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Marcot, B. G., R. E. Gullison, and J. R. Barborak. 2001. Protecting habitat elements and natural areas in the managed forest matrix. Pp. 523-558 in: R. A. Fimbel, A. Grajal, and J. G. Robinson, eds. The cutting edge: conserving wildlife in logged tropical forests. Columbia Univ. Press, N.Y.

# Protecting Habitat Elements and Natural Areas in the Managed Forest Matrix

Bruce G. Marcot, R. E. Gullison and James R. Barborak

How can plant and animal species, ecological communities and processes, and ecosystems be maintained in areas also being used by people for their natural resources commodities? For most developing societies, extensive preservation of natural resources or reverting to indigenous resource use habits and smaller human population sizes (e.g., Alcorn 1993, Gadgil and Berkes 1993) are simply not options. Rather, the answer may lie in managing forests as ecosystems and for long-term conservation of wildlife habitat as well as for human use.

Much scientific literature has highlighted the value of natural areas for conserving the biodiversity of a region (DellaSala et al. 1996, Falkner & Stohlgren 1997) and the need for linking natural areas with habitat corridors or connections (Harrison 1992). Biodiversity is defined as the variety of life and its processes; here, our focus is on wildlife and their habitats. Natural areas can serve as refuges for hunted, threatened, or imperiled species of plants and animals, such as demonstrated for Neotropical migrant birds in Mexico (Gram and Faaborg 1997) and large vertebrates in Paraguay (Hill et al. 1997).

In the tropics, protecting at least small patches of native forest and linking them can greatly help to provide for populations of game and nongame wildlife (Glanz 1991, Johns 1995). However, protecting biodiversity in tropical forests entails more than simply reserving specific forest sites. For example, Bawa & Seidler (1998) concluded that retaining natural tropical forest diversity also entails: conserving some wildlife habitat within secondary forests, restoring degraded lands, managing plantation forestry, providing for nontimber uses for some forests, changing accounting procedures to reflect the true value of natural forests, and supporting forestry agencies charged with protecting forest reserves. Obviously, protecting biodiversity in managed tropical forest landscapes is a challenge that spans ecological as well as economic, social, and political arenas (Panayotou and Ashton 1992).

Managing for non-timber forest products in the tropics also can be integrated with conserving habitat for wildlife and managing natural forests, such as has been demonstrated in Rio San Juan, Nicaragua (Salick et al. 1995). In other examples, in the Petén, Guatemala, and in West Kalimantan, Indonesia, non-timber extractive reserves were found by Salafsky et al. (1993; Chapter 25) to play a key role in forest protection, but their conservation effectiveness was dependent on local ecological, socioeconomic, and political conditions.

In some cases, natural areas that provide for rare or endemic species or high biodiversity coincide with sites of high religious or cultural significance. These can include sacred forest groves and sites with spiritual meaning. For example, in India, China, Myanmar, and Thailand, sacred groves and cemeteries with banyans (*Ficus* spp.) and other trees sometimes provide the last local bastion for indigenous wildlife (Wachtel 1993). In West Africa, sacred groves can help protect habitats for small mammals (Decher 1997). In the Garo Hills of Meghalaya, India, the state government has designated entire national parks (e.g., Balpakram National Park) and wildlife sanctuaries (e.g., Siju Wildlife Sanctuary) based not only on their biodiversity value, but also on their significance to the animistic religious beliefs of the local Garo Hills Tribes (B. Marcot, personal observation). Sacred groves and spiritual sites can survive without official designation, but their formal recognition in a conservation network can help ensure their future protection.

Protecting wildlife habitat is one facet of maintaining the ecological integrity of managed tropical forests (Chapters 3-14). By planning protected areas as a network, their value to wildlife can be strengthened. Protected areas of various types and sizes, within managed landscapes, serve as important refugia and corridors for wildlife.

The purpose of this chapter is to recommend where and how wildlife (vertebrates, invertebrates, and their habitat) can be protected within tropical production forest landscapes. We begin by defining terms and provide an overall framework for understanding wildlife habitat. Then we briefly review what is known about the elements of that framework, including habitat corridors, habitat connections, and natural areas, and their ecological and economic or social values. We next outline a set of habitat elements and landscape conditions that managers can map and delineate in the field, using existing information, for wildlife and ecosystem conservation. We end with a discussion of research needs, and we offer some conclusions on a concerted approach to wildlife habitat conservation that spans ownership, species, and ecosystems.

## 23.1 PROTECTED AREAS AND THEIR OBJECTIVES

The conservation biology and wildlife literature extensively discusses the utility of delineating protected areas (Harris 1984, Hunter 1990, Meffe & Carroll 1994, Beier & Noss 1998). Authors have focused on a wide variety of factors when recommending protected areas, including maintaining genetics or dynamics of specific plant or animal populations, and protecting rare species, unique species assemblages, rare plant communities, rare successional stages, ecosystem dynamics, global climate change, and economics (Box 23-1). Other objectives of protected areas include the protection of a representative sample of all vegetation types (representativeness) and capturing the full range of habitat conditions within a region (complementarity).

Protected natural areas in timber management landscapes can serve as refugia for native plants and animals and as means of conserving biodiversity (Hunter 1990, Sayer et al. 1995). Within such production forests, protected natural areas can be used to conserve sensitive sites such as wetlands, grottos, and steep slopes, and act as source areas from which organisms can recolonize post-logged sites. These refugia can range in size from small zones of uncut forest along watercourses and hillsides, to larger blocks reserved from commercial timber harvests (e.g., parks and non-timber extraction areas). Collectively, the set of conserved habitat elements and the larger refugia may be called a 'protected area network' or PAN (Table 23-1). The four PAN elements, from smallest to largest, are: 1 = local habitat elements within the managed forest matrix, 2 = zones of protected forest conditions within the managed forest matrix, 3 = habitat connections and corridors between and among managed forests and larger protected areas, and 4 = large protected areas such as parks. A schematic of how these 4 elements might occur on the landscape is shown in Figures 23-1 and 23-2.

PAN elements 1 and 2 are within the purview of planners, field foresters, and logging operators. These habitat elements and natural reserves within timber concessions (or cutting blocks, that is, the managed forest matrix) may include sites or stands that are of limited interest for timber harvesting and forest production, such as steep sites, wet areas, areas of low commercial tree stocking and low productivity, and individual trees of low or no commercial value. Natural areas within cutting blocks also can include some areas of special interest to a particular region or country, such as areas with unique habitats, fragile soils, high cultural values, and rare plants. Conserving specific habitat elements in the managed forest matrix (PAN element 1), and providing small natural areas as zones within timber concessions (PAN element 2), should help conserve wildlife and their ecological processes by: a) preserving sites important for protected or rare plants and animals that do not occur elsewhere, or that have been severely impacted elsewhere; b) safeguarding specific locations of resources, such as key fruit trees or open water, important to maintaining populations of some wildlife species throughout a broader landscape or region; and c) contributing to conserving the full variety of ecological communities and native biodiversity of a broader region (Zuidema et al. 1997).

The larger PAN elements 3 and 4 are vital parts of the overall protected area network, although their specific discussion is beyond the scope of this chapter. Delineating PAN element 3 areas, the larger habitat linkages and reserves occurring between the cutting blocks, can follow many of the guidelines presented below for PAN element 2. PAN element 3 areas typically are larger than the natural area reserves within the cutting blocks. This element protects habitats important for wider-ranging wildlife, maintains genetic diversity of plants and animals, and provides natural ecological processes such as fruit production. To the extent possible, PAN element 3 should be interconnected to within- and between-cutting block reserves and corridors of older secondary forests or uncut primary forests in upland or riparian situations. Also, the larger, between-cutting unit reserves of PAN element 3 should be connected to large parks and preserves (PAN element 4) outside the production forest area.

The four PAN elements can be expressed in the complementary roles of Federal, State, and private forest lands, and associated parks, preserves, wildernesses, and conservation forests established for preserving biodiversity in the United States (Loomis 1993). They also can be related to traditional IUCN land allocation categories (Table 23-1). All elements must be designed in concert for them to function correctly, that is, to help provide for productive forests and to conserve or restore native biodiversity and ecosystem processes.

## 23.2 WHAT INFORMATION IS NEEDED FOR DELINEATING PROTECTED AREA NETWORKS?

Information useful for delineating protected areas and identifying specific habitat elements within a timber harvest area or concession includes the following:

### 23.2.1 *Distribution of Terrestrial Vegetation Conditions or Communities*

The distribution of terrestrial vegetation communities and conditions can be described as: a) maps of vegetation types; b) maps of vegetation structural stages, age classes, and/or disturbance classes; and c) information on the effects of forest management activities on vegetation types, structural stages, age classes, and/or disturbance classes. Such information might be obtained from a variety of sources including aerial photos, stocking surveys, and forest inventories. This information describes the location and extent of scarce terrestrial vegetation types or communities which may be adversely changed by forest management conditions. Where published scientific studies are lacking, much of this information may have to come from local experts such as in-field biologists and ecologists, zoologists, and habitat managers.

### 23.2.2 *Wildlife Species:*

The distribution and abundance of wildlife species can be described by: a) lists of species of amphibians, reptiles, birds, and mammals (and selected plants and invertebrates of conservation interest), b) information on the general abundance and distribution of each 'focal' species, c) information on area requirements of the focal species, and d) information on specific resource requirements of focal species (Ryti 1992). Focal species are those of special conservation interest which can include species of known viability concern, species with large body size or large home ranges (that is, large habitat area requirements, e.g., the Group 2 or 3 species in Table 23-2 and Figure 23-3), species reliant on rare conditions or resources, and species hunted heavily and extirpated elsewhere. Much of this information on wildlife species may have to come from local experts or be extrapolated from other geographic areas with similar vegetation and environmental conditions (Chapters 4-14).

### 23.2.3 *Plants and Animals Important to Forest Productivity*

Identifying and describing the importance of plant and animal species to the productivity of managed forests requires a) information on ecology of soil productivity and tree production, and b) lists of species and ecological conditions providing such services, particularly those more closely associated with unmanaged forest conditions. These species are those that play key ecological roles, such as plant pollination, seed dispersal, soil turnover, creation of tree cavities and burrows, decay and physical breakdown of wood, and nutrient cycling (Chapters 3-14). This kind of information is hard to quantify, but ultimately may prove vital in maintaining long-term productivity of managed tropical forests.

### 23.2.4 *Habitat Connectivity*

The extent to which the habitat for focal plants and animals is connected across the landscape can be assessed by use of vegetation and habitat maps, and regional maps showing locations of parks and other reserves (PAN elements 3 and 4), managed forests, and general information on their conditions. The vegetation and habitat maps can be related to general habitat requirements of the focal species, and the regional maps can show where such conditions occur that could provide important connections across the landscape.

## 23.3 GUIDELINES FOR IDENTIFYING PROTECTED ZONES AND HABITAT ELEMENTS WITHIN CUTTING AREAS

### 23.3.1 *Key Habitat Elements in the Managed Forest Matrix (PAN element 1)*

This section lists key habitat elements that can be protected during timber harvest and other activities in the managed forest matrix outside protected zones.

#### 23.3.1.1 Protect Snags and Down Logs

Snags (standing dead or partially dead trees) and down logs (logs on the forest floor) provide critical habitats for many species of plants, invertebrates, lizards, snakes, cavity-using birds, and other kinds of wildlife (Johns 1997). In turn, many of these organisms aid in the breakdown of wood and its eventual return to productive soil. Such organisms, including ants and termites, also serve as a major prey source and base for food chains in the forest (Sazima 1989; Chapters 12 & 13). Primary cavity-excavating birds such as woodpeckers, barbets, and toucans often create hollows in snags which are used in turn by a variety of secondary-cavity using species such as swallows and small owls (Chapters 8-10). In general, larger diameter snags and down logs are used more extensively by wildlife than are smaller ones. At a minimum, snags 25-30 cm diameter and 3 m tall, and down logs at least 25 cm diameter and 3 m long, provide habitat for many species. Large species of woodpeckers, owls, hornbills, flying squirrels, and other species may require snags or hollow trees at least 40-50 cm diameter, and large ground-dwelling mammals may require logs over 35-40 cm diameter for den sites. Where possible, snags and down logs should be left undamaged, whether standing or on the forest floor, to provide these services.

#### 23.3.1.2 Protect Trees Prone to Hollowing

Trees prone to hollowing provide cavities for a wide variety of wildlife (Johns 1997). Such trees include figs and palms, which also provide important fruit food sources. Some trees with physical defects, such as large dead branches, lightening strikes, and butt rot, might be prone to hollowing and can serve as indicators of potential value to wildlife.

23.3.1.3 Protect Epiphyte Patches

Patches of epiphytes, such as terrestrial or epiphytic bromeliads, occur in many forest types and are of particular value to wildlife (Remsen 1985). These patches provide important food sources (fruits and stalks) for birds, tapirs (*Tapirus* spp.), deer, monkeys, peccaries or wild boar (*Sus scrofa*), and other species. The patches also provide shelter for wildlife species that disperse seeds. The water-filled interiors of individual epiphytes often provide habitat for many frogs and invertebrates, some of which occur or breed nowhere else in the forest. Epiphytes can be protected for wildlife as individual habitat elements within managed forest situations, such as in coffee plantations of Mexico (Moguel and Toledo 1999).

23.3.1.4 Protect Large Seed- and Fruit-Bearing Trees

Large seed- and fruit-bearing trees (Photo 23-1) provide important food sources for toucans, hornbills, birds of the family Cracidae, many monkeys including spider monkeys and langurs, and many other arboreal and terrestrial fruit-eating wildlife species (Johns 1988). Figs (*Ficus* spp.) are keystone resources that appear to be high in calcium and provide fruit throughout the year. Although some seed predation may not be desired by timber managers, the ecological function of seed dispersal by wildlife is critical to maintaining forest diversity and distribution of some desirable trees (Howe 1977, 1980).

23.3.1.5 Protect Large Overstory/Emergent Trees

Where possible, protection of large overstory or emergent trees can greatly add to the overall vertical structure of forest vegetation (Photo 23-3). These trees provide feeding, resting, cover, and nesting habitats for a very wide variety of birds, monkeys, invertebrates, plants, sloths, and many other species (Pearson 1971). Large overstory trees, even a few per hectare, can help serve as wildlife habitat connectors linking protected areas of primary forests within a managed, secondary forest landscape (Photo 23-4; B. Marcot, personal observation).

23.3.1.6 Provide Sites and Habitat Elements for Species Critical to Forest Health and Productivity

Identify the following kinds of key habitats and sites for groups of species which play critical roles in maintaining the health and productivity of forest ecosystems. For many of these species groups, specific publications and local knowledge of experts can be sought to help identify key types of habitats and specific sites for protection.

23.3.1.6.1 Habitat for Essential Plant Pollinators

In the Neotropics, nectar-feeding or long-tongued bats (family Phyllostomidae, subfamily Glossophaginae) pollinate nectar-producing plants with large, pale flowers that open at night, and with musky odors. Key habitats for these bat species include caves, rock outcrops, tree hollows, and patches of dense primary forest and deciduous forest. Bat-pollinated New World plants include balsa trees, ceiba (silk-cotton) trees, and jicaro (calabash) (Emmons 1990).

Hummingbirds, orioles, sunbirds, and a multitude of invertebrates serve as important pollinators for many plant species not served by bats. Collectively, this bird and invertebrate group occupies a wide array of nesting or breeding substrates, including dense low shrubs, riparian thickets, understory tree canopies, tree bark, and other sites. Individual nest or breeding sites, as known or as discovered opportunistically or by surveys, can be protected during forest management operations.

23.3.1.6.2 Habitat for Essential Seed Dispersers

In the Neotropics, short-tailed fruit bats of the genus *Carollia* (family Phyllostomidae, subfamily Carolliinae) feed on fruits of shrubs and small trees, especially Piper species; they are one of the most important seed dispersers for many plants with small or large fruits. They carry fruits into cleared areas, stimulating forest regeneration after logging. In some instances, these bats feed on mangos and banana crops and may become pests (Hill and Smith 1984), but they do serve critical seed dispersal functions in forest environments (Emmons 1990). They do well in disturbed habitats but need tree hollows, caves, overhanging banks, tunnels, culverts, or abandoned buildings for roosting, as well as understory forest vegetation for cover and feeding.

Although many of the forest plants pollinated by these bats are not of commercial value, the array of other wildlife associated with such plants can provide pollination or dispersal services to commercial tree species. It is this array of ecological services that constitutes an ecosystem, and which foresters may wish to conserve to ensure overall ecological health and integrity of their managed forests. To this end, foresters specifically may wish to provide known or potential roost and feeding sites for short-tailed fruit bats, in order to maintain their ecological functions within a forest ecosystem. For these species, this would entail maintaining such elements within mature or disturbed forests, gardens and plantations, deciduous forests, and gallery forests.

All species of Neotropical fruit bats of the subfamily Stenodermatinae (family Phyllostomidae) feed on fruit, supplemented by flower nectar in the dry season when fruit is scarce (Emmons 1990). These bats are the main dispersers of seeds for many plants. They carry seeds for early secondary or early successional growth into forest gaps caused by natural disturbances or cutting, thus restoring new forests and maintaining plant species richness of the forest. They can play roles of dispersing seeds of plants into newly burned or cut sites, thereby helping to stabilize soils or quickly add to soil organic matter, to help maintain soil productivity for future forestry use. These bats, like many other Neotropical and old world species, require hollow trees for their roosting sites. Foresters can identify and protect key roost and feeding sites of these species. Roosts are used many times and are identified by piles of seeds, feces, and wads of fibers below large leaves which may be several meters above the ground (Emmons 1990).

In both Old and New World tropics, many species of monkeys disperse seeds of plant species, especially canopy trees and lianas (Chapters 3 & 4). Sites known to be used heavily by monkey troops can be identified by field surveys and protected. Also, and perhaps more importantly, to provide for monkeys, maintain the continuity of the tree canopy, maintain the diversity of fruit and vegetation food resources, and control hunting.

In many forests, birds including toucans, aracaries, trogons, cotingas (in the New World) and hornbills and fruit pigeons (in the Old World) serve as key seed dispersers for many canopy plant species including trees of commercial value (Chapters 8-10). Individual nests, often in cavities and hollows of trees of limited to no commercial value themselves, can be located and protected during forest management operations.

#### 23.3.1.6.3 Habitat for Fungal Spore Dispersers

Some wildlife species play critical roles in dispersing spores of underground fungi, including mychorrizal fungi which can be critical to the growth, productivity, and health of many commercial forest trees (Chapter 6**)**. Examples in the New World are the spiny rats (*Proechimys* spp.) and rice rats (*Oryzomys* spp.) (Janos and Sahley 1995), which also are important prey for small carnivores including large snakes and birds of prey. These rats also depend on fruits, seeds, and insects and likely also disperse seeds of palms and other trees of commercial interest. To provide for such species, den sites and ground cover could be maintained as well as appropriate fruit- and seed-bearing plants. Spiny rats and rice rates shelter under dense fallen brush, in hollow logs, or in holes in the ground (Emmons 1990); such substrates could be provided (brush piles) or protected (hollow logs, ground burrows) during ground-disturbing forestry operations.

In another New World example, brocket deer (*Mazama* spp.) feed on fungi on decaying logs and may serve to disperse underground fungi, including mychorrizal fungi. Specific bedding, birthing, and key foraging sites for brocket deer could be protected. In general, for beeding and birthing, deer use forest stands with hiding cover; hiding cover can be any foliage within 2 meters high that largely obstructs the visibility of a standing deer within a few dozen meters distance. Deer foraging areas include dense brush below 2 meters high that shows obvious sign of pruning. Where possible in areas of known deer occurrence, such understory foliage for hiding and foraging could be provided for at least a portion of a forest stand. Often, this would not entail any special management activities or directives other than ensuring that the entire understory cover is not removed during operations.

#### 23.3.1.6.4 Habitat for Predators of Seeds, Seedlings, and Animals

In both the New and Old World tropics, pigs (wild boar) and peccaries have an important influence on the spatial distribution of plants, including some of the commercial palm species (e.g., heart-of-palm). Pigs and peccaries can decline from hunting and from habitat destruction (Chapters 5, 15, 16). In Neotropical forests, pacas (*Agouti paca*) and agoutis (*Dasyprocta* spp.) eat large seeds of trees and aid their dispersal by caching (burying and storing) seeds (Chapter 6). In Paleotropical forests, such seed-eating is done by wild boar and other species. Large carnivores, including puma (*Felis concolor*) and jaguar (*Panthera onca*) in the New World, and tiger (*P. tigris*) and leopard (*P. pardus*) in the Old World, control the herbivory impacts of their prey species. Their absence can signal potentially undesirable changes in plant communities and plant diversity.

Conservation of large carnivores is relegated more to PAN Elements 3 and 4 – large parks and preserves, and their connections. Some countries have established management programs for specific large carnivores, such India's system of tiger reserves (Panwar 1978). However, by far most large carnivores do not enjoy the luxury of such species-specific protection. Thus, in managed forest landscapes their prey and the food of their prey could be provided. Many species of large carnivores are not choosy about specific plant species or vegetation conditions, but rather depend on some kind of general cover such as rocks and dense brush, and on availability of prey including herbivorous mammals such as boar and deer. Foresters could provide the habitats and foods on which such prey depend, including low (< 2 m-tall) shrub foliage, seed- and nut-bearing shrubs and trees, tuber-producing forest floor plants, and other substrates and foods as discussed in sections above.

23.3.1.6.5 Habitat for Nutrient Cyclers and Insectivore Prey

Termites, ants, and earthworms play major roles in transferring organic material, altering vegetation structure and composition, and cycling nutrients throughout forest ecosystems (Chapters 12 & 13). They include leaf-cutter ants in the Neotropics, which appear resilient to the effects of selective timber harvesting (Johns 1988). Termites serve to break down dead forest wood and thereby recycle organic matter back into the soil. Termites are eaten by smaller armadillos, birds, pangolins, and many other species. Termite nests are often used by birds, such as trogons, for nest holes. Protection of soils from undue erosion, compaction, burning, and scarification would help provide for this species group. To the extent possible, termite mounds and ground ant nests should be protected during ground-disturbing operations.

<u>23.3.1.7 Protect individual trees or forest groves supporting colonies of birds</u>

Some tropical birds nest or roost in colonies. Examples include some parrots and crows. Protection of individual trees or small forest groves with colonial nest or roost sites can greatly help to maintain these species, some of which can provide important benefits to foresters by dispersing seeds of desirable plants.

### 23.3.2 *Universal Considerations for Natural Areas (PAN element 2)*

This section lists key habitat elements that could be protected from forest and timber management operations, within zones located in timber concessions (also variously termed cutting blocks or management units in some areas).

23.3.2.1 Preserve Habitat for Priority Wildlife Species

23.3.2.1.1 Determine Kinds of Habitats for Priority Species

One of major steps in providing wildlife habitat within timber concessions is to identify priority wildlife species and their habitats, and then to protect such key habitats. Priority species can include threatened, endangered, and IUCN Red Data Book species, as well as locally and regionally endemic species (species found nowhere else). Depending on local management objectives, these species also could include those of great economic or social importance, species of traditional value, or sacred organisms.

One example of a priority species is the endangered Sokoke scops owl (*Otus ireneae*) which is endemic to the *Cynometra* woodland of the Arabuko-Sokoke forest of East Kenya, Africa (Virani 1994). The Sokoke scops owl is threatened by loss of its forest habitat and by specimen collectors (Everett 1977). Its total population was reported by Clark et al. (1978) to be 1,300 - 1,500 pairs, and estimated by Virani (1994) to be 1,000 pairs within the Arabuko-Sokoke forest (Virani 1994). Between 1956 and 1966, its forest habitat was halved to 350 $km^2$, and by 1991 only one forest reserve of 40 $km^2$ had been established for its protection (Hume and Boyer 1991). Few studies have been done on the species, but its habitat requirements likely include cavities in hollow or dead trees and lack of disturbance in its foraging territory which is about 12-14 hectares (Virani 1994). Field surveys could help identify locations of cavity trees and breeding pairs, and such areas of *Cynometra* woodland could be protected at least in local, small forest reserves of 12-14 hectares.

Habitats of other priority species can include nest or den sites, important resting sites, and important feeding sites, and are too diverse to annotate here. We encourage foresters to consult with local biological experts to determine presence of priority species and to identify their habitat requirements. Presence of threatened, endangered, Red Data Book, or endemic species also can be determined from existing or new biological surveys (Chapter 19) and by consulting wildlife occurrence records for the area.

23.3.2.1.2 Size of Habitats

The size of individual forest protected zones can vary according to the site-specific objective or conditions. These zones may range from a tiny patch of a few hectares or less for protecting endangered or rare plants, to forming a part of a broader forest area that protects wide-ranging, disturbance-sensitive species such as spider monkeys (*Ateles paniscus*) (McFarland-Symington 1988) in the Neotropics. It is important to realize that no single size will meet all conservation needs and all species' requirements. Protecting from timber harvest undisturbed forest blocks of 100-200 ha, or 10+% of the total forest area, has been recommended (Blockhus et al. 1992; Chapters 16 & 21).

Size of habitats for PAN element 2 protection zones typically would focus on key breeding or roosting sites for smaller-ranging animals, such as the Group 1 species listed in

Table 23-2, and depicted in Figure 23-3. Local management objectives and conditions would dictate the specific sizes and distribution of PAN element 2 protection zones. For example, an overall objective may be to place 10% of a timber concession, plus areas uneconomical to cut, into protection zone status. Arrangements should follow stream courses, dense interlinked tree canopies, and other natural features important to species of conservation interest. Protection zones within a timber concession should be as contiguous as possible to provide habitat connections for organisms. In general, as far as feasible, protection zones also should be: a) larger than smaller, so as to encompass more resources and cover; b) rounder than more linear (except for gallery type forests in riparian buffers), so as to reduce adverse edge effects; and c) closer together rather than more spread apart, so as to increase opportunities for wildlife to move among areas.

A buffer sufficient to shield protected areas from forestry activities that could unduly disrupt vegetation conditions or cause the site to be abandoned by wildlife also needs to be considered (Johns 1997). The width of the buffer should be defined on a site-specific basis depending on the type and intensity of the forest management activities, local topography, age of the edge, and other factors, but more than 30 m width on each side would begin to protect interior habitat from the adverse effects associated with forest edge environments. Depending on the kinds, some limited activities could be allowed within buffer areas, such as collection of nontimber forest products or reduced cutting intensities. However, the objective should be primarily to buffer the adverse effects of more intensive activities outside the area.

One study of anthropogenic edges in a Neotropical montane forest in southwestern Columbia (Restrepo & Gómez 1998) suggests that edges of various ages influence understory birds differently by species and by ecological functional group such as feeding guilds, and that some effects can extend up to 200 m from the edge. Studies at La Selva, Costa Rica, report that avian predation effects occur at distances greater than 30 meters from the edge (Gibbs 1991). The Smithsonian Minimum Critical Area studies in the Brazilian Amazon also demonstrated impacts of wind throw, sunlight, and other conditions farther than 30 meters from the forest edge (Bierregaard et al 1992). A wonderful synthesis by Laurance et al. (1997) of Amazonian edge effects studies suggests that some effects (leaf-litter invertebrate species composition and invasion by disturbance-adapted beetles and butterflies) penetrate up to 250 meters into a forest. However, most biological and physical effects occur within 100 meters, including bird-density effects up to 50 meters. On this basis, forest buffers for vertebrate wildlife habitat could be targeted to be at least 50-100 meters wide.

#### <u>23.3.2.2 Provide Buffers for Streams and Roads</u>

Another means of habitat protection for species is to protect streamside riparian vegetation and to provide a no-cut buffer along all perennial, intermittent, and ephemeral streams (Chapter 21). Riparian buffers help lessen undue erosion and sedimentation of the stream channel from upland clearing and from adjacent road-building (Chapter 14). Buffers also help protect vegetation cover close to water sources, which provides essential habitat for primates (Wallace et al. 1996) and other wildlife species (e.g., Mason 1995; Machtans et al. 1996; Ochoa

1997).

Riparian buffers should be large enough to protect the integrity of the stream system, and to provide sufficient shading, vegetation canopy structure for canopy-using organisms, and natural sources of dead wood for standing, down, and in-stream coarse woody debris. Buffers would vary in width according to local topography and stream channel morphology. At the least, several tree heights are typically needed to buffer stream temperatures, but wider buffers are needed to provide longer-term habitat structure such as sustainable sources of large down wood (Reeves et al. 1991). Finally, as part of riparian protection, only temporary bridges should be built if necessary and when feasible. If roads must cross streams, to the extent possible crossing should be at right angles to the stream, and culverts or other structures provided along roads to minimize erosional damage to the stream channel (Sist et al. 1998).

#### 23.3.2.3 Protect Scarce and Declining Habitats

Scarce and declining habitats include any plant communities or wildlife habitats that are unique, rare, or greatly declining locally or regionally. Representative examples should be conserved of each type of community or habitat, including a sufficient buffer to help maintain the integrity of the protected area. Local biologists can be consulted to identify such species, communities, and locations of key sites.

#### 23.3.2.4 Protect Unique Wildlife Habitats

The following special wildlife habitats typically cover a small land area but on a per-hectare basis are especially important to a wide variety of wildlife. Such habitats can be identified in the field or from aerial photographs, and delineated as small protected areas. They should be delineated during, and excluded from, stocking surveys both on maps and on the ground.

##### 23.3.2.4.1 Riverine Gallery Forests

Forests alongside creeks, streams, and rivers often hold exceptionally high levels of biodiversity (Naiman 1993) (Photo 23-6). Riverine forests and wet valley bottoms are particularly important during the dry season in seasonally dry forest types (B. Marcot, personal observation). In dry forest types, during very dry years with many fires, riverine gallery forests may be the only green foliage and open water available as habitat and cover for much of the wildlife.

Riverine forests also provide important sources of plants with fleshy fruits, including palms and other plant families (e.g., in the Neotropics the families Moraceae, Sapotaceae, Annonaceae) (B. Marcot, personal observation). Fleshy fruits are important resources for a wide variety of wildlife species.

23.3.2.4.2 Salt Licks and Mineral Soil

Areas of bare mineral soil, particularly where soil salts have evaporated to the surface, usually occur in wet areas near riverine forests. They are frequently used by peccaries, tapirs, deer, parrots (if on cliffs), butterflies, bees, and variety of other wildlife (D. Rumiz, personal communication; B. Marcot, personal observation).

23.3.2.4.3 Caves and Rock Outcrops

Caves are important roosting and hibernation habitats for many bats (Chapter 7). They also provide denning sites for carnivores (including cats, dogs, and foxes), owls, oilbirds (*Steatornis caripensis*), swifts, rodents, porcupines, bears, and a variety of other medium to large mammals, as well as habitat for unique invertebrate communities.

Rock outcrops may support unique and scarce plant communities, often containing plants with fleshy fruits eaten by many kinds of wildlife. After short rainfalls, rock outcrops often hold temporary ponds which become important watering holes for nightjars and other birds, and for amphibian reproduction. In addition, rock outcrops provide crevices for bats and specialized rodents and lizards, and seem to attract an especially high concentration of carnivores, rabbits, and other species. Heat captured by these areas during the day provided warmth in the evening that attracts invertebrates, reptiles, and nocturnal birds during the cool dry season (D. Rumiz, personal communication). Rare cliff-dwelling organisms can serve as sensitive indicators of environmental change (Everett and Robson 1991).

23.3.2.4.4 Natural Forest Openings

Some tropical forests have savanna openings (usually adjacent to semi-deciduous forests such as those found in south-east Cameroon; Letouzey 1985). Savannas may look ‘poorer’ than forest environments, but as they occur as inclusions in generally forested regions, they often provide unique environments for plants and animal (Fimbel et al. 1996). Some plant species are found only in savannas, such as the totai palm (*Acrocomia aculeata*) in lowland Bolivia. Natural gaps in forest cover often provide ground vegetation cover and seed-bearing herbs and shrubs which are used by a variety of wildlife. In lowland Bolivia, large savannas in northern Santa Cruz harbor the endangered marsh deer (*Blastocerus dichotomus*), pampas deer (*Ozotoceros bezoarticus*), and maned wolf (*Chrysocyon brachyurus*), and birds such as rheas (*Rhea americana*) (Photo 23-7). Insectivorous bats feed over natural forest openings. Because savannas may burn during the dry season, providing some adjacent forest cover, especially riverine forests, for wildlife is an important conservation measure.

Natural forest openings are not at risk of being logged, but may be degraded if used as landings, camp sites, or converted to forest cover.

23.3.2.4.5 Palm Groves

In some tropical forests, palm groves can provide special habitats for wildlife (Photo 23-5). In the Upper Amazon, Mauritia palms (*Mauritia flexuosa*) have large trunks and grow large fruits which are eaten by many kinds of wildlife including tapirs and peccaries (D. Rumiz, pers. comm.). As the trunks decay, they provide cavity sites for macaws, toucans, and other species. In some cases, palm groves are logged, as for heart-of-palm in the upper Amazon Basin and in south India; in other cases, palm groves may be felled during forestry operations aimed at accessing other commercial trees.

Care can be taken, when designing forestry operations, to retain palm groves. Roads and skid trails should avoid palm groves. Palm groves can be protected as PAN element 2 zones, and individual palms suspected or known to be important for wildlife use can be protected as PAN element 1 habitat elements.

23.3.2.4.6 Lagoons and Other Water Sources

Especially in seasonally dry forests, lagoons and other water sources such as springs provide critical sources of water during the dry season for a wide variety of wildlife. Gallery forests often contain pools well into the dry season. These are important wildlife habitats needing protection.

23.3.2.4.7 Low Hills Within Seasonally-Flooded Forests

In the wet season within seasonally-flooded forests, low hills provide critical refuges for many wildlife species. As an example, in the north coast of Honduras, the most critical habitats to protect for wildlife are low hills which serve as wildlife refugia during occasional major floods (J. Barborak, personal observation). In another example, in northern India and southern Nepal and Buthan, during monsoons in the terai (foothill wet grassland) habitats along the base of the Himalayas, great Indian one-horned rhinoceroses (*Rhinoceros unicornis*) move to the security of locally higher ground covered by sal (*Shorea robusta*) forests. Maintaining forest cover within such high ground conditions can help protect wildlife.

<u>23.3.2.5 Other Considerations and Design Criteria for Delineating Protection Zones</u>

23.3.2.5.1 Habitat Corridors and Connections

PAN element 2 protection zones also can be delineated as wildlife corridors or connections between other important wildlife sites. In many cases, streamside riparian buffers can help serve as habitat corridors and connectors (Johns 1997). It is important to protect mosaics of contiguous, different habitats (Wong 1985; but see Beier and Noss 1998).

23.3.2.5.2 Natural Disturbances

Delineating protected areas should account for major disturbances, even if intermittent or periodic such as drought or inundation. In such circumstances, the distribution and abundance of habitats, resources, and wildlife populations may be vastly different, possibly confined to more important refugia, than in normal years. Protected areas should be designed based on those less frequent conditions when wildlife needs are more extreme.

23.3.2.5.3 Logging Effects and General Suitability of the Logged Forest Matrix

Effects of forest management activities, particularly logging, on wildlife can vary greatly according to harvest rates, re-entry schedules, prior stand condition, and additional silvicultural activities conducted such as enrichment planting or thinning. These will affect the suitability of the logged matrix for wildlife, and this in turn influences the need for and design of PAN element 2. The less suitable the logged matrix is for wildlife, the more comprehensive the PAN element 2 needs to be. Suitability of the matrix for wildlife can be determined by comparing the list of wildlife habitats presented in the sections in this chapter on PAN 1 and 2 elements.

23.3.2.5.4 Meeting Other Objectives

Protected areas are established not just to protect biological diversity but for other objectives as well (Box 23-1 and Appendix 23-1). In impoverished nations with weak institutional governance mechanisms and great land scarcity, efforts to conserve biological diversity often are most successful when other societal concerns also are considered when designating protected zones. Important wildlife habitat often occurs on sites for which societal support for protection might be forthcoming anyway. Examples include potable water catchments for downstream communities; sites with historic, spiritual, or traditional recreational value; areas with steep slopes and fragile soils; and wetlands where, because of past natural disasters (floods, mudslides, etc.), local inhabitants already respect site limitations. Finally, providing PAN element 2 (and element 1, above) are likely to benefit timber production by providing mature seed trees and ecological services of wildlife that contribute to regeneration of timber and other forest products. Reserving elements or patches of timber species can be an economically effective way to improve natural regeneration in the logged matrix.

### 23.3.3 *Consideration of the Human Element*

This section pertains to identifying areas of wildlife habitat that can also coincide with sites of cultural, religious, or other non-timber interests.

#### 23.3.3.1 Protect Sites of Cultural or Religious Interest

In some cases, wildlife habitats can be conserved concomitant with conserving sites of cultural or religious significance for people. These can include sacred groves, spirit groves, or sites of traditional and ritualistic use. In some cases, habitat protection can coincide with controlled or limited traditional hunting or gathering of native animals and plants.

#### 23.3.3.2 Protect Sites of Other Use to Humans

Some sites are of value to people for tourism, non-timber forest products, seed trees, and other uses. In particular, superior quality seed trees (or groves of them) for important timber species often provide seed sources for use in enrichment plantings and reforestation projects. For example, at La Selva, Costa Rica, where considerable research is ongoing regarding native timber trees suitable for reforestation projects, a major limitation is that some of the most promising tree species have seed that rapidly loses viability or that are produced very erratically among individual trees or stands (J. Barborak, pers. obs.). Many of those seeds also are important to fruit-eating and seed-dispersing wildlife.

Many of these sites or elements provide habitat or resources for wildlife. If protected as PAN elements 1 or 2, they also help to bridge planned protected zones within and around the production forest matrix (PAN elements 3 and 4).

## 23.4 SOCIO-ECONOMIC CONSIDERATIONS AND INCENTIVES FOR MANAGING A PROTECTED AREA NETWORK

Why should forest managers exempt even a small portion of their harvestable timber concession lands or commercial trees for protecting natural areas and habitat elements? In some areas, local tax laws might provide an incentive. For example, Bolivia has a law where up to 30 percent of the concession can be reserved from cutting, for the reasons noted above, and the contractor does not have to pay taxes on those areas (there is a flat tax per hectare in Bolivia, rather than stumpage pricing) (Chapter 29). In other countries, protecting natural areas and habitat elements can contribute to local economies through eco-development or by encouraging an ecotourism economy with community forests (Chapter 25); an example is the La Selva ecotourism lodge along Rio Napo in lowland Ecuador. As in the example of managed protected areas on some Pacific Islands, there may be several social and economic goals met at the same time (Gilman 1997). In these cases, a PAN approach, particularly the PAN elements 1 and 2, can complement timber harvest.

Privately-owned nature reserves in Sub-Saharan Africa and Latin America can help stave off regional depletion of native biodiversity (Langholz 1996). Such reserves could be established as PAN element 2 zones, or as PAN element 3 or 4 conservation areas or parks. They could provide profitable ventures for their owners and a basis for involving the private sector in conservation. At the site level, private nature reserves are functioning quite well, profitably and ecologically, such as in parts of New Zealand, and might fit well into several of the PAN elements described in this paper for tropical forest regions. If integrated with private timber management sites and objectives, they can provide useful examples of successfully meeting several, very different objectives of forest use in an area. Private forest management need not be antithetical to private nature reserve conservation.

The different facets of PAN elements 1 and 2 vary significantly in their opportunity cost, making some far cheaper to implement than others. The main cost to forest managers of implementing PAN elements 1 and 2 is the opportunity cost of excluding merchantable timber from harvest, although many of the habitat elements that comprise these two PAN elements are not necessarily of commercial value (e.g., dead standing trees and steep slopes). The relative cost would vary by site, forest type, and management objectives. All else equal, areas with the highest access cost (i.e. least accessible) can be chosen over easily accessible areas for protection to minimize reductions in profit. This approach could actually save operators money if they were not required to exploit all areas of their concession, including those of low value, as is required in many countries (R. Fimbell, pers. comm.). Some types of PAN elements such as rocky outcrops and natural grasslands have no opportunity costs associated with protecting them, although they may incur some limited costs if forest protection buffers are needed. Within the logged matrix, habitat elements such as dead trees and live rotten or hollow trees will have no timber value and thus no opportunity costs associated with their protection.

The largest opportunity costs will occur if important wildlife tree species are also valuable timber species. A classic example is the depletion of sandalwood (*Santalum* spp.) from tropical Pacific islands which occurred during the early 1800's. Sandalwood was one of the native tree species that comprised the natural mixed mesic and lowland forests and wildlife habitats of these islands (Sohmer and Gustafson 1987). It also had high commercial value for timber, joss sticks, aromatic tapers, incense, medicines,and perfumes. Decimation of sandalwood and other native trees of commercial value on Hawaii, the Society Islands, New Caledonia, the New Hebrides (Vanuatu), and Fiji, coincided with degredation of the islands' native lowland wildlife communities (Mitchell 1990).

If important wildlife tree species are not commercial, then they can be favored over other less valuable non-commercial species, with little or no opportunity cost. Where commercial tree species are involved, it may still be to the advantage of timber production to protect at least some individual or patches of mature trees to serve as seed trees and help ensure long-term, locally-adapted genetic resources.

A final incentive for the PAN approach is that it may be possible and desirable to include PANs in eligibility criteria for receiving funding from carbon offsets. This could ease any opportunity cost of excluding lands from the timber estate, help provide funds for active management, and help protect genetic and wildlife resources for overall protection of timber production, forest resource sustainability, and biodiversity (Chapter 27).

## 23.5 PAN RESEARCH PRIORITIES AND WAY TO FILL THE KNOWLEDGE GAPS

PAN elements provide a baseline from which to monitor natural changes and forestry induced within the production forest landscape (Arcese & Sinclair 1997; Chapter 19). This can help tell us the degree to which refuges protect native biodiversity, such as populations of threatened species, and the differences between natural and anthropogenic disturbances and their impacts on wildlife. PAN elements 1 and 2 within active timber concessions can be monitored to determine the degree to which logged areas can protect key environments and wildlife habitats, and especially how individual elements and forest structures can even be created silviculturally.

Overall, monitoring PAN elements can help managers and ecologists determine how each element best contributes to the overall goals of conserving the ecological integrity of tropical forests at a variety of spatial scales. Local ecological communities, broader ecoregions, and even entire biomes can be monitored as to the degree to which their indigenous plants and animals and associated ecological processes are represented and maintained over time. Research also can be conducted on the population distribution, density, and dynamics of species related to key ecological functions of forests, such as listed in the guidelines above. Such research would help identify reserve dimensions and habitat characteristics to be maintained within managed forests.

Priority areas for future research, to fill in major information gaps related to a PAN approach, include the following: a) Research on the optimal size, shape, and spatial distribution (connectivity) of PAN element 2 zones, for specific wildlife conservation objectives. b) Improvements in the rapid assessment techniques for inventory and survey of biodiversity elements in a timber concession area (Cannon 1997; Oliver and Beattie 1993, 1996). c) Research on effective corridor and buffer zone widths. d) The capacity of all four PAN elements, particularly 1 and 2, to serve as refugia and dispersal centers for sensitive organisms. Some research on tropical forest fragments has provided some understanding (e.g., Laurance & Bierregaard 1997), but more needs to be done. e) Need for better understanding of how PANs benefit timber production objectives. This would include research on how PANs, particularly PAN elements 1 and 2 within the logged forest matrix, provide sources of seeds of commercial tree species, as well as habitat for wildlife critical to pollination, seed dispersal, soil health, and many other aspects of ecosystems that contribute to sustainable production of timber and non-timber forest products.

In the end, reserving natural areas of various scales (PAN elements 2, 3 and 4) and providing habitat elements (PAN element 1) in the managed forest landscape by mimicking natural disturbance events (Chapter 22) and indigenous long-term forest management practices (Gadgil & Berkes 1993) are complementary approaches to protecting forest productivity and biodiversity for future generations.

## ACKNOWLEDGMENTS

Our thanks to Robert Fimbel, Alejandro Grajal, John Robinson, and an anonymous reviewer for providing helpful reviews of the manuscript. Our appreciation to Todd Fredrickson for providing the references on reserve size for carnivores. Very special thanks to Damián Rumiz, Todd Fredrickson, and Dick Rice for discussions on conservation approaches in tropical forests and identifying specific Neotropical habitat elements and species for conservation focus. Ted Gullison devised the term and acronym PAN.

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**Table 23-1**. A protected area network or PAN can consist of four major elements, listed here with corresponding IUCN (International Union for the Conservation of Nature and Natural Resources) categories of protected areas.

| **PAN Element** | **Examples** | **Corresponding IUCN Category (See Appendix for detailed description)** |
|---|---|---|
| (1) Individual habitat elements conserved within a portion of the cutting block (concession, management unit, or whatever term is locally used) that is actually open to harvesting. | Large overstory trees bearing many bromeliad epiphytes; standing dead or hollow trees; select fruit-bearing shrubs; large down wood; concentrated feeding areas such as salt licks; wildlife watering holes. | These elements are usually so small and common as to not require specific zoning; rather they are located on detailed silvicultural management maps and plotted through GPS systems where available; they occur within IUCN categories IV and VI. |
| (2) Small natural area zones (that is, small parcels and corridors reserved from cutting within a concession, cutting block or management unit) | Grottos with rare plants; groves of old-growth trees; riparian buffers along streams or around springs; wetlands; nest sites of rare birds. | Specific management zones within extractive categories, primarily VI (Managed Resource Protected Area), but also category IV (Conservation through active management). |
| (3) Reserves of large size between cutting blocks (but still within the production forest landscape). | Riparian gallery forests along major river courses; travel corridors for migrating wildlife; pristine, baseline research natural areas; unique natural phenomena. | Where they have stricter statutory protection than the surrounding production forest matrix, they can be IUCN categories I, II or III; otherwise, they are zones or management units within categories IV and VI, and primarily the latter. |
| (4) Parks or similarly protected areas such as wildlife sanctuaries outside of the production forest landscape. | Strict nature reserves, wilderness areas, national parks, ecological reserves, and natural monuments. | Categories Ia, Ib, II, and III. |

**Table 23-2**. Key to species shown in Figure 23-3, with species listed in order of increasing mean body size and home range area. (See Figure 23-3 for source.)

| Entry no.[1] | Common name | Scientific name | Location[2] |
|---|---|---|---|
| GROUP 1 (body weight < 20g, home range up to 20 ha) | | | |
| 1 f | Pygmy mice | *Baiomys taylori* | P |
| 2 m | Pygmy mice | *Baiomys taylori* | P |
| 3 | Northern pygmy gerbil | *Gerbillus gerbillus* | P |
| 4 | Tarsier | *Tarsius bancanus* | P |
| 5 | African swamp rat | *Otomys irroratus* | P |
| GROUP 2 (body weight 200-20,000g, home range up to 1000 ha) | | | |
| 6 f&m | Tree shrew | *Tupaia glis* | P |
| 7 f&m | Wood rat | *Neotoma lepida* | N |
| 8 | Spiny rat | *Proechimys trinitatis* | N |
| 9 g | Tamarin | *Saguinus nigricollis* | N |
| 10 | Titi monkey | *Callicebus moloch* | N |
| 11 f | African palm civet | *Nandinia binotata* | P |
| 12 g | Brush-tailed porcupine | *Atherurus africanus* | P |
| 13 m | African palm civet | *Nandinia binotata* | P |
| 14 g | Coati | *Nasua nasua* | N |
| 15 m | Coati | *Nasua nasua* | N |
| 16 p | Duiker | *Cephalophus monticola* | P |
| 17 | Howler monkey | *Alouatta* spp | N |
| 18 f | Ocelot | *Felis pardalis* | N |
| 19 | Macaque | *Macaca fascicularis* | P |
| 20 | Macaque | *Macaca nemestrina* | P |
| 21 | Macaque | *Macaca radiata* | P |
| 22 | Macaque | *Macaca silenus* | P |
| 23 | Macaque | *Macaca mulatia* | P |

| GROUP 3 (body weight > 50,000g, home range over 1000 ha) | | | |
|---|---|---|---|
| 24 f | Jaguar | *Panthera onca* | N |
| 25 f | Jaguar | *Panthera onca* | N |
| 26 | Sloth bear | *Ursus ursinus* | P |
| 27 m | Jaguar | *Panthera onca* | N |
| 28 m | Jaguar | *Panthera onca* | N |
| 29 f | Tiger | *Panthera tigris tigris* | P |
| 30 g | Gorilla | *Gorilla gorilla* | P |
| 31 m | Tiger | *Panthera tigris tigris* | P |
| 32 m | Tiger | *Panthera tigris tigris* | P |
| 33 m | Tiger | *Panthera tigris altaica* | P |
| 34 g | Gaur | *Bos gaurus* | P |

[1] m = males; f = females; p = pair; g = group; blank = not specified
[2] P = occurs in the Paleotropics (Old World); N = occurs in the Neotropics (New World)

Figure 23-1. Examples of protected area network (PAN) element 1 components – individual habitat elements that can be protected during forestry operations. These elements do not necessarily require specific zoning of protection areas within the managed forest matrix. (Photos by Bruce G. Marcot)

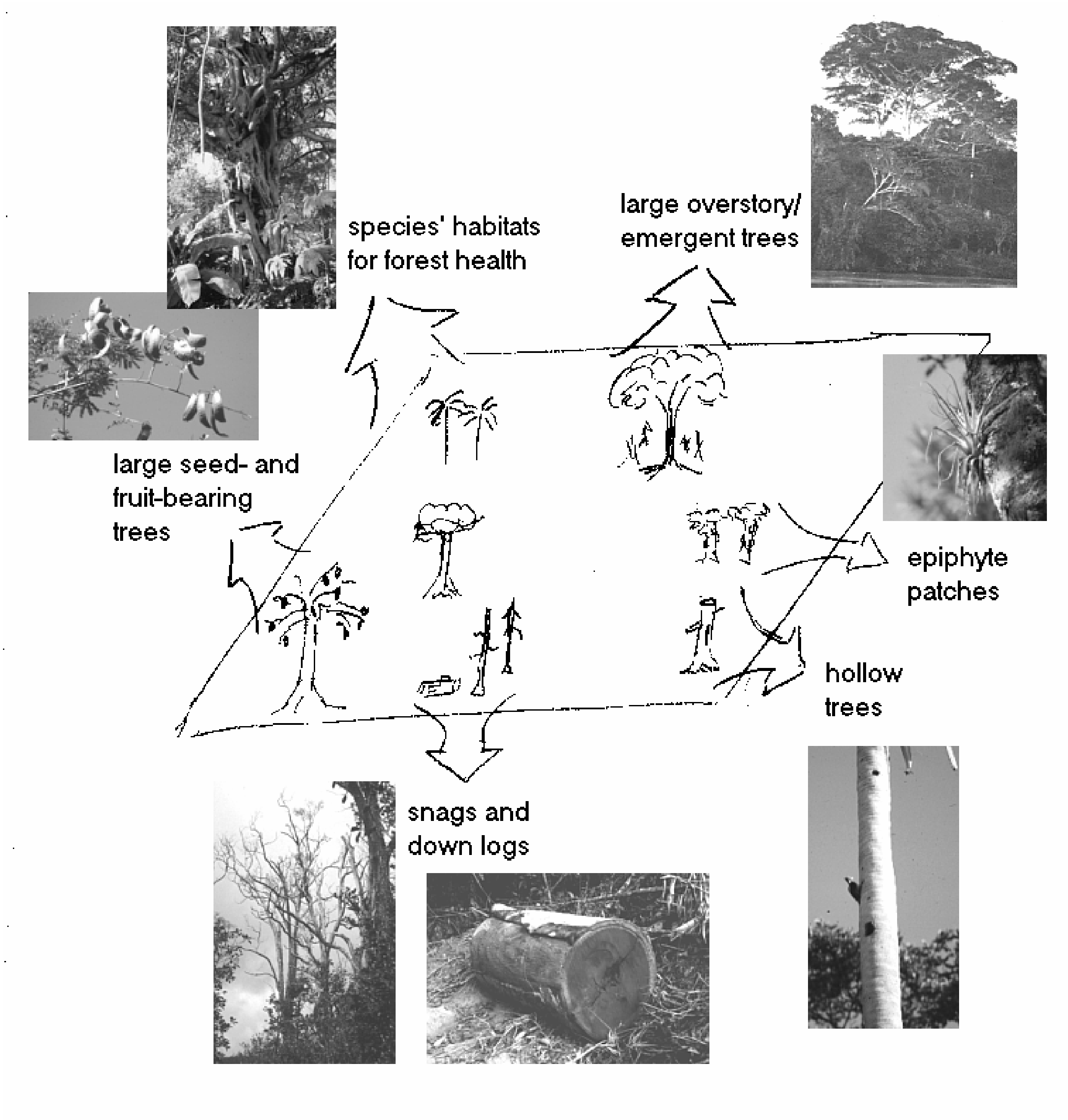


Figure 23-2. Examples of protected area network (PAN) element 2 components – natural areas. These components can be mapped as protection zones within the managed forest matrix prior to harvest operations. Specific sizes, orientations, and patterns of these zones will vary widely among tropical forests. (Photo of natural forest opening by Rob Fimbel, used with permission; all other photos by Bruce G. Marcot)

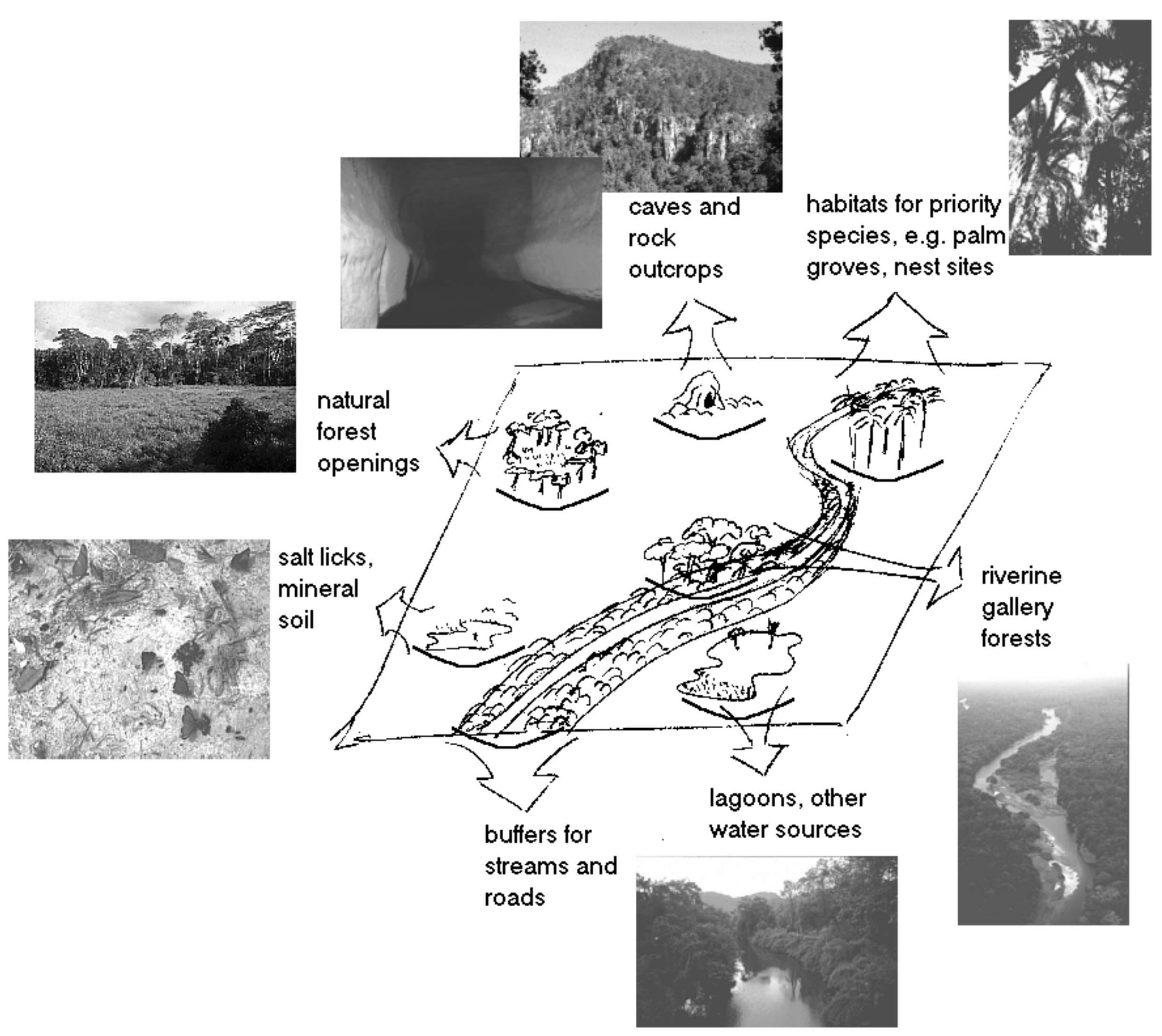
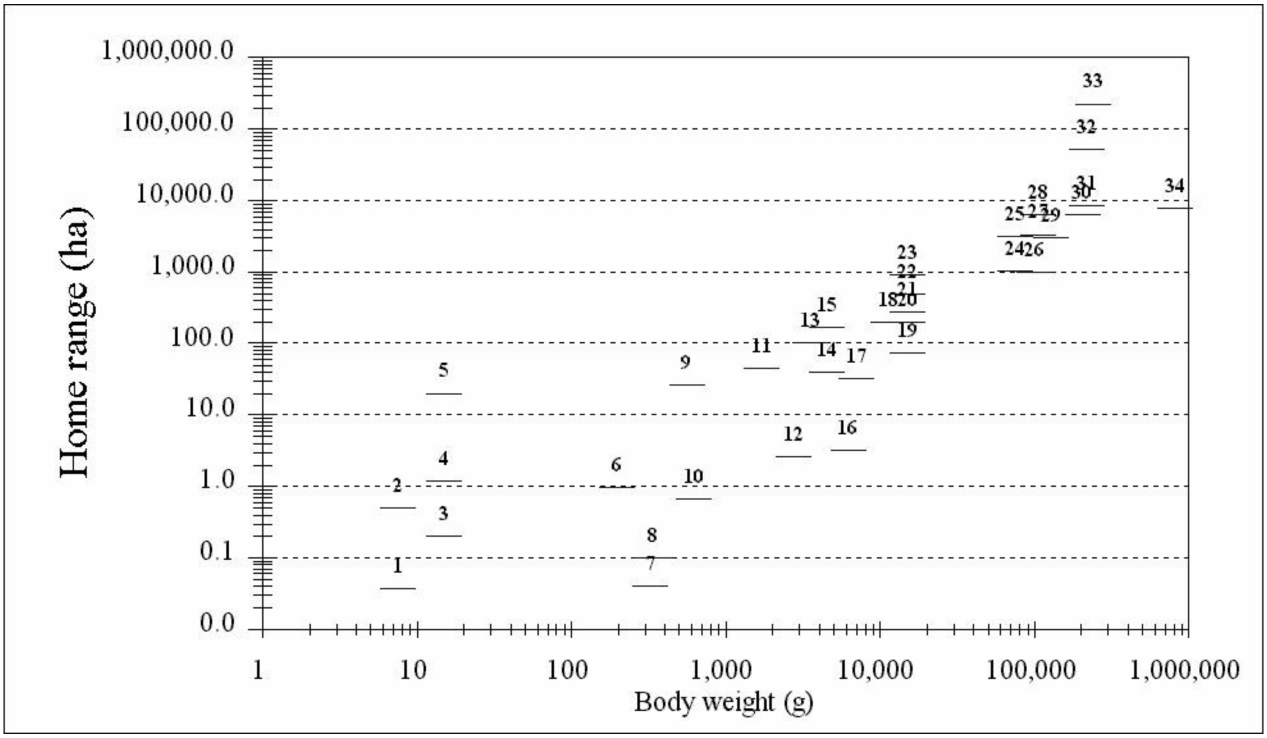


Figure 23-3. What sizes of natural areas are needed to provide for various species? This may be answered by the size of home ranges of wildlife. Here, home range size of selected tropical mammals is plotted as a function of their body weight. Note the logarithmic axes. Species are coded as shown in Table 1. Three major groups of species can be identified based on home range area (note that such body size and home range groups were also identified for northern temperate wildlife species by Holling 1992): species with home ranges up to 20 ha, up to 1000 ha, and over 1000 ha. Each group can be provided by a different PAN element or combinations thereof, as discussed in the text. Note that carnivorous species (e.g., tiger, species 31-33) often have larger home ranges and area needs, than do herbivorous species (e.g., gorilla, species 30, and gaur, species 34) of the same body weight class. Source of data: Nowak (1991).



PHOTOS (SLIDES) FOR CHAPTER 23, "PROTECTING HABITAT ELEMENTS AND NATURAL AREAS IN THE MANAGED FOREST MATRIX" BY MARCOT, GULLISON, AND BARBORAK

*[NOTE: THESE PHOTOS ARE NOT INCLUDED IN THIS PDF VERSION OF THE CHAPTER; SEE BOOK FOR THESE IMAGES]*

Photo Captions:

EXAMPLES OF PAN ELEMENT 1 COMPONENTS - KEY HABITAT ELEMENTS IN THE MANAGED FOREST MATRIX

[1] Example of a PAN Element 1 component: Large seed- and fruit-bearing trees. This mature fig tree (*Ficus* sp.) in a timber management area of lowland Amazonian Bolivia has deep fluting of its bark and is prone to hollowing. It provides not just fruits and overstory canopy cover for arboreal wildlife such as monkeys and toucans, but its bark crevices and hollows can provide nesting or roosting habitat for bats, birds, reptiles, and other wildlife. (Photo by Bruce G. Marcot)

[2] Need for planning for down wood, a PAN element 1 component. Slash and burn agroforestry in tropical forests of Amazonia (as shown here), India, and elsewhere eliminates large overstory trees. However, with careful planning, some of the large down wood can be retained to help stabilize and replenish soils, provide nurse logs for new vegetation, and provide habitat for small wildlife species such as spiny rats in the Neotropics that in turn disperse seeds of palms and other trees. (Photo by Bruce G. Marcot)

[3] Example of a PAN Element component 1: Large overstory/emergent trees. In some forests, large overstory or emergent trees can be retained during timber harvest operations to provide high foliage, branches, and food resources used by some wildlife. This example shows a mature *Dalbergia paniculata* retained in a managed teak forest of central India. *Dalbergia* also is prone to fluting of the bole and thus can also provide bark crevices for roosting and nesting wildlife. (Photo by Bruce G. Marcot)

[4] Example of a PAN Element component 1: Large overstory/emergent trees across the managed forest matrix. Retaining at least selected large overstory or emergent trees across a landscape of managed forest can help maintain suitability of the overall managed forest matrix for some species of canopy-using birds and other wildlife. In this photo, many overstory trees have been retained in this managed forest just outside Reserva de Amigos de la Naturaleza de Mindo on the Pacific slope of the Andes Mountains in Ecuador. This type of management here, in fact, can help retain key overstory lek (breeding) sites for the rare Andean cock-of-the-rock (*Rupicola peruviana*). However, wildlife species requiring extensively interconnected tree canopies, such as many monkeys, sloths, tree squirrels, and others, will not be able to persist in such circumstances; for them, it may be better to provide the retained trees in locally dense clumps at least 0.1-0.5 ha in size (see home range sizes in Fig. 23-3). (Photo by Bruce G. Marcot)

EXAMPLES OF PAN ELEMENT 2 COMPONENTS - ZONES OF PROTECTED FOREST CONDITIONS WITHIN THE MANAGED FOREST MATRIX

[5] Example of a PAN Element 2 component: Unique wildlife habitats. One type of unique wildlife habitat is palm groves, such as the heart-of-palm grove shown here in Taruma Timber Concession in the Amazon Basin in Bolivia near the border with Brazil. Such palm groves provide fruits for both canopy- and ground-dwelling wildlife which can help disperse their seeds, thus helping ensure a sustainable crop, and can be delineated and retained during timber harvest layout and operations. The palm trunks also are used by many birds for

nesting. (Photo by Bruce G. Marcot)

[6] Example of a PAN Element 2 component: Riverine gallery forests. Dense riparian or streamside forests, such as this riparian gallery forest in Caribbean lowland Costa Rica, provide habitat for a strikingly wide array of wildlife species, and can help to link other habitats by acting as a habitat corridor throughout a managed forest matrix. Plants in such habitats provide an array of fruits and other food and cover resources for wildlife. (Photo by Bruce G. Marcot)

[7] Example of a PAN Element 2 component: Natural forest openings. Natural savannas (such as shown in the left half of this photo of lowland Bolivia) provide unique habitats for many wildlife species not found in more closed canopy, managed forests (such as in the right). Savannas can be protected for deer, birds, bats, and other species.

**Appendix 23-1. The IUCN International Protected Area Classification System** (excerpted from IUCN 1994).

Protected areas are defined as "an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means."

Protected areas are designated for numerous reasons, but usually for a mix of the following management purposes:

Scientific research
Wilderness protection
Preservation of species and genetic diversity
Maintenance of environmental services
Protection of specific natural and cultural features
Tourism and recreation
Education
Sustainable use of resources from natural ecosystems
Maintenance of cultural and traditional attributes

According to the specific mix and priority of the management objectives for a given protected area, the following distinct categories have been identified:

Category I. Strict Protection
- Category Ia. Strict Nature Reserve
- Category Ib. Wilderness Area

Category II. Ecosystem Conservation and Recreation (i.e National Park)
Category III. Conservation of Natural Features (i.e. Natural Monument)
Category IV. Conservation Through Active Management ((i.e. Habitat/Species Management Area)
Category V. Landscape/seascape conservation and Recreation (i.e. Protected Landscape/ Seascape)
Category VI. Sustainable use of natural ecosystems (i.e. Managed Resource Protection Area)

Though the primary purposes of management determine the category that will be assigned, management plans will often contain management zones for a variety of purposes which take account of local conditions. However, in order to establish the appropriate category, at least three quarters of the area must be managed for the primary purpose, and the management of the remaining area must not be in conflict with that primary purpose.

Protected areas of different categories are often contiguous; sometimes one category 'nests' within another. This is entirely consistent with the application of the system, providing such areas are identified separately for accounting and reporting purposes. Although there are obvious benefits in having the entire areas within the responsibility of one management authority, this may not always be appropriate. In such cases, close cooperation between authorities will be essential.

**Matrix of management objectives and IUCN protected area management categories**

| | **IUCN Protected Area Management Categories** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Management Objective** | **Ia** | **Ib** | **II** | **III** | **IV** | **V** | **VI** |
| Scientific research | 1 | 3 | 2 | 2 | 2 | 2 | 3 |
| Wilderness preservation | 2 | 1 | 2 | 3 | 3 | - | 2 |
| Preservation of species and genetic diversity | 1 | 2 | 1 | 1 | 1 | 2 | 1 |
| Maintenance of environmental services | 2 | 1 | 1 | - | 1 | 2 | 1 |
| Protection of specific natural/ cultural features | - | - | 2 | 1 | 3 | 1 | 3 |
| Tourism and recreation | - | 2 | 1 | 1 | 3 | 1 | 3 |
| Education | - | - | 2 | 2 | 2 | 2 | 3 |
| Sustainable use of resources from natural ecosystems | - | 3 | 3 | - | 2 | 2 | 1 |
| Maintenance of cultural/traditional attributes | - | - | - | - | - | 1 | 2 |

**Key to numbers:**
1 = Primary Objective
I. 2 = Secondary Objective
II. 3 = Potentially
III. Applicable Objective
IV. - = Not Applicable
V.
VI.
VII.

**Key to Management Categories:**
I. Strict Protection
II. Ia. Strict Nature Reserve
III. Ib. Wilderness Area
IV. Ecosystem Conservation and Recreation (ie: National Park)
V. Conservation of Natural Features (ie: National Monument)
VI. Conservation through Active Management (ie: Habitat/Species Management Area)
VII. Lanscape/Seascape Conservation and Recreation (ie: Protected Landscape/Seascape)
VIII. Sustainable Use of Natural Ecosystems (ie: Managed Resource Protection Area)

I.

**NEW CHAPTER 23: PRE-PROOF VERSION (2/99)**

Source: IUCN (1994). Guidelines for Protected Area Management Categories. CNPPA with the assistance of WCMC. IUCN, Gland, Switzerland and Cambridge, UK. x + 261pp.

SIDEBAR

Incentives for developing and maintaining a protected area network (PAN) for wildlife and biodiversity conservation, particularly for conserving habitat elements and zones within timber management and concession areas:

PANs provide for:

- sources of plants and animals, including invertebrates, whose ecological roles and services may be crucial to the productivity and sustainability of commercial forest products (timber and non-timber) in adjacent areas
- sources of specific non-timber forest products, to replenish those taken in surrounding areas
- opportunities for area-effective monitoring of the effects of management actions on biodiversity and wildlife conservation, and the trends of biodiversity and species
- opportunities for integrating research, ecotourism, and forest management in the same location, thereby enhancing the economic and social values of a managed forest

**Box 23-1**. Reasons for delineating protected areas and protected area networks.

The following is a list of reasons for protecting natural areas and providing for natural elements in the managed forest matrix. In many cases, such protection can provide multiple benefits simultaneously. The manager can use this appendix as a checklist to determine which objectives might pertain to their needs, and then determine the specific habitat elements that can be included in a management plan (see text).

1. Protection of scarce terrestrial vegetation conditions or communities
    - A. Protection of old-growth, ancient, or primary forests (Barnes 1989)
    - B. Protection of degraded ecosystems (Schmidt 1996)
    - C. Providing for rare or sensitive plants (Lesica 1992)
    - D. Protection of floral diversity (Rebelo and Siegfried 1992)
2. Protecting vertebrate and invertebrate wildlife
    - A. Providing for rare or viable populations of individual species (Ryti 1992)
    - B. Providing for multiple species (assemblages, guilds, communities, richness) (Kershaw et al. 1995)
    - C. Providing for multiple species (island biogeography theory) (Higgs 1981)
    - D. Providing for invertebrates (Stokland 1997)
3. Protecting aquatic and riparian systems (Rabe and Savage 1979)
4. Providing for research and management (Chapters 18-22, 24, 25)
    - A. Protection of baseline conditions for measuring change and effects of management (Arcese and Sinclair 1997)
    - B. Providing for other research use, including experimental forestry (Stoms et al. 1998)
5. Providing for specific ecological conditions or processes
    - A. Soil conservation (Burke et al. 1995)
    - B. Providing for natural disturbance events and regimes (e.g., fire, hydrology) (Baker 1989)
    - C. Accounting for climate change effects (Halpin 1997)
    - D. Representing ecological conditions ('representativeness') (Bedward et al. 1992)
    - E. Staving off invasion by exotic species (Soule 1994)
    - F. Accounting for natural spatial and temporal variation in resources and in the distribution and abundance of species that use them (Brown et al. 1995)
6. Providing for, or considerations of, human uses, interests, and needs
    - A. Areas for economic income and incentives (Pressey et al. 1993)
    - B. Areas to offset adverse effects of urbanization on habitat loss (Bolger et al. 1997)
    - C. Areas for other uses by non-indigenous peoples (esp. recreation) (Gotmark and Nilsson 1992)
    - D. Areas for traditional (indigenous) resource use
        - i. Ethnobotanical or ethnobiomedical uses (also benefits non-indigenous peoples) (Peres 1994)
        - ii. Forestry (Pinedo-Vasquez et al. 1990)

    iii. Providing for other cultural or economic values (Gotmark and Nilsson 1992)
    iv. Accounting for poaching (Lewis et al. 1990)
    v. Sites of religious or ritual significance (e.g., spirit groves) (Decher 1997)

E. Providing for a long-term source of plant and animals that may contribute to the productivity of adjacent managed forests used mostly for commodity production (no examples found in the literature)

Source: This list was derived from an extensive review of the literature conducted by the senior author. An example reference is given for each category; a fuller list of literature is available from the senior author upon request.

**Box 23-2**. A quick checklist for forest managers, of wildlife habitat categories that could be maintained or protected in managed tropical forests. These categories pertain to protected area network (PAN) elements 1 and 2 (see text for explanation).

PAN ELEMENT 1 - KEY HABITAT ELEMENTS IN THE MANAGED FOREST MATRIX

- Snags and Down Logs
- Trees Prone to Hollowing
- Epiphyte Patches
- Large Seed- and Fruit-Bearing Trees
- Large Overstory/Emergent Trees
- Sites and Habitat Elements for Species Critical to Forest Health and Productivity
    - Habitat for Essential Plant Pollinators
    - Habitat for Essential Seed Dispersers
    - Habitat for Fungal Spore Dispersers
    - Habitat for Predators of Seeds, Seedlings, and Animals
    - Habitat for Nutrient Cyclers and Insectivore Prey
- Individual Trees or Forest Groves Supporting Colonies of Birds

PAN ELEMENT 2 - ZONES OF PROTECTED FOREST CONDITIONS WITHIN THE MANAGED FOREST MATRIX

- Habitat for Priority Wildlife Species
    - Kinds of Habitats for Priority Species
    - Size of Habitats
- Buffers for Streams and Roads
- Scarce and Declining Habitats
- Unique Wildlife Habitats
    - Riverine Gallery Forests
    - Salt Licks and Mineral Soil
    - Caves and Rock Outcrops
    - Natural Forest Openings
    - Palm Groves
    - Lagoons and Other Water Sources
    - Low Hills Within Seasonally-Flooded Forests
- Other Considerations and Criteria for Delinating Protection Zones
    - Habitat Corridors and Connections
    - Natural Disturbances
    - Logging Effects and General Suitability of the Logged Forest Matrix
    - Meeting Other Objectives

CONSIDERATION OF THE HUMAN ELEMENT

- Sites of Cultural or Religious Interest
- Sites of Other Use to Humans