staff gages on a phosphate mine reclamation site in Florida. Readings of these gages and wells should be taken on at least a monthly basis for the first year of most projects. The actual measurement interval will depend on the hydrologic regime, soil type, topography, and type of study.

In some cases periodic water level measurements may be inadequate, and more frequent monitoring will be necessary. Several methods are available to provide continuous measurements of above- or belowground water levels. Chart type water level recorders have been used extensively in the past. These recorders typically use a chain/cable and weight attached to a float in a stilling well. As the float moves up and down with water levels, a chart is rotated under a pen and water levels are recorded on the scaled chart. The main shortcoming of these types of recorders is that they are relatively expensive and can only measure one variable (water level) at one location. Another disadvantage is that the data on the chart must be read and recorded separately, adding another step and delay in making the data available. Updated (and more expensive) versions of these recorders that log the measurements electronically are also available.

More recently, dataloggers have been used extensively for recording water levels and numerous other variables, such as wind direction and speed, total solar radiation and/or photosynthetically active radiation, temperature of the air, soil or water, relative humidity, precipitation, etc. A good quality datalogger can be obtained for about the same price as a chart type recorder, but individual probes push the cost somewhat higher. Although some probes such as air/water/soil temperature probes are inexpensive at about $70 each, other probes such as commercially available water level sensors can be quite expensive at about $600 each. Inexpensive water level sensors can, however, be constructed using readily available materials for about $60 or less each (Keeland and others, 1997).

Many researchers have started using single purpose water level recorders, such as the WL-40 or WL-80 manufactured by Remote Data Systems (fig. 13.6).

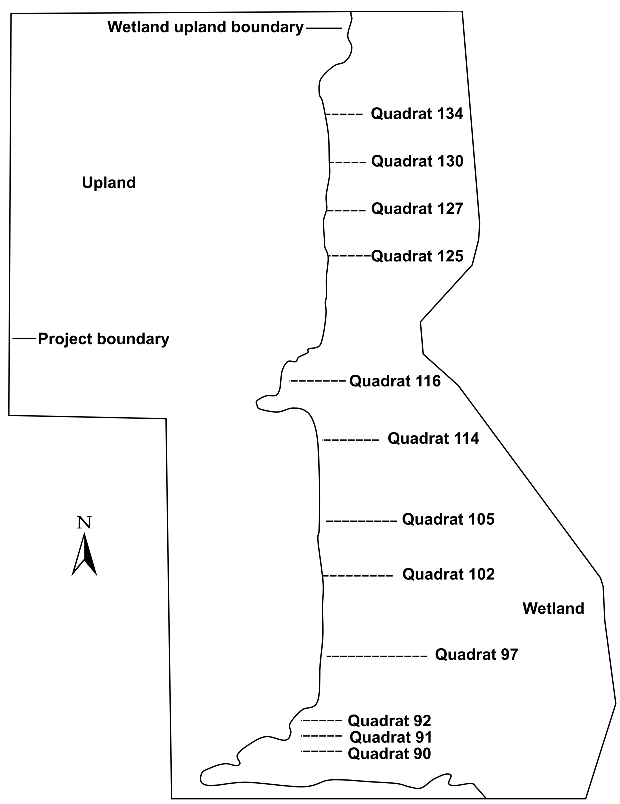

Figure 13.2. Location of forest reclamation strip quadrats at the Morrow Swamp (Agrico Swamp West) restoration site (from Kevin L. Erwin, Consulting Ecologist, Inc., 1990).

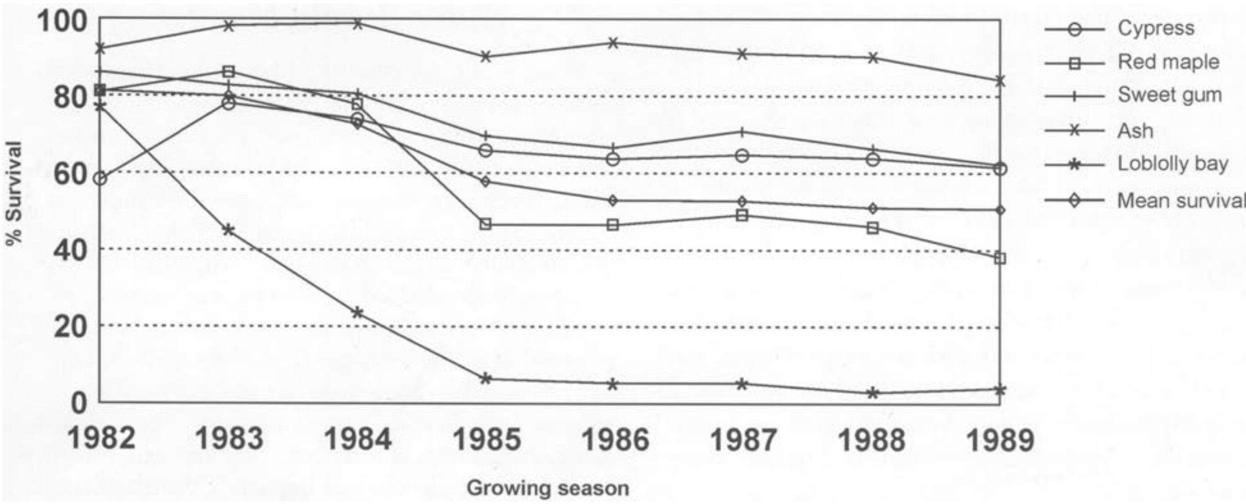

Figure 13.3. Tree survival trends at Morrow Swamp (Agrico Swamp West) restoration site (from Kevin L. Erwin, Consulting Ecologist, Inc., 1990).

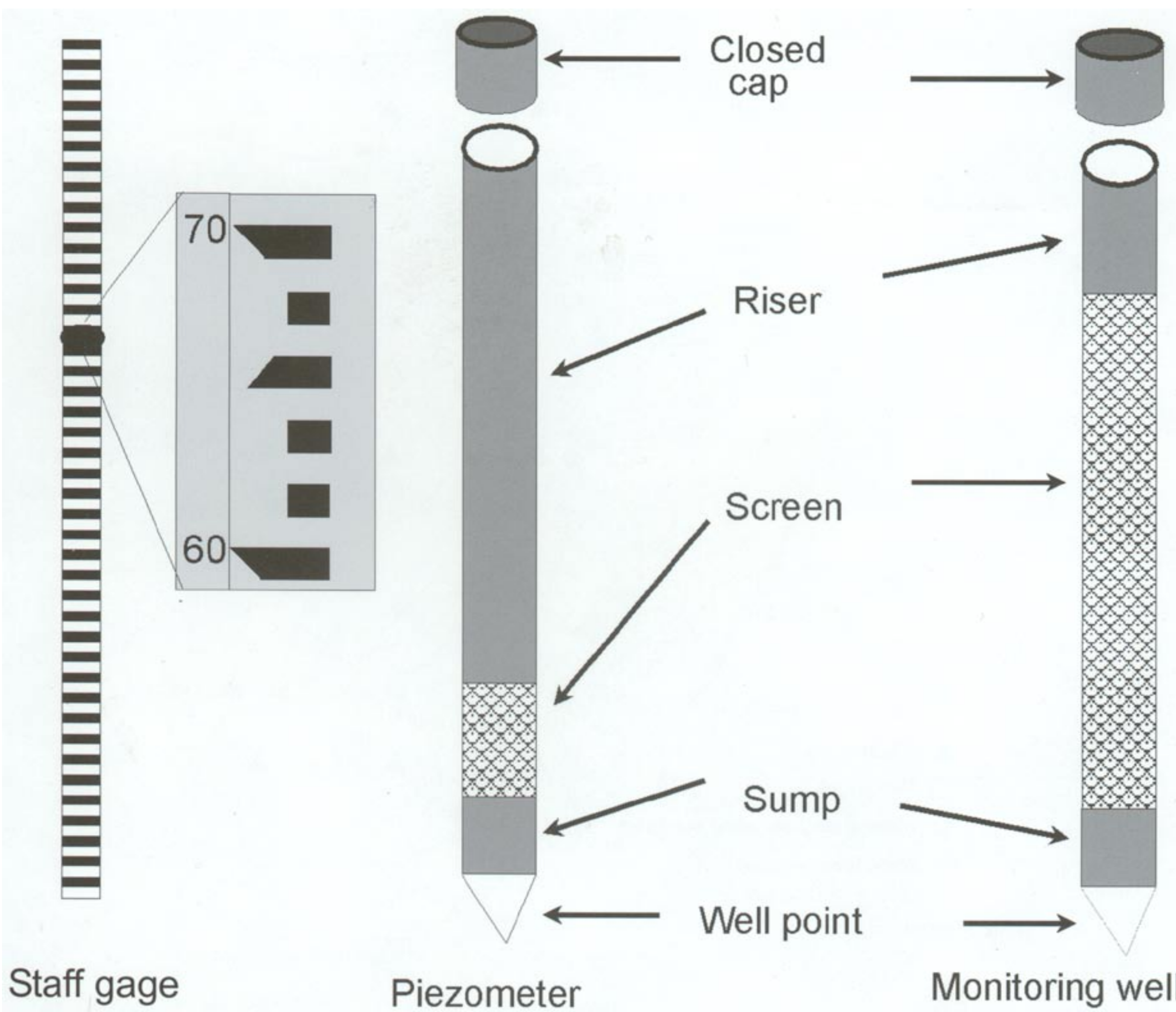

Figure 13.4. Staff gages, piezometers, and monitoring wells can be used to determine the pattern of flooding (hydrologic regime) of a restoration site. Such piezometers and wells can be purchased commercially or made from PVC pipe.

An advantage of these instruments is the ease of data downloading, which is accomplished with a hand held calculator using an infrared-light communications pathway. The instruments can be easily camouflaged (do not use paint for camouflage as it may block the water entry pathways) in field situations where tampering may be likely. A disadvantage is that they only work over a limited range (1 or 2 m - 40 or 80 inches) and are almost as expensive as the chart type recorders or more capable dataloggers which work over a much wider range of water levels. In areas with a limited range of water level fluctuations, single purpose water level recorders are probably the instrument of choice, but in riverine sites where water levels fluctuate more than 2 m, they may not be adequate.

Water Quality Monitoring

Water quality monitoring of bottomland hardwood restoration projects may be required to demonstrate compliance with state water quality regulations; otherwise, monitoring will be useful primarily in those cases where specific problems are anticipated. Examples of water quality parameters that may be measured include pH, alkalinity, dissolved oxygen, nitrogen, phosphorus, turbidity, suspended solids, total organic carbon, presence of heavy metals, water temperature, redox potential, specific conductance and/or salinity, etc.

Considerations for a water quality monitoring program include measurement protocols (these should generally conform to Environmental Protection Agency standards), sample size and frequency, distribution of

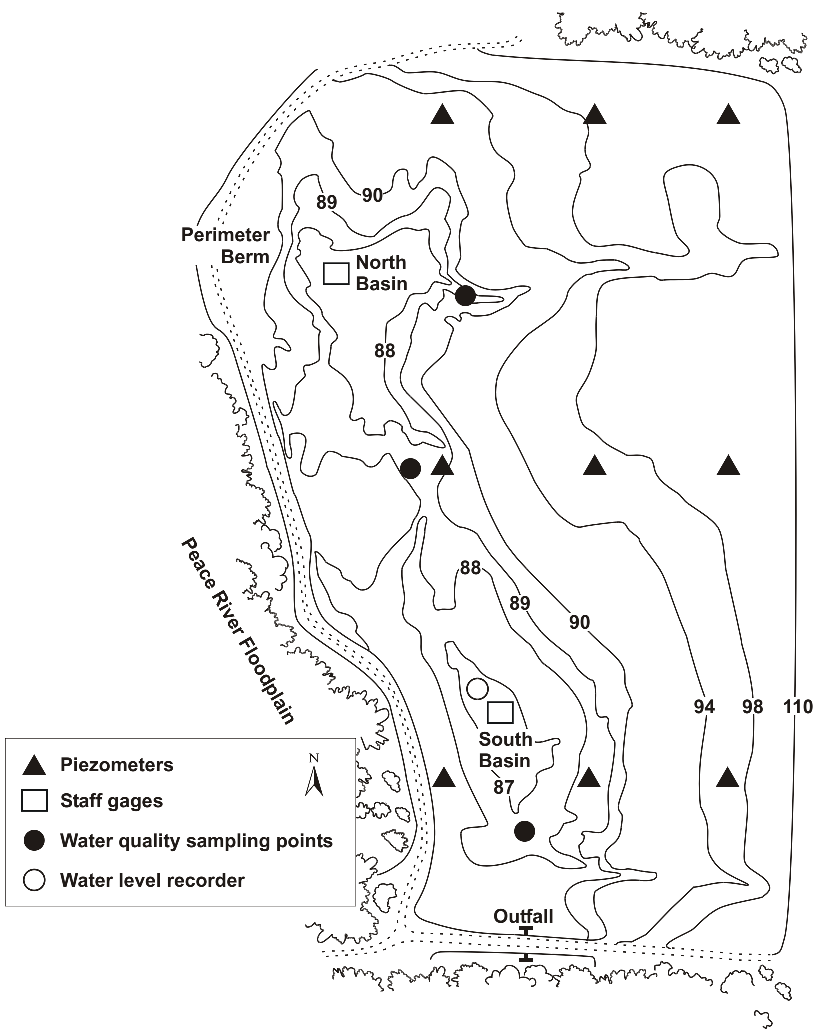

Figure 13.5. Placement of piezometers and staff gages on a reclaimed phosphate site in Florida (from Kevin L. Erwin, Consulting Ecologist Inc., 1990).

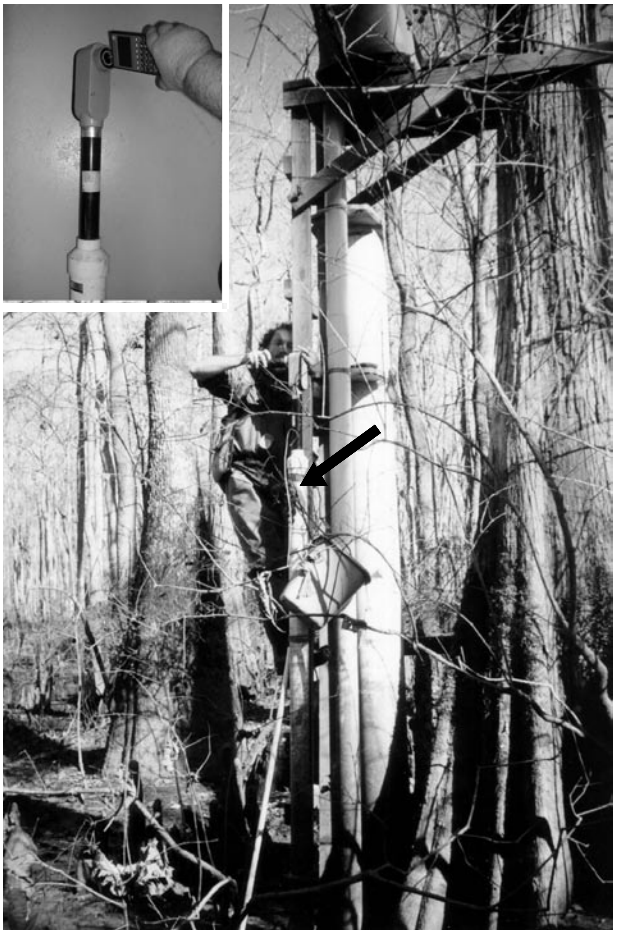

Figure 13.6. Example of an automated, single purpose water level recorder, the WL-80 being downloaded. The WL-80 (arrow) is mounted next to the stilling well of a Stevens type recorder. Inset shows the head of the WL-80 and the calculator used for downloading.

sampling stations, and the availability of a suitable site for comparison (i.e., a reference site or a suitable upstream location). The MiST document (White and others, 1990) suggests that at a minimum, 24 sets of samples from surface water and groundwater be taken on a monthly basis from both the restoration site and a reference site for the first 2 years of the project (see table 2.1). Other monitoring programs, such as the Agrico phosphate mine site in Florida, have sampled water quality on a quarterly basis.

In addition to regular sampling, it may be desirable to sample water quality during unusual conditions, such as peak floods and low water events. Water quality conditions during these times may be a controlling influence on the overall success of the wetland restoration project.

Soils Monitoring

On sites with minimal soil disturbance, such as old-field sites, very little soil monitoring is necessary, especially if the project is not being conducted as mitigation for a specific development project. It might be worthwhile, however, to inspect the site and determine if one or more of the field indicators of hydric soils described in the U.S. Army Corps of Engineers Wetlands Delineation Manual (Environmental Laboratory, 1987) are present. These field indicators include presence of organic soils; histic epipedons; sulfidic material; an aquic or peraquic moisture regime; direct evidence of reducing conditions; gleyed, low chroma and low chroma/mottled soils; and iron and manganese concretions. The delineation manual provides additional indicators of wetland hydrology for special soils, such as highly sandy soils or soils with spodic horizons.

On heavily disturbed sites, bulk density, soil pH, nutrient status, organic matter, and in some cases, redox potential or specific phytotoxin levels need to be assessed. Measurement of soil macroinvertebrates and microorganisms may also be worthwhile, especially when compared to an appropriate reference wetland, since the biomass and species composition of these communities are two of the best indicators of whether a soil is functioning as desired.

Wildlife Monitoring

Monitoring the wildlife use of restored bottomland forests is in some ways more difficult than monitoring vegetation, hydrology, and soils. For one thing, many animal species are secretive, and it may therefore be very difficult to determine whether they are using the restoration site. A more fundamental problem is that many years must pass before an adequate evaluation can be made if the goal is to provide habitat for wildlife that use mature forest habitat.

One way to address the difficulties of monitoring wildlife is to characterize use of the site by common, relatively conspicuous (or easily trapped) species that use forested wetlands in early stages of succession. Table 13.2 lists some wildlife species that use forested wetland sites in the early stages of forest development, from open fields or forest gaps to a stage just before crown closure. More extensive lists of expected species could be developed for particular project sites and compared with the species actually found on the site.

Where direct monitoring is employed, techniques will vary depending on the species being sought and whether the goal is simply to determine presence or absence (qualitative monitoring) or approximate numbers of individuals present (quantitative monitoring). Another

Table 13.2. Wildlife species that use early successional stages of bottomland hardwood forested wetlands (order of species, common names, and scientific names follows Banks and others, 1987).

Common Name	Scientific Name	Common Name	Scientific Name
Amphibians		***Birds, continued***	
Eastern newt	*Notophthalmus viridescens*	Wild turkey	*Meleagris gallopavo*
Flatwoods salamander	*Ambystoma cingulatum*	Northern bobwhite	*Colinus virginianus*
Eastern tiger salamander	*Ambystoma tigrinum*	American woodcock	*Scolopax minor*
Southern dusky salmander	*Desmognathus auriculatus*	Mourning dove	*Zenaida macroura*
Two-lined salamander	*Eurycea bislineata*	American crow	*Corvus brachyrhynchos*
Dwarf salamander	*Eurycea quadridigitata*	House wren	*Troglodytes aedon*
Mud salamander	*Pseudotriton montanus*	American robin	*Turdus migratorius*
Many-lined salamander	*Stereochilus marginatus*	Gray catbird	*Dumetella carolinensis*
Greenhouse frog	*Eleutherodactylus planirostris*	Brown thrasher	*Toxostoma rufum*
Bird-voiced tree frog	*Hyla avivoca*	Loggerhead shrike	*Lanius ludovicianus*
Pine woods treefrog	*Hyla femoralis*	White-eyed vireo	*Vireo griseus*
Squirrel treefrog	*Hyla squirella*	Yellow-rumped warbler	*Dendroica coronata*
Gray treefrog	*Hyla versicolor*	Common yellowthroat	*Geothlypis trichas*
Ornate chorus frog	*Pseudacris ornata*	Yellow-breasted chat	*Icteria virens*
Striped chorus frog	*Pseudacris triseriata*	Northern Parula	*Parula americana*
Wood frog	*Rana sylvatica*	Prothonotary warbler	*Protonotaria citrea*
		Northern cardinal	*Cardinalis cardinalis*
Reptiles		Bachman's sparrow	*Aimophila aestivalis*
Common mud turtle	*Kinosternon subrubrum*	Dark-eyed junco	*Junco hyemalis*
Snapping turtle	*Chelydra serpentina*	Song sparrow	*Melospiza melodia*
Painted turtle	*Chrysemys picta*	Rufous-sided towhee	*Pipilo erythrophthalmus*
Diamondback terrapin	*Malaclemys terrapin*	White-throated sparrow	*Zonotrichia albicollis*
Eastern fence lizard	*Sceloporus undulatus*	Red-winged blackbird	*Agelaius phoeniceus*
Eastern glass lizard	*Ophisaurus ventralis*	Common grackle	*Quiscalus quiscula*
Ground skink	*Scincella lateralis*		
Eastern indigo snake	*Drymarchon corais couperi*	***Mammals***	
Black rat snake	*Elaphe obsoleta*	White-tailed deer	*Odocoileus virginianus*
Yellow rat snake	*Elaphe obsoleta quadrivittata*	Virginia opossum	*Didelphis virginiana*
Green rat snake	*Elaphe triaspis*	Nine-banded armadillo	*Dasypus novemcinctus*
Eastern mud snake	*Farancia abacura*	Carolina shrew	*Blarina carolinensis*
Rainbow snake	*Farancia erythrogramma erythrogramma*	Least shrew	*Cryptotis parva*
		Prairie mole	*Scalopus aquaticus machrinus*
Common kingsnake	*Lampropeltis getulus*	Gray fox	*Urocyon cinereoargenteus*
Plain-bellied water snake	*Nerodia erythrogaster*	Red fox	*Vulpes vulpes*
Gopher snake	*Pituophis melanoleucus*	Black bear	*Ursus americanus*
Pine woods snake	*Rhadinaea flavilata*	Raccoon	*Procyon lotor*
Midland brown snake	*Storeria delayi wrightorum*	Mink	*Mustela vison*
Eastern ribbon snake	*Thamnophis sauritus*	Striped skunk	*Mephitis mephitis*
Common garter snake	*Thamnophis sirtalis*	River otter	*Lontra canadensis*
Southern copperhead	*Agkistrodon contortrix contortrix*	Bobcat	*Lynx rufus*
Eastern cottonmouth	*Agkistrodon piscivorus piscivorus*	Muskrat	*Ondatra zibethicus*
		Beaver	*Castor canadensis*
Birds		Eastern woodrat	*Neotoma floridana*
Great blue heron	*Ardea herodias*	Marsh rice rat	*Oryzomys palustris*
Green-backed heron	*Butorides striatus*	Southern golden mouse	*Peromyscus aureolus*
Great egret	*Casmerodius albus*	Cotton mouse	*Peromyscus gossypinus*
Yellow-crowned night heron	*Nycticorax violaceus*	White-footed mouse	*Peromyscus leucopus*
Wood stork	*Mycteria americana*	Fulvous harvest mouse	*Reithrodontomys fulvescens*
Wood duck	*Aix sponsa*	Eastern harvest mouse	*Reithrodontomys humulis*
Blue-winged teal	*Anas discors*	Hispid cotton rat	*Sigmodon hispidus*
Mallard	*Anas platyrhynchos*	Nutria	*Myocaster coypus*
Red-tailed hawk	*Buteo jamaicensis*	Swamp rabbit	*Sylvilagus aquaticus*
American swallow-tailed kite	*Elanoides forficatus*	Cottontail rabbit	*Sylvilagus floridanus*
American kestrel	*Falco sparverius*	Marsh rabbit	*Sylvilagus palustris*

alternative for monitoring wildlife is to take an indirect approach. Indices such as those provided by habitat suitability index models (Schamberger and Farmer, 1978; U.S. Fish and Wildlife Service, 1981), the Wetland Evaluation Technique (WET; Adamus, 1983), the Hydrogeomorphic Method (Brinson and others, 1994; Smith and others, 1995), or the Rapid Impact Assessment Method (Stein and Ambrose, 1998) can be used to evaluate the suitability of wildlife habitat for key species or species groups.

Selected References

Adamus, P.R., 1983, A method for wetland functional assessment: Washington, D.C., U.S. Department of Transportation, Federal Highway Administration, FHWA-IP-82-23.

Banks, R.C., McDiarmid, R.W., and Gardner, A.L., 1987, Checklist of vertebrates of the United States, the U.S. Territories, and Canada: Washington, D.C., U.S. Department of the Interior, Fish and Wildlife Service, Resource Publication 166, 79 p.

Bookhout, T.A., ed., 1994, Research and management techniques for wildlife and habitats: Bethesda, Md., The Wildlife Society, Inc., 740 p.

Brinson, M.M., Kruczynski, W., Lee, L.C., Nutter, W.L., Smith, R.D., and Whigham, D.F., 1994, Developing an approach for assessing the functions of wetlands, *in* Mitch, W.J., ed., Global wetlands: old world and new: Amsterdam, The Netherlands, Elsevier Sciences B.V., p. 615-624.

Environmental Laboratory, 1987, Corps of Engineers wetlands delineation manual, Technical Report Y-87-1: Vicksburg, Miss., U.S. Army Corps of Engineers Waterways Experiment Station, 165 p. [This, or the current edition of the manual, provides information on field indicators of wetland hydrology, soils, and vegetation.]

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Englewood Cliffs, N.J., Prentice-Hall, 604 p.

Keeland, B.D., Dowd, J.F., and Hardegree, W.S., 1997, Use of inexpensive pressure transducers for measuring water levels in wells: Wetlands Ecology and Management, v. 5, p. 121-129.

Kentual, M.E., Brooks, R.P., Gwin, S.E., Holland, C.C., Sherman, A.D., and Sifneos, J.C., 1992, An approach to improving decision making in wetland restoration and creation: Washington, D.C., Island Press, 151 p.

Kevin L. Erwin, Consulting Ecologist, Inc., 1990, Agrico swamp west eighth annual report: Mulberry, Fla., Prepared for Agrico Chemical Company.

Ludwig, J.A., and Reynolds, J.F., 1988, Statistical ecology: New York, John Wiley and Sons, 337 p.

Schamberger, M., and Farmer, A., 1978, The habitat evaluation procedures: their application in project planning and impact evaluation: Transactions of the Forty-Third North American Wildlife and Natural Resources Conference, p. 274-283.

Schamberger, M., and Krohn, W.B., 1982, Status of the habitat evaluation procedures: Transactions of the North American Wildlife and Natural Resources Conference, v. 47, p. 154-164.

Schemnitz, S.D., ed., 1980, Wildlife management techniques manual: Washington, D.C., The Wildlife Society.

Smith, R.D., Ammann, A., Bartoldus, C., and Brinson, M., 1995, An approach for assessing wetland functions using hydrogeomorphic classification, reference wetlands, and functional indices: Vicksburg, Miss., U.S. Army Corps of Engineers, Waterways Experiment Station, WRP-DE-9, 72 p.

Sprecher, S.W., 1993, Installing monitoring wells/piezometers in wetlands, WRP Technical Note HY-IA-3.1: Vicksburg, Miss., U.S. Army Corps of Engineers, Waterways Experiment Station, USA.

Stein, E.D., and Ambrose, R.F., 1998, A rapid impact assessment method for use in a regulatory context: Wetlands, v. 18, no. 3, p. 379-392.

U.S. Fish and Wildlife Service, 1981, Standards for the development of habitat suitability models, Ecological Services Manual 103: Washington, D.C., U.S. Fish and Wildlife Service, Division of Ecological Services.

Van Horne, B., and Wiens, J.A., 1991, Forest bird habitat suitability models and the development of general habitat models: Washington, D.C., U.S. Department of the Interior, U.S. Fish and Wildlife Service, Research 8, 31 p.

White, T.A., Allen, J.A., Mader, S.F., Mengel, D.L., Perison, D.M., and Tew, D.T., 1990, MiST: a methodology to classify pre-project mitigation sites and develop performance standards for construction and restoration of forested wetlands, Results of an EPA-sponsored workshop: Atlanta, Ga., U.S. Environmental Protection Agency, 85 p.

Chapter 14: Rehabilitation and Management of Existing Forests

Although this guide emphasizes restoration of bottomland forests on sites without tree cover, there are extensive areas of degraded natural forests in need of rehabilitation. Often the degradation is due to past mismanagement such as high grading or holding water late into the growing season in green-tree reservoirs. In other cases, hydroperiod alterations, hurricanes, severe floods, or insect outbreaks may have degraded the stands. Many southern bottomland hardwood stands have deteriorated to such a point that they have little value for timber, wildlife production, recreation, or aesthetics (fig. 14.1).

This chapter presents basic information on bottomland hardwood silviculture. The suite of techniques employed by silviculturists can be used to achieve a wide range of objectives, including forest rehabilitation. The principles described in this chapter can be applied not only to rehabilitating existing degraded stands but also to the long-term management of restoration forests as described in the preceding chapters of this guide.

There are three key steps in planning the management of bottomland hardwood forests: (1) understanding current forest and environmental conditions; (2) clarifying objectives (the desired future condition); and (3) defining feasible actions that will transform the stand to the desired condition. In most cases, the silviculturist has several options for intervening in stand development, as there are multiple silvicultural pathways toward the desired future condition. The choice of silvicultural treatment will affect the financial cost, the nature of intermediate stand conditions, and the time it takes to achieve the desired condition. In general, silvicultural treatments consist of partial to complete removal of the trees on a site. Partial removals may consist of thinnings of desirable species to allow greater growing space of the leave trees or removal of undesirable species. If the silvicultural treatment can be combined with a timber sale, the landowner may be able to accomplish the treatment at no cost or even at a profit. It is imperative that silvicultural decisions are made with clear objectives in mind and with an eye toward rehabilitation success.

Determining Present Site and Stand Conditions

Diagnosing present site and stand conditions requires information to be gathered in an organized and rigorous fashion. The first step in forest management, including rehabilitating degraded bottomland forests, is to determine what currently occupies the site. A simple reconnaissance can give much of the preliminary information

Figure 14.1. Bottomland hardwood stand degraded by years of mismanagement.

needed for planning subsequent forest management. The initial reconnaissance should be followed by a more detailed site inventory before a silvicultural system is selected and interventions are prescribed. These activities should be performed by a knowledgeable forester.

Site Reconnaissance and Inventory

In the reconnaissance, boundaries of the site should be located and possible boundary-related problems identified. Potential problems could stem from trespassing or land-use practices on adjacent tracts, such as burning or herbicide spraying that may endanger the forest to be rehabilitated. Examples of other urgent problems discovered at this stage include destructive grazing, the presence of dump sites containing hazardous materials, or beaver dams in areas where they will cause excessive damage to the stand or limit access to the site. These problems should be addressed immediately.

The operability of the site, including soil and flooding conditions affecting accessibility to logging and other heavy equipment, existence of roads, and other practical considerations that will affect management options, should also be assessed during the reconnaissance. Included in this assessment should be a rough estimate of the timber volume and quality on the site. Getting a contractor to carry out desired management on the site may depend on the existence of enough timber to cover the costs of the operation.

A final goal of the reconnaissance should be to identify logical subunits of the site, called compartments, for subsequent inventory and management. Identifying subunits is important if the project site is large enough to contain different forest types, stands of different ages, or areas with special problems such as lack of access. Readily identifiable compartment boundaries, such as roads, streams, or power lines, should be used when possible.

A more detailed inventory of the site should generally follow the reconnaissance. If an area is large and rehabilitation will proceed over several years, it may be advantageous to delay the inventory until just before the first managed cut (i.e., the first thinning or the regeneration cut). The main advantage of delaying the inventory is that more accurate information on timber volume and quality will be available for setting up a contract with a timber buyer. Several references listed at the end of this chapter describe forest inventory techniques. Most often, the inventory will make use of randomly or systematically located sample plots for the overstory trees and nested subplots for seedlings and saplings. Methods for evaluating regeneration potential are discussed later in this chapter.

Assessment of Site Potential

Site "potential" refers to the combination of relatively unchanging physical factors which affect species composition and stand vigor: soil and landform (characteristics of which determine moisture availability, aeration, and fertility) and hydroperiod (flood frequency, duration, depth, and seasonal timing). These physical factors are not immutable, however, and changes in hydroperiod especially can degrade a site. On the other hand, selectively logging the biggest and best trees of a few species may degrade the stand without lowering the potential of the site.

Often a stand is so degraded that true site potential, in terms of species composition and productivity, is masked. Conversely, one must be careful to avoid attributing a higher potential than is warranted and mistakenly blaming degradation for inherently poor site conditions. A site's potential, and whether it has been degraded, sets limits on what can be achieved by silvicultural intervention. Site potential also determines the general direction of stand development and the likely outcome of any major disturbance that affects the existing stand. Because site potential has to do with physical factors, it is necessary to first place a site within a landscape context; for example, a silviculturist should assess whether a site occurs in the floodplain of a major or minor river system (Hodges, 1998; Kellison and others, 1998). On major river systems, sediment deposition causes a pattern of higher sites (ridges, fronts, natural levees) nearer to present or historic river channels, with lower lying sites farther away (flats). Inactive older channels (sloughs) and depressions are the wettest sites. Each of these "topographic sites" has the potential of being managed as a different compartment. Minor river bottomlands occur within a narrow floodplain, and therefore landform patterning is at a much finer scale. Stands in minor river bottoms may not differentiate into large enough areas to manage as separate compartments.

Each of these differences in topography and hydrology affect the species composition of the individual stands. Eight important species groups of bottomland hardwood forests are described briefly in table 14.1; more detail can be found in Meadows and Stanturf (1997); Hodges (1997); Johnson (1981); and Kellison and others (1988). The adaptation of species important for timber production to specific site conditions can be found in Baker and Broadfoot (1979), and the important silvical characteristics of most bottomland hardwood trees are treated by individual authors in Burns and Honkala (1990). Once a site's potential is understood, it is important to compare that to actual stand conditions and then to diagnose why there may be a difference.

Table 14.1. Species groups and expected regeneratio Meadows and Stanturf, 1997).

Species Association	Site Preference		Silvicultural System	Species Favored
	Major Bottom	Minor Bottom		
Cottonwood	Front (new land)		Seed tree with site preparation	Eastern cottonwood
			Clearcut	Sycamore, sweet pecan, green ash, boxelder
Black willow	Bar (new land)		Seed tree with site preparation	Black willow
			Clearcut	Sugarberry, green ash, baldcypress, American elm, overcup oak, bitter pecan, Nuttall oak
Cypress-water tupelo	Swamp	Slough	Group selection	Baldcypress, water tupelo, sometimes green ash, overcup oak, bitter pecan
			Clearcut	Baldcypress, water tupelo, sometimes green ash, overcup oak, bitter pecan, or elm and maple
Elm-sycamore-pecan-sugarberry	Front, high ridge		Group selection or clearcut	Sweetgum, red oaks[1], sycamore, sweet pecan, sugarberry, green ash
Elm-ash-sugarberry	Wide flats		Clearcut or group selection	Elm, green ash, sugarberry, Nuttall oak, willow oak
Sweetgum-red oaks	Ridges	High flats	Group selection	Sweetgum, red oaks, green ash
			Clearcut	Sweetgum, red oaks, and green ash favored, with sweetgum favored the most
			Shelterwood	Red oaks, sweetgum, green ash
Red oaks-white oaks[2]-mixed	Second bottoms, high ridges	Terrace	Shelterwood or group selection	Red oaks, white oaks, hickory, green ash, sweetgum, American hornbeam
Overcup oak-bitter pecan	Low flats, sloughs	Flats	Group selection	Overcup oak, bitter pecan
			Shelterwood	Overcup oak, bitter pecan, Nuttall oak, green ash

[1] Cherrybark oak, laurel oak, Nuttall oak, pin oak, Shumard oak, water oak, and willow oak.
[2] Bur oak, Delta post oak, live oak, overcup oak, swamp chestnut oak, white oak, and swamp white oak.

Site Inventory

Ideally, the inventory should quantify the species composition, timber volume, and quality of the overstory trees. Just as important is the inventory of the seedling and sapling component of the stand. This understory component, called advance regeneration, has the potential to dominate the stand in time. Quantifying advance regeneration helps the silviculturist predict the future species composition of the stand and decide whether planting of desired species will be necessary. Quantifying existing regeneration is particularly important if the management goal is to obtain a large component of oak species (or other heavy-seeded species with limited or unreliable seed dispersal) in the stand.

Advance regeneration can also alert the silviculturist to possible changes in site hydrology; if the flood tolerance of the species making up the overstory and understory differ substantially, hydrologic changes probably have occurred. At this point, the silviculturist will have to decide whether to work with the new hydrologic regime or attempt to restore the former regime.

Oaks are an important component of bottomland hardwood forests, valued for their timber quality, their hard mast production for wildlife, and generally for their aesthetically pleasing growth habit. As a group, oaks, and red oaks in particular, are difficult to perpetuate in successive stands on a site. In addition, oaks are the most likely species to have been selectively removed in high grading. Therefore a key challenge for silviculturists is successfully maintaining a viable oak component, which can be done by ensuring that adequate oak advance regeneration exists before timber removal or by artificial regeneration (i.e., planting seedlings or direct seeding of acorns). Information on oak regeneration potential is critical in most stand rehabilitation efforts. Johnson (1980) developed a system for assessing regeneration potential for a variety of bottomland hardwoods. Belli and others (1999) evaluated Johnson's system for high quality sites in terms of red oaks and green ash, which is another valuable timber species. Their method is based upon 1/100-acre (0.004 ha) circular plots systematically located throughout a stand. Each plot is evaluated for the number of red oak or green ash seedlings in three height classes: less than 1 ft (30 cm), 1 to 3 ft (30-90 cm), and greater than 3 ft (90 cm) tall. In addition, points are given for trees with high potential for producing acceptable stump sprouts (red oak or green ash trees 1 to 5 inch [2.5-12.7 cm] dbh). Each plot can be evaluated for the probability that it will have at least one seedling in a free-to-grow position after three growing seasons. From this information, one can determine the number and distribution of "stocked" plots, an indication of the future stocking of the stand.

Identifying Cause of Site Degradation

The cause of site or stand degradation should be identified. Stand degradation from high grading can often be remedied through vegetation manipulation alone. Alteration of the site by changed hydroperiod, on the other hand, poses broader questions. Can the hydroperiod be restored or the effects of alteration somehow mitigated? Should the rehabilitation effort target a different vegetation assemblage more adapted to the present hydroperiod and site conditions? Hydroperiod alterations caused by flood control projects, dams, or highway construction tend to be irrevocable, at least in the short-term. Flooding caused by beaver dams, however, can be reduced by removing the dam, but ongoing management of beaver population levels will be required to avoid recurring problems. Management of green-tree reservoirs is often politicized, and management of water levels to protect the vigor and survival of the hardwood stand in many instances conflicts with public perception of how to optimize waterfowl habitat. The guiding principle should be to rehabilitate or restore in accordance with existing hydroperiod, unless alteration is feasible, affordable, and within the control of the silviculturist.

Clarifying Objectives

Appropriate silvicultural practices can be designed for any objective. Most common objectives include timber, wildlife habitat for game species, or aesthetics. Increasingly other objectives are considered, including carbon sequestration, biological diversity, nongame mammals and birds, endangered animals and plants, protection of water quality and aquatic resources, and recreation. Different outputs may be sought for each objective. The timber management objective, for example, may be for sawlogs and veneer logs, or for pulpwood. Appropriate timber management, in particular rotation length, will vary according to the desired product size. Appropriate management techniques for wildlife will also vary for different species. Even Neotropical migratory birds have different habitat requirements, from mature closed forests to early successional seres. Choosing the appropriate silvicultural techniques presents a challenge for those individuals managing for apparently incompatible objectives. Slight modifications in technique may have negligible impacts on outcomes or outputs for one objective but major effects on another objective. Clarity of objectives, combined with an adequate understanding of feasible goals developed from information on current conditions, allows the silviculturist to choose a silvicultural system that will maximize satisfaction of multiple objectives; however, no single objective is usually optimized when multiple objectives are undertaken. Nevertheless, the chosen system may be adjusted to minimize impacts on other ecosystem functions.

The most developed basis for specifying a silvicultural system to meet an objective is for timber production. To the extent that we know the habitat requirements for a wildlife species, we can prescribe an appropriate silvicultural system that will provide suitable habitat. All species of bottomland hardwoods provide some benefit to wildlife (table 14.2), but we lack the knowledge to specify optimal habitat conditions for many species. Nevertheless, most objectives can be tied to some combination of vegetation species composition and stand structure, which can be manipulated by silvicultural techniques.

Choosing the Silvicultural System

Silvicultural systems in southern bottomland hardwoods integrate regeneration and intermediate treatments in an orderly process for managing stand development (Meadows and Stanturf, 1997). Techniques can be designed for manipulating species composition and stand structure to meet any management objective. Species favored under any silvicultural system can support several objectives. Although the greatest emphasis is usually placed on maintaining an oak component, forests can be managed without oaks and still yield multiple benefits. Silvicultural systems are commonly divided into even-aged and uneven-aged management, with the regeneration method used defining the system. Even-aged regeneration methods include clearcut, seed-tree, and shelterwood. Uneven-aged methods include single-tree and group selection (Meadows and Stanturf, 1997). In practice, there are many variations of these practices with some overlap and hybridization. A general guide to the types of regeneration expected under different silvicultural systems applied to important bottomland hardwood associations is given in table 14.1.

Management Versus Regeneration

The silviculturist must initially decide whether the degraded stand has the potential to attain the future desired condition through judicious manipulation, or whether the stand is so lacking in vigor, stocking, or acceptable species that the only alternative is to regenerate. Manuel and others (1993) developed a model to help make this decision. Their model is based on expert judgement and is constrained to consider only clearcutting for regeneration. It has been calibrated for a limited set of timber management objectives, but the approach is valid for any management objective. Each tree in a sample from the stand is evaluated for its contribution to future stocking, based on species, size (dbh), crown class, merchantable height, butt log grade, and vigor. This approach can be extended to include other management objectives and additional regeneration techniques.

Is Oak An Objective?

If maintaining oak in the stand is necessary to meet objectives, extra attention to regeneration potential is needed and extraordinary steps may be necessary. Clatterbuck and Meadows (1993) summarized the complexity of attempting to regenerate oaks in bottomland hardwood forests. Although no blanket prescription can account for all the factors which impact oak regeneration potential, their generalized prescription offers the best approach present knowledge can provide (table 14.3).

A regeneration evaluation is necessary at the outset. A modified system such as that of Belli and others (1999), where points are assigned based on species and size of advance regeneration can be used. For example, if a regeneration plot has at least 20 points from oak advance reproduction or stump sprouting potential, the probability of obtaining at least one free-to-grow oak stem at age three is 83% or more. If most of the regeneration plots in a stand meet this criterion, the regenerated stand has a high probability of oak dominance at maturity. We recommend that 80% of the plots in the entire stand meet this level of oak stocking. This is a judgement, however, and should be adjusted depending upon site conditions and landowner objectives. For example, if most of the points come from large seedlings (greater than 1 m or 3 ft tall), a lower probability level may be justified. On the other hand, sites prone to growing season flooding may require a more stringent criterion.

When the prospects for oak regeneration are good, the stand should be harvested while trees are dormant to maximize stump sprouting. All residual stems 2 inches dbh and larger should be felled to create the proper light environment for the oak regeneration and to minimize competition from other species. Retaining some stems in a clearcut (depending on the purpose of these residual trees, this may be called a deferment cut, clearcut with residuals, or an irregular shelterwood) may be necessary to meet wildlife or aesthetic objectives.

A follow-up examination to determine regeneration stocking at age three is needed to guide future management. Experience has shown that as few as 150 free-to-grow oaks per acre (370 per ha) at age three will result in an oak dominated stand.

Table 14.2. S
LA = leaf gall aphids; BU = buds; IB = inner bark; BA = bark.

Species	Deer	Turkey	Squirrel	Waterfowl	Quail	Songbirds	Raccoon	Beaver	Other
Ash, green	FO				S	S			S[1]
Ash, pumpkin						S			S[1]
Ash, white	FO				S	S			S[1]
Birch, river	FO					S			S[1]
Buckthorn bumelia						FR			
Buttonbush	FO			S				FO	
Cottonwood, eastern	FO	LA							
Cypress, bald (baldcypress)									S[1]
Dogwood, swamp	FO	FR	FR			FR	FR		FR[2,] FO[3]
Elm, American						FR			
Elm, cedar						FR			
Elm, water				FR					
Elm, winged						FR			
Blackgum	FO,FR	FR				FR	FR		FR[1,2]
Sweetgum			S, BU	S	S			IB	S[1]
Hawthorn		FR	FR	FR	FR	FR			FR[1]
Pecan, sweet	FR		FR				FR		
Hickory, water			FR	FR					FR[1]
Holly, American	FO	FR			FR	FR			
Holly, deciduous	FO	FR			FR	FR			FR[1]
Hornbeam, American	FR	FR							
Locust, black[6]	FR		FR		FR				FO[3], FR[1,3]
Locust, honey[6]	FO		S		S				
Locust, water	FR		FR						FR[3]
Boxelder	FO					S			S[1]
Maple, red	FO		S, BU			S			S[1]
Mulberry, red	FO	FR	FR			FR	FR		FR[1] , BA[3]
Oak, cherrybark	FO,FR	FR	FR	FR		FR			FR[1]
Oak, Delta post	FR	FR	FR			FR			FR[1]
Oak, Nuttall	FO,FR	FR	FR	FR					FR[1]
Oak, overcup	FR		FR						FR[1]
Oak, Shumard	FO,FR	FR	FR			FR			FR[1]
Oak, swamp chestnut	FR,FO		FR						FR[1]
Oak, swamp white	FR	FR	FR	FR			FR		FR[1]
Oak, water	FO,FR	FR	FR	FR	FR				FR[1]
Oak, white	FR,FO		FR			FR	FR		FR[1]
Oak, willow	FO,FR	FR	FR	FR		FR			FR[1]
Pawpaw							FR		FR[2]
Persimmon, common	FO,FR	FR			FR	FR	FR		FR[1,2,4]
Privet, swamp				FR		FR			FR[1]
Sassafras	FO	FR	FR		FR	FR	FR		FR[5]
Sugarberry	FO				FR	FR			FR[1]
Sycamore, American						S			
Tupelo, water[6]	FO,FR		FR	FR		FR	FR		
Willow, black								IB	

[1] Small mammals
[2] Opossum
[3] Rabbit
[4] Skunk and fox
[5] Black bear
[6] Flowers furnish nectar for honey bees

Table 14.3. Decision key for choosing a regeneration procedure for bottomland oaks (Clatterbuck and Meadows, 1993; Belli and others, 1999)

		Go to
1.	Regeneration Evaluation	
	a. 20 points or more, average of all plots; oak prospects good	2
	b. Less than 20 points, oak prospects poor	6
2.	Treat and harvest during dormant season; control residual stems prior to next growing season	3
3.	Evaluate at age 3	
	a. More than 150 free-to-grow oaks per acre	4
	b. Less than 150 free-to-grow oaks per acre	5
4.	Leave alone or clean, weed, or thin if needed	
5.	Oak stocking is less than adequate	
	a. Accept	
	b. Convert to plantation	
6.	Promote oak advance reproduction and evaluate again	
	a. Increase light to forest floor (understory removal and/or overstory reduction, shelterwood)	1
	b. Shelterwood with understory removal and supplemental planting of oak seedlings	1
	c. Convert to plantation	

If oak regeneration is inadequate in the current stand (table 14.3), the challenge is to create the proper light conditions on the forest floor to promote seedling growth. Reducing the overstory and removing the understory through a shelterwood treatment can be successful if small oak seedlings are already present. It may even be possible to time the shelterwood treatment (see shelterwood section, this chapter) with a good mast year; otherwise underplanting oak seedlings before the final overstory removal can augment the shelterwood. This may require releasing the oak seedlings from competition by using herbicides. There are no guidelines on how to accomplish this successfully. Another approach is to supplement a clearcut by planting or direct seeding of oak but again, no guidelines are available.

Managing the Existing Stand

In a stand with trees of commercial value, a logical sequence of management actions would be (1) initial intermediate management, consisting of an "improvement cut" to favor a desirable species composition and to increase the quality and value of the stand; (2) advanced intermediate management, where thinning is used mostly to favor growth on residual trees but also to improve stand value; and (3) regeneration cutting. Intermediate stand management in most bottomland hardwood situations is a combination of improvement cutting and thinning. The relative emphasis changes with the degree of stand management (initial versus advanced).

In the short term, the silviculturist will be most concerned with improvement cutting because thinning and regeneration cuts may not be needed for 10 or more years. In the case of extremely degraded stands with inadequate advance regeneration, however, it may be necessary to bypass the first two management steps and go straight to a regeneration cut. A general guideline used by some foresters to decide whether to proceed straight to a regeneration cut is shown in figure 14.2. If the average basal area per acre for a stand of a given age is below the line, then the stand is promptly cut. For most stands older than 40 years, basal areas below 60 ft^2 per acre indicate the need to regenerate. More precise guidance is available in stand density diagrams that take into account average stem size and age.

Timber Stand Improvement

By definition, degraded stands have a history of high grading, liquidation cuts, fire, and other destructive influences that have resulted in a high proportion of trees that are undesirable as future growing stock. Low-grade, overcrowded, damaged, diseased, and cull trees, as well as exotic or otherwise undesirable species, may be occupying space and competing for light, water, and nutrients that ideally could be supporting more valuable trees. Therefore the first stand manipulation is usually a judicious improvement cut designed to "clean up" the forest.

In ideal cases, the stand will be accessible and there will be enough timber to interest potential buyers. In such a situation, timber stand improvement can be done at no cost (or possibly even at a profit) to the landowner. Some desirable growing stock may need to be cut to make openings for regeneration or to have enough timber to interest a buyer. The goal, however, should be to cut the over-mature, damaged, or dying trees of marketable size and quality. One should not remove a large component of desirable growing stock just to make

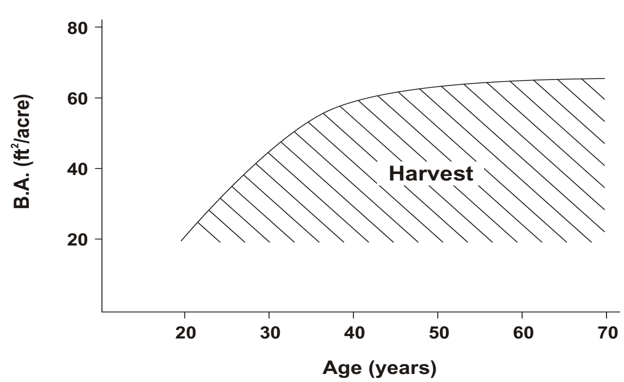

Figure 14.2. A generalized guide for regenerating southern hardwoods based on basal area (measured in ft^2 per acre) of desirable trees and stand age (redrawn from Kellison and others, 1988).

a sale, as such trees are often growing at a high rate and will be much more valuable to the landowner in the future.

Landowners unfamiliar with contracting with buyers for removal of timber are well advised to consult with a professional forester. A properly designed and supervised timber sale should lead to the improvement of the forest. Under the wrong conditions, however, a buyer may end up removing trees that should remain, damaging remaining trees in felling or skidding of harvested trees, creating inordinate amounts of soil disturbance, or degrading water quality of adjacent streams (fig. 14.3).

After marketable trees are cut and removed, cull and otherwise undesirable trees that remain should be killed to enlarge or clear openings for regeneration. Injection is the usual method of killing unwanted trees. Generally, injection just after full leaf-out in the spring gives good results, but satisfactory results have also been obtained with applications in other seasons. Girdling is another method that is occasionally used to kill unwanted trees, but this is often unsuccessful when used alone because trees can heal over incomplete wounds and girdled trees may sprout.

It should be kept in mind, of course, that a "clean" forest from a strictly timber management perspective may not be the goal of the silviculturist. Mature cane breaks (fig. 14.4) will not bring any financial return to the landowner but they provide habitat for numerous wildlife species (including swamp rabbits and several species of rare warblers). Leaving some large, poorly formed trees and snags may be beneficial to several species of wildlife or may meet other objectives (fig. 14.5). As with other silvicultural techniques, timber stand improvement should be viewed as a flexible tool that can accomplish a variety of objectives.

Thinning

Once timber stand improvement has produced a stand consisting of good quality trees at desirable spacing, growth rates of the remaining "leave" trees should increase. Eventually, the leave trees will fully occupy the space opened up by the removal of undesired trees and begin to compete intensely with each other. Thinning at this point allows for the use of trees that would otherwise die and allows for distribution of growth over fewer, larger trees. Thinning has the additional advantages of increasing mast production in the overstory and allowing more light to reach the forest floor. This stimulates understory and midstory plant growth, which increases vertical structure important to some Neotropical migratory birds.

Thinning has not been widely practiced in southern bottomland hardwood stands, especially in stands with

Figure 14.3. Example of damage caused by poor logging practices.

Figure 14.4. Mature cane brakes provide habitat for numerous wildlife species.

only pulpwood or smaller sized trees (i.e., less than about 25-30 cm [10-12 inches] dbh). As markets develop for pulpwood and firewood, thinning is becoming more common. The first commercial thinning typically occurs when trees reach small sawtimber size, about 35 cm (14 inches) dbh. A second thinning may be conducted when trees reach 50-56 cm (20-22 inches) dbh. Earlier thinning (precommercial) is practical from an economic standpoint if one of the major goals of management is production of sawtimber.

Because of inherent growth differences among species, it would be hard to give an average age for the first thinning. Cottonwood may reach merchantable size by age 5 to 10 years, whereas it may take green ash 20 to 30 years to reach pulpwood or small sawtimber size. Findings thus far in natural and planted stands offer some guidelines for thinning (Meadows, 1996). Thinning should begin early, and larger trees with well-developed crowns should be favored. For good diameter growth, most species require a minimum live crown to total height ratio of 40%. Trees with less crown are usually in a subordinate position, so thinning is from below (i.e., the trees removed in the thinning are usually partially or completely overtopped by other trees).

Frequent light thinnings are better than infrequent heavy thinnings. Light thinnings allow fuller use of the site and less chance for epicormic branches to develop on the leave trees. One disadvantage of frequent thinnings, though, is the greater chance of logging damage to the leave trees. As a stand matures, thinning should be used to develop advance reproduction of desirable species so that the need for corrective measures at the time of regeneration will be less.

Regeneration

Bottomland hardwoods reproduce naturally and prolifically through seedlings established in the understory, through sprouts that emerge from stumps or roots of cut trees, or through seedlings that start in new openings. As long as there are no fundamental changes to the site, management of the natural regeneration can generally be relied upon to yield the desired forest composition.

As a rule, silviculturists should rely on natural regeneration. Artificial regeneration, however, will be needed for rehabilitation when none of the natural means of reproduction can be counted on to provide adequate numbers of desirable species. This situation arises where there is inadequate advance regeneration of desirable

Figure 14.5. Snags left in a clearcut on Scott Paper land near Mobile, Alabama.

species and there are no mature trees of desired species in the overstory or adjacent to the site to provide a seed source. In such cases, the silviculturist has two main alternatives. First he or she must try to increase the component of desirable species by planting before (enrichment underplanting) or after a regeneration cut (supplemental planting). Second, the silviculturist can take the more drastic measure of converting the stand to another vegetation type by clearcutting the site, shearing all remaining trees and saplings, and preparing the soil to plant seedlings of one or more species (fig. 14.6). Generally, this will only be warranted if the site has been captured by invasive exotic species such as Chinese tallow, Japanese privet, or melaleuca.

Regeneration Cuts

A landowner may wish to manage a stand as an old-growth forest without any human intervention. Over time, natural mortality and gap phase regeneration will convert the forest to shade tolerant species. Otherwise, all stands will eventually reach a stage when it is appropriate to harvest some or all of the large trees. This not only allows for an economic return from the stand, but also gives the landowner the ability to control the future composition of the stand to meet any of a variety of management goals. By proper choice and application of a regeneration system, the landowner can help ensure that the desired type of forest will occur on the site for many years to come.

Bottomland hardwoods can be managed as even-aged or uneven-aged forests. Silvicultural systems used for even-aged management are clearcuts, shelterwood cuts, and seed tree cuts. The primary silvicultural system for uneven-aged management is single-tree selection. Group selection is technically an uneven-aged management system, but as practiced in bottomland hardwood forests, it should be viewed as a compromise between even- and uneven-aged management. All of these systems can be used effectively in bottomland hardwood forests. The choice of silvicultural system will depend primarily on the management goals for the forest, as constrained by the initial condition of the stand. Even-aged management, in particular clearcutting, is the most common form of management when timber is the primary goal or when rehabilitating a high-graded stand. Shelterwood and group selection are more commonly used when wildlife management is an important goal, when

Figure 14.6. Natural forest site that has been clearcut, sheared, root-raked, and disked.

aesthetics are important, and when adequate advance regeneration is not present. Group selection can be used for timber production in fully stocked stands, and variations on shelterwood can be used especially when attempting to regenerate oak.

Clearcuts

Clearcutting involves the cutting and removal of all merchantable trees in an area of about 4 ha (10 acres) or more. Typically, the residual trees, which are comprised of undesirable species or are of poor quality and may interfere with regeneration of desirable trees, are either cut down and left in place or killed by injection or girdling. The site usually will be left to regenerate naturally, although site preparation, supplemental planting, and other measures may be applied to control species composition. A clearcut site will go through a jungle-like stage for about 10 years before individual stems begin to restore a forest-like appearance to the area (fig. 14.7).

Clearcutting is designed to favor the reproduction of shade-intolerant species, which also tend to be the more economically valuable species. While often criticized as a destructive and unsightly form of forest management, clearcutting with natural regeneration repeatedly has been demonstrated to be effective for regenerating nearly every major forest type found on bottomland hardwood sites in the Southeast. The aesthetic impacts and risk of erosion associated with clearcutting are real but are less in relatively flat bottomland settings as compared to steep mountainsides.

As a general rule, clearcutting with natural regeneration will tend to favor shade-intolerant, light-seeded species that are easily transported by wind or water (see table 4.1). Species that regenerate from coppice such as the oaks must be present prior to cutting as large seedlings or small trees. Conversely, seedlings of more shade-tolerant species such as hickories, elms, ashes, ironwood, and some oaks tend to become established in small openings.

To the silviculturist, it will be appropriate to employ clearcutting as the first step in rehabilitating a stand that is so completely degraded that there is very little advance regeneration of desirable species. In such cases, there is little point in attempting to manipulate the stand by timber stand improvement and thinning. Essentially starting over by clearcutting with natural regeneration and possibly some planting, or totally by artificial regeneration, will be the most efficient means of rehabilitation.

Shelterwood Cutting

The goal of shelterwood cutting is the same as clearcutting—to favor species that require high light levels to regenerate. With a shelterwood cut, however, the overstory is harvested in at least two stages. In the first stage, a large portion of the existing overstory (perhaps about 50%) is harvested. Trees that are left are generally

Figure 14.7. Five to ten-year-old regenerating clearcut.

of good quality and expected to be good seed producers (fig. 14.8). After about 5-8 years, either all or about half of the remaining overstory trees are removed. In the latter case, the remaining trees are generally harvested in a third cut after another 5-8 years. Shelterwood may be combined with the underplanting of oaks before final overstory removal. Usually midstory removal is necessary in bottomland hardwoods to gain the full benefits of the shelterwood system.

The main purpose of the shelterwood system is to favor regeneration of species with limited seed dispersal and those that regenerate best in partial shade. Oaks, for example, are believed to respond well to shelterwood regeneration when there are sufficient individuals in the existing overstory. The shelterwood system is also a good alternative to clearcutting when aesthetics are important and complete overstory removal in one cut is not an option.

Seed Tree System

The purpose of the seed tree system is to provide a seed source after a complete overstory removal. Theoretically, heavy-seeded species such as oaks can be regenerated by this method, but in reality this method regenerates light-seeded species in bottomland hardwoods. Approximately 25 per ha (10 per acre) are usually retained after the first cut, so the area will resemble a clearcut with just a few, large scattered trees remaining. In appearance, this is the same as a deferment cut for aesthetics or leaving potential den trees for wildlife. What separates these variants on even-aged management is the purpose for leaving residual trees.

As a regeneration method, seed tree cuts are more effective for light seeded species such as sweetgum. When coupled with intensive site scarification, it is the recommended method to naturally regenerate Eastern cottonwood and black willow. Experience suggests that bottomland hardwood stands dominated by oaks respond to a seed tree cut as if they were clearcut (i.e., by advance regeneration, by sprouts, and by germination of existing seeds or seeds brought in by wind, water, or animals). Furthermore, the remaining trees often become degraded by epicormic branching, lightning strikes, and wind damage, and therefore lose much of their economic value.

Single-Tree Selection

This system involves the selective removal of individual mature trees at regular intervals. It may also be accompanied by deadening (i.e., injection, girdling) or

Figure 14.8. Shelterwood cut.

removal of unmerchantable trees. Because single-tree selection opens relatively small holes in the canopy, it tends to favor regeneration of species that are shade tolerant. Repeated application of single-tree selection in a stand will shift species composition to the less valuable, more shade-tolerant sugarberry, boxelder, elms, maples, and hickories (table 14.1).

Properly practiced, this method can be very effective for maintaining a relatively dense uneven-aged forest over a large area. It can, however, result in the degradation of the forest. In fact, many of the degraded bottomland hardwood forests that are the subject of this chapter were created by what might be considered a very poor form of single-tree selection. Too often, only the best trees were selected for harvest. If this cycle is repeated, then over time the stand will become dominated by a mix of damaged, diseased, and poorly formed trees and trees of undesirable species. This form of management is known as high-grading.

Single-tree selection is not generally viewed as economically feasible because it leaves species which are generally less valuable and also because it requires frequent small harvests, thereby sacrificing the economy of scale of larger harvests. Frequent entry into the stand with heavy logging equipment also poses the risk of damage to the remaining trees and the introduction of diseases. Such stresses may predispose a stand to insect outbreaks.

Group Selection

The goal of group selection is to develop a patchy environment made up of numerous very small even-aged groups. This is accomplished by making numerous scattered large openings (small patch clearcuts) ranging in size from 1 to several acres (fig. 14.9). The distinction in opening size between group selection and patch clearcut is a blurry one. A 10-acre cut can be viewed as a very large group selection or a small clearcut, depending on one's perspective. The real difference is whether the resultant stand will be managed as an uneven-aged stand or several even-aged stands.

The group selection system has several advantages. By creating sufficiently large openings, it favors the more economically valuable shade-intolerant species such as oaks. In addition, by creating a patchy environment of several different age classes, it favors numerous species of wildlife. As the openings are small and scattered, group selection is more aesthetically pleasing

Figure 14.9. Aerial photo of several group selection cuts.

than larger clearcuts. Although group selection may not be desirable for maximizing income from timber production, it has become widely used on wildlife refuges and other areas where wildlife management is a primary goal. Disadvantages include the necessity of more entries into a stand and higher risk of logging damage to residual trees, higher incidence of disease from the logging damage, and the need for more demanding management in terms of expertise, inventory, and record keeping.

Bringing Back the Bush

The preceding sections have covered traditional silvicultural approaches to rehabilitating degraded forests. These are the most appropriate techniques for rehabilitating relatively large tracts and those tracts where timber harvests are feasible. In some situations, especially on very small tracts and in urban settings where exotic vegetation is a primary concern, a smaller scale but more labor-intensive approach might be more acceptable.

An interesting approach to this type of rehabilitation has developed in Australia under the catchphrase "bringing back the bush" (Bradley, 1988). This approach was developed to restore small areas of Australian bush in urban settings that have been overrun by exotic plants.

The Bradley method is based on the gradual weeding out of the exotics by working through the tract in small increments. Landowners and managers are advised to follow three principles that guide this approach: (1) work from areas of native plants towards weed-infested areas, (2) make minimal disturbance, and (3) let native plant regeneration dictate the rate of weed removal. From the third principle, it should be clear that this is a slow approach to rehabilitation. It also requires a fairly high degree of knowledge about the growth habits and ecology of plant species and is very labor intensive.

The best way to apply this approach may be to work with knowledgeable volunteers to rehabilitate a small tract of forest in or near an urban area. The most valuable aspect of this approach may be as a tool for promoting environmental awareness and education.

Selected References

Baker, J.B., and Broadfoot, W.M., 1979, Site evaluation for commercially important southern hardwoods: New Orleans, La., U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, General Technical Report SO-26.

Beattie, C.T., and Levine, L., 1983, Working with your woodland: A landowner's guide: Hanover and London, University Press of New England, 310 p.

Belli, K.L., Hart, C.P., Hodges, J.D., and Stanturf, J.A., 1999, Assessment of the regeneration potential of red oaks and ash on minor-bottoms of Mississippi: Southern Journal of Applied Forestry, v. 23, no. 3, p. 133-138.

Burns, R.M., and Honkala, B.H., 1990, Silvics of North America, v. 2, hardwoods: Washington, D.C., U.S. Department of Agriculture, Forest Service, Agricultural Handbook 654, 877 p.

Bradley, L., 1988, Bringing back the bush: the Bradley method of bush regeneration: Chicago, Landsowne Press, 111 p.

Clatterbuck, W.K., and Meadows, J.S., 1993, Regenerating oaks in the bottomlands, *in* Loftis, D.L., and McGee, C.E., eds., Oak regeneration: serious problems, practical recommendations: Asheville, N.C., U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station, General Technical Report SE-84, p. 184-195.

Hodges, J.D., 1997, Development and ecology of bottomland hardwood sites: Forest Ecology and Management, v. 90, p. 117-126.

Hodges, J.D., 1998, Minor alluvial floodplains, *in* Messina, M.G., and Conner, W.H., Southern forest wetlands, ecology and management: Boca Raton, Fla., Lewis Publishers, p. 325-341.

Johnson, R.L., 1980, New ideas about regeneration of hardwoods, *in* Proceedings of Hardwood Committee's Symposium on Oak Regeneration: Atlanta, Ga., Southeastern Lumber Manufacturing Association, p. 17-19.

Johnson, R.L., 1981, Wetland silvicultural systems, *in* Jackson, B.D., and Chambers, J.L., eds., Timber

Harvesting In Wetlands: 30th Annual Forestry Symposium: Baton Rouge, La., Louisiana State University, Division of Continuing Education, p. 63-79.

Kellison, R.C., Martin, I.P., Hansen, G.D., and Lea, R., 1988, Regenerating and managing natural stands of bottomland hardwoods: Washington, D.C, American Pulpwood Association, APA 88-A-6, 26 p.

Kellison, R.C., Young, M.J., Braham, R.R., and Jones, E.J., 1998, Major alluvial floodplains, *in* Messina, M.G., and Conner, W.H., Southern forest wetlands, ecology and management: Boca Raton, Fla., Lewis Publishers, p. 291-323.

Kennedy, H.E., Jr., and Johnson, R.L., 1984, Silvicultural alternatives in bottomland hardwoods and their impact on stand quality, *in* Guldin, R.W., ed., Proceedings of the 14th Annual Southern Forest Economics Workshop, March 13-15, 1984, Memphis, Tenn., p. 6-18.

Manuel, T.M., Belli, K.L., Hodges, J.D., and Johnson, R.L., 1993, A decision-making model to manage or regenerate southern bottomland hardwood stands: Southern Journal of Applied Forestry, v. 17, no. 2, p. 75-79.

McGee, C.E., 1986, The first decision: to rehabilitate or to regenerate immature low-quality hardwoods, *in* Smith, H.C., and Eye, M.C., eds., Proceedings: Guidelines for Managing Immature Appalachian Hardwood Stands: Morgantown, W.Va., West Virginia Books, p. 134-139.

McKevlin, M.R., 1992, Guide to regeneration of bottomland hardwoods: Asheville, N.C., U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station, General Technical Report SE-76, 35p.

Meadows, J.S., 1996, Thinning guidelines for southern bottomland hardwood forests, *in* Flynn, K.M., ed., Proceedings of the Southern Forested Wetlands Ecology and Management Conference, March 25-27, 1996, Clemson, S.C.: Clemson, S.C., Consortium for Research on Southern Forested Wetlands, Clemson University, p. 98-101.

Meadows, J.S., and Stanturf, J.A., 1997, Silvicultural systems for southern bottomland hardwood forests: Forest Ecology and Management, v. 90, p. 127-140.

Putnam, J.A., Furnival, G.M., and McKnight, J.S., 1960, Management and inventory of southern hardwoods: U.S. Department of Agriculture Handbook No. 181, 102 p.

Smith, D.M., 1986, The practice of silviculture (8th ed.): New York, John Wiley and Sons, 527 p.

Stanturf, J.A., and Schoenholtz, S.H., 1998, Soils and landforms, *in* Messina, M.G., and Conner, W.H., Southern forest wetlands, ecology and management: Boca Raton, Fla., Lewis Publishers, p. 123-147.

Acknowledgments

This guide is based on the knowledge and experience built over the years by many researchers, field foresters, wildlife managers, and wetland restoration professionals. In particular, we have drawn heavily on the research of the U.S. Department of Agriculture, Forest Service's Southern Forest Experiment Station, especially the work of James Baker, Frank Bonner, Walter Broadfoot, Bob Johnson, Harvey Kennedy, and Roger Krinard. Several practitioners of bottomland hardwood reforestation provided especially valuable assistance, including Tim Wilkins and Jon Wessman of the U.S. Fish and Wildlife Service, Larry Moore of the U.S. Department of Agriculture, Forest Service, and Larry Savage and Kenny Ribbeck of the Louisiana Department of Wildlife and Fisheries. Other people who provided assistance include Judy Buys, Kelia Fontenot, DeMarion McKinney, and John McCoy.

Frank Bonner, U.S. Department of Agriculture, Forest Service; Ronnie Haynes, David Smith, Bob Strader, and Larry Threet, U.S. Fish and Wildlife Service; Larry Savage, Kenny Ribbeck, and Jimmy Anthony, Louisiana State Department of Wildlife and Fisheries; Jim Chambers, Louisiana State University; and Wylie Barrow, Lee Foote, and Sammy King, U.S. Geological Survey, reviewed drafts of all or part of this manuscript and provided valuable comments and suggestions. Except where noted, all photos were provided by the authors.

Glossary

Advance regeneration - Advance growth seedlings or saplings that develop and are present in the understory.

Adventive plants - Nonnative plants that have been introduced to an area but have not become permanently established.

Basal area - The cross-sectional area of a stand of trees measured at breast height (140 cm or about 4 ft 6 inches aboveground). The area is expressed in square meters per hectare (ft per acre) and is a measure of stocking density.

Broad-leaved - Characterizing plants that have leaves that are broad and flat rather than needle-shaped.

Clustering - With respect to the planting of seed or seedlings, clustering refers to planting in groups within close proximity of each other so that cross-fertilization within species can occur with some level of certainty.

DBH (diameter at breast height) - The diameter of a standing tree measured 140 cm (4.5 ft) from the ground.

Deciduous - Pertaining to perennial plants that lose their leaves part of the year, that is, hardwood trees such as oak, hickory, and maple.

Epicormic branching - The development of small branches along the bole, or trunk, of a tree. This often develops in response to thinning operations where substantially greater sunlight penetrates to the tree stems.

Even-aged management - Silvicultural system in which the individual trees originate at about the same time and are removed in one or more harvest cuts, after which a new stand is established.

Exotic species - Species that are not native to an area and have become naturalized.

Gap phase regeneration - Progressive changes in community structure, composition, and diversity resulting from the canopy gap created by the death of individual trees (as a result of events such as old age, wind, lightning strikes, insect attacks, etc.) being filled by young individuals of the same or other species.

Green manure - Refers to herbaceous plants that are plowed under while still green to add large quantities of organic matter to the soil, improving soil structure.

Green-tree reservoir - Any impoundment created with the intention of flooding a forested area for a portion of the year, yet retaining the forest cover. Green-tree reservoirs are usually flooded during a portion of the fall and winter to provide waterfowl habitat. Quite often, however, the tree species desirable for waterfowl habitat are gradually killed by the repeated flooding.

Hard mast-producing - Species such as oaks, pecans, or hickories that produce a large nut (acorn) that in turn provide food for a variety of wildlife such as deer, turkey, hogs, and some waterfowl (see heavy-seeded species).

Heavy-seeded species - Species such as oaks, pecans, or hickories that have heavier seeds. These species are generally believed to provide the greatest overall value to wildlife such as deer, turkey, squirrel, and waterfowl.

Herbaceous - Soft and green vegetation which dies back to the ground each year, generally containing little woody tissue.

High grading - Forest harvesting where only the most commercially valuable trees are cut. This method of harvest usually results in a forest dominated by undesirable or weedy tree species.

Hydric - Characterized by or requiring an abundance of moisture.

Hydrologic regime - The pattern of water level dynamics, generally referring to the timing, frequency, depth, and duration of aboveground flooding, but hydrologic regime also refers to belowground water level fluctuations.

Hydroperiod - Generally synonymous with hydrologic regime, but hydroperiod is often considered to refer to aboveground flooding only.

Improvement cutting - A cutting made in a stand past the sapling stage primarily to improve composition and quality by removing less desirable trees of any species.

Initial management - The first management action being performed as part of a long-term multiphase management plan for a given forest stand.

Invader - Any species that disseminates to and becomes established on a site without human intervention can be considered an invader. Invading seedlings can be either desirable or undesirable. The term invader does not refer only to exotic species.

Light-seeded species - Species such as ash, elm, sweetgum, and sycamore that have light weight seeds that can be easily dispersed by wind or water. Many of these seeds, however, can also be dispersed by animals.

Mesic - Characterized by intermediate moisture conditions that are neither excessively wet nor dry.

Nonpoint source pollution - Pollution that is not from a single, well-defined site such as a factory. Runoff from agricultural fields is generally considered nonpoint source.

Palustrine system - A classification by Cowardin and others, 1979, that includes all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 ppt.

Provenance - The original region in which an individual of any plant or animal species was found. Provenance tests take individuals of any selected species from several regions and grow them in a common area (plantation) to search for maximum growth or productivity for that species.

Regeneration - The natural or artificial replacement of old trees with new tree growth.

Self-incompatible species- Plant species for which one flower on an individual cannot fertilize another flower on the same individual.

Sere - Collectively, all temporary plant communities in a chronosequence of change, as different species invade and later dominate or are competitively excluded from a given local area.

Shelterwood cut - A cut in which the mature stand is generally removed in a series of two or more cuts, the last of which is when the new even-aged stand is well developed.

Silviculture - The science and art of regenerating and managing a forest to meet specific objectives.

Soil horizon - A distinct layer of soil parallel to the surface that has definitive physical, chemical, and hydrologic characteristics.

Stand - A contiguous group of trees sufficiently uniform in age class distribution, composition, and structure, and growing on a site of sufficiently uniform quality to be a distinguishable unit.

Stocking - An indication of growing-space occupancy relative to a preestablished standard.

Thinning - Intermediate cuttings aimed primarily at controlling growth of timber stands by adjusting stand density.

Tiling - The placement of drain tiles below the ground to eliminate excess flooding or soil saturation.

Understory - Any plants growing under the canopy formed by other plants, particularly herbaceous and shrub vegetation under a brushwood or tree canopy.

Uneven-aged management - Silvicultural system in which individual trees originate at different times and result in a forest with trees of various ages and sizes. Harvest cuts are often on an individual-tree selection basis.

Selected References

Burns, R.M., and Honkala, B.H., 1990, Silvics of North America, v. 2, hardwoods: Washington, D.C., U.S. Department of Agriculture, Forest Service, Agriculture Handbook 654.

Cowardin, L.M., Carter, V., Golet, F.C., and LaRoe, E.T., 1979, Classification of wetlands and deepwater habitats: U.S. Fish and Wildlife Service Biological Services Program FWS/OBS-79/31. 103 pp.

Stokes, B.J., Ashmore, C., Rawlins, C.L., and Sirois, D.L., 1989, Glossary of terms used in timber harvesting and forest engineering: New Orleans, La., U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, General Technical Report SO-73, 33 pp.

U.S. Department of Agriculture, Forest Service, 1995, Final environmental impact statement for the management of red-cockaded woodpecker and its habitat on national forests in the southern region: Washington D.C., U.S. Department of Agriculture, Forest Service, Southern Region.

U.S. Department of Agriculture, Forest Service, 1996, Final environmental impact statement (FEIS) for the revised land and resource management plan for national forests and grasslands in Texas: U.S. Department of Agriculture, Forest Service, Southern Region.

U.S. Department of Agriculture, Forest Service, 1997, Draft environmental impact statement: draft revised land and resource management plan for Kisatchie National Forest: U.S. Department of Agriculture, Forest Service, Southern Region.