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7

The Dead Wood Cycle

Eric Lofroth

Definitions

Dead wood cycle: This term is rarely used in the literature. It refers to the process of tree death, tree fall, and decay in the forested ecosystem. The cycle begins with live healthy trees and ends with their incorporation into the soil organic horizon and/or aquatic environment.

Coarse woody debris: This term has been defined variously by researchers and managers. Some (e.g., Harmon et al. 1986) have used it to describe all states of dead wood in the cycle, from snags to logs and fallen branches. Others (Lofroth 1993; Steventon 1994; Province of British Columbia 1995) define it as downed woody material, distinguishing it from the 'snag' or standing dead component. The size above which debris is considered 'coarse' varies among studies and has been identified as greater than 2.5 cm in diameter (Harmon et al. 1986), greater than 5 cm in diameter (Mattson et al. 1987), greater than 7.5 cm in diameter (Quesnel 1994; Keenan and Inselberg, in prep.), greater than 10 cm in diameter (Spies et al. 1988), greater than 15 cm in diameter (Sollins 1982), and greater than 20 cm in diameter (Harmon et al. 1987).

Here coarse woody debris (CWD) is defined as downed woody material greater than 10 cm in diameter, and is arbitrarily distinguished from standing dead woody material (wildlife trees or snags) by the angle of repose (less than 45° from the ground).

Snags: dead standing trees, typically with a specified lower size limit. Cline et al. (1980) sampled snags greater than 9 cm in diameter at breast height (dbh) and greater than 4.4 m tall. Raphael and Morrison (1987) set lower boundaries on snags of 13 cm dbh and 1.5 m tall. Lofroth (1993) set a lower limit of 7.5 cm dbh and 2 m tall. The B.C. Ministry of Forests and B.C. Workers' Compensation Board define a snag as a standing dead tree greater than 3 m in height (Backhouse and Lousier 1991). Here snags are considered standing dead trees greater than 10 cm dbh and greater than 2 m tall, with an angle of repose greater than 45° from the ground.

Wildlife tree: 'a tree that provides present or future valuable habitat for the conservation or enhancement of wildlife' (Guy and Manning 1995). Wildlife trees may be distinguished by attributes such as structure, age, abundance, location, and surrounding habitat features. They range from live and healthy trees to decayed stubs, and, as such, include snags.

Large organic debris: essentially, coarse woody debris in aquatic ecosystems. Large organic debris (LOD) is downed woody material, including tree boles, limbs, and rooting structures. Van Sickle and Gregory (1990) define it as material greater than 10 cm in diameter and greater than 1.5 m long. Bisson et al. (1987) used a limit of 10 cm in diameter but did not specify a minimum length. Here LOD is defined as woody material in aquatic ecosystems greater than 10 cm in diameter.

Fine fuel/slash: the debris left behind following forest harvesting, including woody material of any size (McRae et al. 1979; Trowbridge et al. 1987).

Dead wood obligate: organism that *requires* some component of the dead wood cycle for some or all of its life history. The conservation of populations of such species can be considered dependent on the presence of dead wood.

Dead wood facultative: organism that *may use but does not require* some component of the dead wood cycle for some or all of its life history.

Background

Dead and downed woody debris in western forests is still a common attribute. However, technology now allows the removal of more and more of this woody debris from the forest. As well, conversion of forests from old growth to managed stands shortens the rotation age from centuries to decades, thereby reducing the size and age of the trees left in the forest. This reduction drastically decreases the amount, size, and quality of dead and dying trees available for the future (Maser and Trappe 1984).

'Large, fallen trees are unique, critical components of forest systems' (Maser et al. 1979; Maser et al. 1988; Franklin and Hemstrom 1981; Franklin et al. 1981). However, in the early days of forest harvesting, dead wood was considered a hindrance to reforestation and stream access and quality (Triska and Cromack 1979). In the past, CWD was routinely removed in an attempt to limit fuel loading (thereby minimizing wildfires) and make replanting easier. Also, because of the slow rate at which CWD decayed, its role in nutrient cycling, and therefore its importance, was not well understood (Triska and Cromack 1979).

In the Pacific Northwest and British Columbia, removal of LOD in streams began as early as the mid-1800s and continued well into the mid-1900s. Large streams and rivers were used for navigation and transportation of logs to the mills, and were therefore kept clear of debris (Sedell et al. 1988). As

logging encroached further up the stream and river valleys, so did LOD removal. When the streams became too small to transport logs, splash dams were built, allowing water to build up and sluice logs down to the larger rivers and streams (Bisson et al. 1987). Some rivers and streams were scoured down to bedrock, and have not yet recovered from the effects of these practices (Sedell et al. 1988).

In the 1950s and 1960s, fisheries managers were concerned that LOD restricted fish movement and was the cause of channel scouring during floods, besides creating logjams; they therefore prescribed its removal. The role of LOD in channel morphology was not yet understood (Sedell et al. 1988). Although some LOD removal is still prescribed to give fish access to the upper reaches of a stream, LOD is now considered an important part of a functioning fish stream.

Standing dead and dying trees (wildlife trees) were also routinely removed during timber harvest. They were once thought of only as fire and safety hazards that harboured insects and that were of no marketable value (Bull et al. 1986). Despite their newly recognized importance, standing dead or dying trees are still a threatened resource in British Columbia. They are still rapidly declining because of conventional silvicultural practices, fire prevention, firewood cutting, timber utilization standards, and worker safety regulations (Steeger and Machmer 1994).

Ecological Principles

Dead Wood Cycling

Dead wood cycling is the process of the cycling of components of wood (carbon, minerals, moisture, and so on) in the forest ecosystem through the processes of death, decomposition, and uptake. The changes to trees, which are the most significant structural features of forests, during this process affect many other forest components and functions (Maser et al. 1979; Maser and Trappe 1984; Maser et al. 1988; Hammond 1991). In the coastal ecosystems they studied, Franklin and Waring (1979) reported that approximately 17% of all ecosystem organic matter was found within logs (CWD) and standing dead trees (snags).

The dead wood cycle begins when the stem dies. Stem death may be immediate in some cases, such as lightning strikes, but this process is usually slow. The trees are usually the larger ones and remain standing for a relatively long period after they die. Recruitment of snags from the living tree population may vary with such factors as slope, aspect, rooting substrate, site moisture and nutrient conditions, tree species, and causes of mortality. These factors influence the longevity of snags, CWD, and LOD. The dynamics of each of these components are discussed below.

Dynamics of the Dead Wood Cycle

Snags

Thomas et al. (1979) and Backhouse (1993) describe decay classifications of snags and wildlife trees. Often the important characteristics of snags and wildlife trees are functions of previous disease or damage, and the result is a tree form or condition that is valuable to a variety of wildlife species.

In forests that are disturbed by processes other than forest harvesting, most trees eventually become dead wood; those that die and remain standing become part of the snag component of the forest. The causes of mortality in live trees are varied and are likely a combination of factors (Maser 1988). Mortality rates are usually species-specific (Franklin et al. 1987; Raphael and Morrison 1987) and are extremely variable because of multiple causal agents and varying site conditions. Mortality rates are reported to be greater in high-productivity sites than in low-productivity sites (Franklin et al. 1987). Often the mortality agents affecting trees are very different in different sites.

Researchers have reported regional differences in snag population dynamics. For example, stocking of dead standing trees in the Sub-Boreal Spruce (SBS) Zone (Meidinger and Pojar 1991) of interior British Columbia varied both regionally and locally. Mean stocking of standing dead trees greater than 7.5 cm dbh was 97.7 stems per hectare ($n = 51$) in the dry cool (dk) subzone and 218.8 ($n = 329$) in the moist cold (mc) subzone (Lofroth, unpublished data). Franklin et al. (1987) also reported regional differences in snag population dynamics. In mature stands within the SBSmc subzone, stocking of snags varied by as much as a factor of 25 among different site conditions. Dry ridgetop sites (Dry Pine) had the highest stocking of dead standing trees and alluvial sites (Cottonwood Bottomland) had the lowest. Analysis of size distributions revealed that much of this difference could be explained by mortality of small stems (< 20 cm). Furthermore, only sites that were mesic and wetter had dead standing stems greater than 40 cm dbh.

Although 'standing crop' may be important and useful in describing the structural characteristics of a site, rates of input and decay are just as important. Mortality rates are likely highest in younger seral stages (Franklin et al. 1987; Raphael and Morrison 1987; Lofroth, unpublished data), and primary causal agents likely change with succession (Franklin et al. 1987). Cline et al. (1980) reported that snag production rates and density (input) fell with increasing stand age, but mean snag size and longevity increased. Raphael and Morrison (1987) reported that decay rates for pines in their study area were greater than those for firs. They also reported that, regardless of species, falling rates declined with increasing tree diameter.



Dead standing trees are important components of the forest for species such as the Bald Eagle. (Photograph by Steve Voller)

In summary, recruitment of dead standing trees (snags and/or wildlife trees) varies depending on regional and local ecological conditions. Stem mortality (and therefore snag density) is often highest in younger seral stages. Snag densities also vary with ecological condition, but these relationships are influenced to a great extent by mortality agents. More productive sites generally have larger snags. Snag density decreases and longevity increases with increasing snag size.

Coarse Woody Debris (CWD)

Coarse woody debris enters the ecosystem either directly through the death and immediate fall of living trees (e.g., from windthrow), or through tree death and the eventual fall of standing dead material. As with standing dead trees, there is variability in the amount, size, species, and decay class of CWD. The amount of CWD in any stand is a function of mortality agents, site conditions and exposure, and decay mechanisms and rates (Harmon and Hua 1991). CWD biomass in some coniferous ecosystems may exceed the total biomass of many deciduous ecosystems (Spies and Cline 1988). Decay classification for CWD has been described by Maser et al. (1988).

The total volume or biomass of CWD varies with ecological condition (Spies and Cline 1988; Lofroth, unpublished data). Brewer (1993) reported that in plots in some SBS stands ranged from to 384 m³/ha. Mean

volumes for all stand conditions and ages were 44.1 m³/ha in the SBSdk subzone and 159.2 m³/ha in the SBSmc subzone (Lofroth, unpublished data). The driest sites had the lowest biomass and moist sites the greatest in Douglas-fir forests of Washington and Oregon (Spies et al. 1988). Within mature stands in the SBSmc subzone, CWD volumes were lowest in xeric ecosystems (Dry Pine: 36.2 m³/ha) and highest in moist ecosystems (Devil's Club: 268.4 m³/ha) (Lofroth, unpublished data). Mean volumes of CWD in mature stands by natural disturbance type (Province of British Columbia 1995) and biogeoclimatic zone ranged from a low of 60 m³/ha in the Boreal Black and White Spruce Zone in *ecosystems with frequent stand-initiating events* (NDT3) (Province of British Columbia 1995) to a high of 390 m³/ha in the Coastal Western Hemlock Zone in *ecosystems with rare stand-initiating events* (NDT1) (Lofroth, unpublished data). Benson and Schlieter (1979) reported that CWD volumes were 210 m³/ha in dry-site Douglas-fir stands, but as much as 560 m³/ha in grand fir stands.

CWD volumes also vary with successional stage. Mean volumes across a range of moisture and nutrient regimes in the SBSmc subzone were high in early successional stages (herb/shrub) (174.2 m³/ha), declined to a low of 58.2 m³/ha in young forest successional stages, and were highest in old-growth stands (261.5 m³/ha) (Lofroth, unpublished data). Spies et al. (1988) reported that amounts of CWD were high in the youngest successional stages, were lowest in 60-80-year-old forests, and were high in old stands (< 500 years). After 500 years CWD amounts declined to an intermediate level. Spies and Franklin (1988) reported that CWD input may be low in young stands because of the small size of dead and dying stems. Volumes in these stands are often high, however, due to residual CWD from the previous stand. The amount of this residual CWD depends on the disturbance agent causing the change in succession. In stands where succession has been retarded by natural catastrophic events (windthrow, fire, etc.), it can be significant. Spies et al. (1988) suggest that the nature and the timing of disturbance play a key role in CWD dynamics. Human-caused changes (such as logging) will usually result in conditions different than those that may have initiated the original stand. In these circumstances, the amount of CWD, as with standing dead trees, may not be indicative of natural dynamics within ecosystems.

The rates of input and decay also vary with ecological site conditions and stand age, and between tree species (Sollins 1982; Spies and Franklin 1988). Sollins (1982) reported that although there was considerable variability in the data, the highest values for CWD biomass were reported from old-growth stands. Harmon et al. (1987) reported that decay rates of logs may vary with microclimate, size, substrate, and species of log. Mattson et al. (1987) reported that decay rates varied by as much as tenfold between tree species. They also reported that aspect was an important factor

in determining decay rates, and that logs suspended above the ground decayed at slower rates than those on the ground. Keenan et al. (1993) attribute large accumulations of CWD in western redcedar and western hemlock stands on Vancouver Island to slow decomposition rates, high rates of input following windstorms, and the large size and decay resistance of western redcedar. Abbott and Crossley (1982) reported that in chestnut oak (*Quercus prinus*) stands, decomposition was influenced by moisture and temperature and was inversely related to the diameter of the material.

Large Organic Debris (LOD)

The dynamics of large organic debris (LOD) are influenced by factors that influence CWD dynamics and those related to hydrological features and processes. Maser and Trappe (1984) and Sedell et al. (1988) review LOD dynamics in detail. Thomson (1991) produced an annotated bibliography that reviewed a substantial portion of the literature on this topic. Much of this review is abridged from these accounts.

LOD enters aquatic ecosystems from a variety of sources, both chronic and episodic. Chronic input includes debris resulting from litterfall, individual tree mortality, and treefall; to some extent it is influenced by factors that are also important in CWD dynamics. Riparian ecosystems are the primary source of chronic input. Input from these mechanisms are similar in nature to CWD in streamside ecosystems, although some differences have been noted in abundance and piece size (Van Sickle and Gregory 1990). LOD also enters streams through episodic events such as floods, mass wasting, debris torrents, and large-scale mortalities due to events such as insect epidemics. Much of the material entering stream ecosystems is associated with the riparian zone, but some material originates in upslope forested ecosystems. McDade et al. (1990) measured source distances for logs entering small streams in a variety of stream classes and gradients in Oregon and Washington, and found that over 70% of the logs originated within 20 m of the stream channel. Chronic inputs of large material tend to be a feature of mature and old-growth ecosystems. LOD input from younger successional stages tends to be smaller in nature, but volumes may equal or exceed those originating from older stands. Input of LOD may also be influenced by the composition of vegetation. In the U.S. Pacific Northwest, red alder is a common early successional tree in riparian ecosystems and commonly becomes LOD. This is a consequence of its shallow roots and low resistance to undercutting (Bisson et al. 1987).

LOD 'output' from stream ecosystems is primarily a function of the physical breakdown of material and the transport of material downstream. Decay and breakdown processes in stream ecosystems are considered slower than in terrestrial and marine ecosystems (Sedell et al. 1988).

processes are much less important in LOD dynamics than in CWD dynamics, primarily because of the anaerobic nature of the ecosystem. The retention time of LOD in stream ecosystems is influenced by the size and orientation of material, the nature of deposition, the size of the stream, the scale of major flooding events, the gradient of the stream, and the nature of sediment transfer in the stream (Maser and Trappe 1984; Bisson et al. 1987; Sedell et al. 1988; O'Connor and Ziemer 1989).

The Roles of Dead Wood in the Ecosystem

Dead wood (snags, CWD, LOD) functions in many ways in forested ecosystems. It provides habitat for a wealth of invertebrate, vertebrate, and plant species. It affects soil erosion, slope movement, pool and riffle formation, and nutrient capture and retention. Nutrient cycling in terrestrial and aquatic ecosystems is influenced by the characteristics of woody debris.

The following discussion of the relationship between dead wood and forest biota is strongly biased towards vertebrates. Information on plants and invertebrates is limited and incomplete. I briefly review the role of woody debris in a variety of ecosystem processes. The sources of information used to develop Tables 7.1 to 7.7 include Aubry et al. (1988), Backhouse and Lousier (1991), S. Berch (pers. comm., 1995), Campbell et al. (1990a, 1990b), S. Cannings (pers. comm., 1995), D.F. Fraser (pers. comm., 1995), Goward (1993), L. Friis (pers. comm., 1995), E.C. Lea (pers. comm., 1995), Lundquist and Mariani (1991), Nagorsen and Brigham (1993), J. Ptolemy (pers. comm., 1995), Redhead (1993), Ryan (1993), Ryan et al. (1993), Scudder (1994), Tripp (1994), and Terres (1991).

Ecological Roles of Snags

The relationship between cavity users (particularly birds) and snags may be one of the best documented wildlife/habitat relationships in North America (McLelland 1977; Thomas et al. 1979; Mannan et al. 1980; Davis et al. 1983; Mannan and Meslow 1984; Raphael and White 1984; Zarnowitz and Manuwal 1985; Lundquist and Mariani 1991; Machmer and Steeger 1993; and many others). Snags serve as nesting habitat for primary and secondary cavity-nesters (McLelland 1977; Thomas et al. 1979; and others) and perching habitat for many bird species. In British Columbia, 26 Red- and Blue-listed vertebrate species or subspecies depend on or are associated with snags for all or part of their life history (Tables 7.1 and 7.2). Characteristics that affect the value of individual snags as habitat include cause of death, diameter, tree form, bark condition, tree species, and height.

The cause of death affects the class and decay characteristics of snags. The ability of organisms such as fungi and insects to invade wildlife trees greatly affects the value of the snag for wildlife. Decay organisms invading

dead or dying trees serve to further weaken or soften the tree, allowing primary cavity-nesters to excavate nests (Thomas et al. 1979; Terres 1991).

The size of snags strongly influences which species may use them. Cavity-nesters in British Columbia include species as small as nuthatches, chickadees, and small bats to mammals as large as black bears (Tables 7.1 and 7.2) (Backhouse 1993). Black bears are known to use large cavities (particularly in western redcedar) as winter dens (Davis 1996). Fishers whelp almost exclusively in cavities in very large cottonwood trees in central B.C. (Weir 1995). Martens use cavities in trees as resting sites and maternal dens (Buskirk and Ruggiero 1994). Flying squirrels, red squirrels, and many other

Table 7.1

Mammals closely associated with snags in British Columbia

Species	Life history role	Management status
Western Long-eared Myotis (<i>Myotis evotis</i>)	roosting, maternal colonies	Yellow-listed
Northern Long-eared Myotis (<i>Myotis septentrionalis</i>)	roosting, maternal colonies	Red-listed
Keen's Long-eared Myotis (<i>Myotis keenii</i>)	roosting, maternal colonies	Red-listed
Western Red Bat (<i>Lasiurus blossevilli</i>)	roosting	Blue-listed
Hoary Bat (<i>Lasiurus cinereus</i>)	roosting	Yellow-listed
Silver-haired Bat (<i>Lasionycteris noctivagans</i>)	roosting, maternal colonies, hibernacula	Yellow-listed
Big Brown Bat (<i>Eptesicus fuscus</i>)	roosting, maternal colonies	Yellow-listed
Pallid Bat (<i>Antrozous pallidus</i>)	roosting	Red-listed
California Myotis (<i>Myotis californicus</i>)	roosting, maternal colonies	Yellow-listed
Western Small-footed Myotis (<i>Myotis ciliolabrum</i>)	roosting	Blue-listed
Little Brown Myotis (<i>Myotis lucifugus</i>)	roosting, maternal colonies	Yellow-listed
Long-legged Myotis (<i>Myotis volans</i>)	roosting, maternal colonies	Yellow-listed
Yuma Myotis (<i>Myotis yumanensis</i>)	roosting, maternal colonies	Yellow-listed
Southern Red-backed Vole (<i>Clethrionomys gapperi</i>)	nesting, summer dens	Yellow-listed

◀ Table 7.1

Species	Life history role	Management status
Bushy-tailed Woodrat (<i>Neotoma cinerea</i>)	nesting, summer and winter dens	Yellow-listed
Deer Mouse (<i>Peromyscus maniculatus</i>)	nesting, summer and winter dens	Yellow-listed
Columbian Mouse (<i>Peromyscus oreas</i>)	nesting, summer and winter dens	Yellow-listed
Sitka Mouse (<i>Peromyscus sitkensis</i>)	nesting, summer and winter dens	Yellow-listed
Northern Flying Squirrel (<i>Glaucomys sabrinus</i>)	nesting, maternal and thermal dens	Yellow-listed
Yellow-pine Chipmunk (<i>Tamias amoenus</i>)	nesting, summer dens	Yellow-listed
Least Chipmunk (<i>Tamias minimus</i>)	nesting, summer dens	Yellow-listed; subsp. <i>selkirki</i> Red-listed; subsp. <i>oreocetes</i> Blue-listed
Red-tailed Chipmunk (<i>Tamias ruficaudus</i>)	nesting, feeding stations, maternal and thermal dens	Red-listed
Townsend's Chipmunk (<i>Tamias townsendii</i>)	nesting, summer dens	Yellow-listed
Douglas' Squirrel (<i>Tamiasciurus douglasii</i>)	nesting, feeding stations, maternal and thermal dens	Yellow-listed
Red Squirrel (<i>Tamiasciurus hudsonicus</i>)	nesting, feeding stations, maternal and thermal dens	Yellow-listed
Marten (<i>Martes americana</i>)	thermal and maternal dens	Yellow-listed
Fisher (<i>Martes pennanti</i>)	maternal dens	Blue-listed
Ermine (<i>Mustela erminea</i>)	maternal and summer dens	Yellow-listed
Long-tailed Weasel (<i>Mustela frenata</i>)	maternal and summer dens	Yellow-listed
Least Weasel (<i>Mustela nivalis</i>)	maternal and summer dens	Yellow-listed
Spotted Skunk (<i>Spilogale putorius</i>)	maternal, summer, and winter dens	Yellow-listed
Raccoon (<i>Procyon lotor</i>)	maternal, summer, and winter dens	Yellow-listed
Black Bear (<i>Ursus americanus</i>)	winter dens	Yellow-listed; subsp. <i>emmonsii</i> Blue-listed

Table 7.2

Birds closely associated with snags in British Columbia

Species	Life history role	Management status
Great Blue Heron (<i>Ardea herodias</i>)	nesting, roosting	Blue-listed
Wood Duck (<i>Aix sponsa</i>)	nesting	Yellow-listed
Common Goldeneye (<i>Bucephala clangula</i>)	nesting	Yellow-listed
Barrow's Goldeneye (<i>Bucephala islandica</i>)	nesting	Yellow-listed
Bufflehead (<i>Bucephala albeola</i>)	nesting	Yellow-listed
Hooded Merganser (<i>Lophodytes cucullatus</i>)	nesting	Yellow-listed
Common Merganser (<i>Mergus merganser</i>)	nesting	Yellow-listed
Turkey Vulture (<i>Cathartes aura</i>)	roosting	Blue-listed
Osprey (<i>Pandion haliaetus</i>)	nesting, roosting, perching	Yellow-listed
Bald Eagle (<i>Haliaeetus leucocephalus</i>)	nesting, roosting, perching	Blue-listed
Red-tailed Hawk (<i>Buteo jamaicensis</i>)	nesting, roosting, perching	Yellow-listed
Golden Eagle (<i>Aquila chrysaetos</i>)	nesting	Yellow-listed
American Kestrel (<i>Falco sparverius</i>)	nesting, perching	Yellow-listed
Merlin (<i>Falco columbarius</i>)	nesting	Yellow-listed
Barn Owl (<i>Tyto alba</i>)	nesting, winter roosting	Blue-listed
Flammulated Owl (<i>Otus flammeolus</i>)	nesting, roosting	Blue-listed
Western Screech Owl (<i>Otus kennicottii</i>)	nesting, roosting	Yellow-listed; subsp. <i>kennicottii</i> and <i>saturatus</i> Blue-listed
Great-horned Owl (<i>Bubo virginianus</i>)	nesting, perching	Yellow-listed
Northern Pygmy Owl (<i>Glaucidium gnoma</i>)	nesting	Yellow-listed; subsp. <i>swarthy</i> Blue-listed

◀ Table 7.2

Species	Life history role	Management status
Northern Saw-Whet Owl (<i>Aegolius acadicus</i>)	nesting, roosting	Yellow-listed; subsp. <i>brooksi</i> Blue-listed
Spotted Owl (<i>Strix occidentalis</i>)	nesting, roosting	Red-listed
Barred Owl (<i>Strix varia</i>)	nesting, roosting	Yellow-listed
Boreal Owl (<i>Aegolius funereus</i>)	nesting, roosting	Yellow-listed
Vaux's Swift (<i>Chaetura vauxi</i>)	nesting, roosting	Yellow-listed
Belted Kingfisher (<i>Megaceryle alcyon</i>)	perching	Yellow-listed
Lewis Woodpecker (<i>Melanerpes lewis</i>)	nesting, roosting, perching, foraging	Blue-listed
Yellow-bellied Sapsucker (<i>Sphyrapicus varius</i>)	nesting, roosting, foraging	Yellow-listed
Red-naped Sapsucker (<i>Sphyrapicus nuchalis</i>)	nesting, roosting, foraging	Yellow-listed
Red-breasted Sapsucker (<i>Sphyrapicus ruber</i>)	nesting, roosting, foraging	Yellow-listed
Williamson's Sapsucker (<i>Sphyrapicus thyroideus</i>)	nesting, roosting, foraging	subsp. <i>thyroideus</i> Blue-listed; subsp. <i>nataliae</i> Red-listed
Downy Woodpecker (<i>Picoides pubescens</i>)	nesting, roosting, foraging	Yellow-listed
Hairy Woodpecker (<i>Picoides villosus</i>)	nesting, roosting, foraging	Yellow-listed; subsp. <i>picoideus</i> Blue-listed
White-headed Woodpecker (<i>Picoides albolarvatus</i>)	nesting, roosting, foraging	Red-listed
Three-toed Woodpecker (<i>Picoides tridactylus</i>)	nesting, roosting, foraging	Yellow-listed
Black-backed Woodpecker (<i>Picoides arcticus</i>)	nesting, roosting, foraging	Yellow-listed
Northern Flicker (<i>Colaptes auratus</i>)	nesting, roosting, foraging	Yellow-listed
Pileated Woodpecker (<i>Dryocopus pileatus</i>)	nesting, roosting, foraging	Yellow-listed
Pacific-slope Flycatcher (<i>Empidonax difficilis</i>)	nesting, perching	Yellow-listed

◀ Table 7.2

Species	Life history role	Management status
Ash-throated Flycatcher (<i>Myiarchus cinerascens</i>)	nesting, perching	Yellow-listed
Purple Martin (<i>Progne subis</i>)	nesting, roosting	Red-listed
Tree Swallow (<i>Iridoprocne bicolor</i>)	nesting, roosting	Yellow-listed
Violet-Green Swallow (<i>Tachycineta thalassina</i>)	nesting, roosting	Yellow-listed
Black-capped Chickadee (<i>Parus atricapillus</i>)	nesting, roosting, foraging	Yellow-listed
Mountain Chickadee (<i>Parus gambeli</i>)	nesting, roosting, foraging	Yellow-listed
Boreal Chickadee (<i>Parus hudsonicus</i>)	nesting, roosting, foraging	Yellow-listed
Chestnut-backed Chickadee (<i>Parus rufescens</i>)	nesting, roosting, foraging	Yellow-listed
Red-breasted Nuthatch (<i>Sitta canadensis</i>)	nesting, roosting, foraging	Yellow-listed
White-breasted Nuthatch (<i>Sitta carolinensis</i>)	nesting, roosting, foraging	Yellow-listed
Pygmy Nuthatch (<i>Sitta pygmaea</i>)	nesting, roosting, foraging	Yellow-listed
Brown Creeper (<i>Certhia americana</i>)	nesting, roosting, foraging	Yellow-listed
Bewick's Wren (<i>Thryomanes bewickii</i>)	nesting	Yellow-listed
House Wren (<i>Troglodytes aedon</i>)	nesting	Yellow-listed
Western Bluebird (<i>Sialia mexicana</i>)	nesting, perching	Yellow-listed
Mountain Bluebird (<i>Sialia currucoides</i>)	nesting, perching	Yellow-listed
Common Grackle (<i>Quiscalus quiscula</i>)	nesting	Yellow-listed
House Finch (<i>Carpodacus mexicanus</i>)	nesting	Yellow-listed

mammalian species utilize cavities in snags and trees for part of their life history. Herpetofauna will use the space between loose bark and the trunk. Species such as Pileated Woodpeckers in western North America require trees in the 10-15 cm diameter classes for the ecological corridors found there (Thomas et al. 1979; Bull et al. 1992; Bull and Holthausen 1993).



Snags are used by many species such as raccoons for cover and denning. (Courtesy B.C. Ministry of Environment, Lands and Parks)

Snags also provide perches for birds of prey and insectivores such as hawking flycatchers. Tree form and height are often important features of perches.

Bark retention and condition also influence the value of a snag as wildlife habitat. Species such as nuthatches, a variety of bats (including Red-listed Keen's long-eared myotis [*Myotis keenii*] and Northern long-eared myotis [*Myotis septentrionalis*]), and the clouded salamander use the space between sloughing bark and the tree bole as roosting and thermal habitat (Davis and Gregory 1993; Nagorsen and Brigham 1993). Some plant species, such as licorice fern (*Polygonum glycyrrhiza*), are epiphytic on snags. Others may be snag obligates (Maser, pers. comm., 1995).

Different tree species differ in their value to wildlife. Harestad and Keisker (1989) reported a preference for aspen as a primary cavity-nesting tree in southern B.C. Lundquist and Mariani (1991) report that in the southern Washington Cascade Range, white pine snags were particularly important for woodpeckers and creepers, while Douglas-fir and western hemlock were more valuable for chickadees and nuthatches.

Ecological Roles of Coarse Woody Debris

Coarse woody debris plays numerous roles in providing habitat for organisms in forested ecosystems. Logs become habitat for a variety of invertebrate species shortly after falling. CWD is used by invertebrates as a source of food, for nesting and brooding sites, for protection from predators and environmental extremes, as a source of construction material, and as overwintering and hibernating sites (Samuelsson et al. 1994). Many invertebrates use or require particular species of CWD, and different communities of invertebrates occupy and use different decay stages of CWD (Harmon et al. 1986; Samuelsson et al. 1994). Insectivorous species such as woodpeckers, small mammals, and bears forage on insects dwelling in CWD (Maser et al. 1979; Maser and Trappe 1984; Samuelsson et al. 1994) (Tables 7.3 and 7.4).

Coarse woody debris provides thermal and security cover for a variety of small mammals in British Columbia. Sound CWD provides secure travel corridors for small mammals (Maser et al. 1979; Maser and Trappe 1984; Carter 1993), and provides subnivean habitat during winter. The value of this habitat is positively correlated with piece size (Maser and Trappe 1984; Hayes and Cross 1987; Carter 1993). Nordyke and Buskirk (1991) found that southern red-backed vole abundance was positively correlated with the decay stage of logs in the central Rocky Mountains. Maser and Trappe (1984) and Rhoades (1986) reported associations of small mammals with CWD because of the food source provided by the fungal fruiting bodies growing in and on the CWD.

Gyug (1993) reported that fur-bearers (martens and weasels) used clearcuts with logging debris more than those with no CWD; however, the level of use was much less than that of the adjacent forest. The value of CWD to mustelids (particularly martens, weasels, and fishers) is well documented (Baker 1992; Corn and Raphael 1992; Lofroth 1993; Buskirk and Powell 1994; Buskirk and Ruggiero 1994; and others). Martens select habitats partly on the basis of thermal microhabitats (Taylor 1993), such as those provided by CWD (Lofroth 1993; Buskirk and Powell 1994; Buskirk and Ruggiero 1994). Corn and Raphael (1992) reported that martens selected subnivean access points that had greater volumes of CWD, more layering of logs, more sound and moderately decayed logs, and fewer highly decayed logs than random sites.

Table 7.3

Mammals closely associated with coarse woody debris in British Columbia

Species	Life history role	Management status
Dusky Shrew (<i>Sorex obscurus</i>)	cover, foraging, reproduction	Yellow-listed
Water Shrew (<i>Sorex palustris</i>)	cover, foraging, reproduction	Yellow-listed
Vagrant Shrew (<i>Sorex vagrans</i>)	cover, foraging, reproduction	Yellow-listed
Shrew Mole (<i>Neurotrichus gibbsii</i>)	cover	Yellow-listed
California Myotis (<i>Myotis californicus</i>)	foraging	Yellow-listed
Snowshoe Hare (<i>Lepus americanus</i>)	cover	Yellow-listed
Southern Red-backed Vole (<i>Clethrionomys gapperi</i>)	cover, foraging	Yellow-listed; subsp. <i>occidentalis</i> Red-listed
Northern Red-backed Vole (<i>Clethrionomys rutilus</i>)	cover, foraging	Yellow-listed
Beaver (<i>Castor canadensis</i>)	dam construction	Yellow-listed
Cascades Golden-mantled Ground Squirrel (<i>Spermophilus saturatus</i>)	cover	Yellow-listed
Deer Mouse (<i>Peromyscus maniculatus</i>)	cover	Yellow-listed
Columbian Mouse (<i>Peromyscus oreas</i>)	cover	Yellow-listed
Sitka Mouse (<i>Peromyscus sitkensis</i>)	cover	Yellow-listed
Douglas' Squirrel (<i>Tamiasciurus douglasii</i>)	cover	Yellow-listed
Marten (<i>Martes americana</i>)	denning, foraging	Yellow-listed
Fisher (<i>Martes pennanti</i>)	denning	Blue-listed
Ermine (<i>Mustela erminea</i>)	denning, foraging, cover	Yellow-listed; subsp. <i>haidarum</i> Red-listed; subsp. <i>anguinae</i> Blue-listed
Long-tailed Weasel (<i>Mustela frenata</i>)	denning, foraging, cover	Subsp. <i>altifrontalis</i> Red-listed; trapped
Least Weasel (<i>Mustela nivalis</i>)	denning, foraging,	Yellow-listed

Table 7.4

Birds closely associated with coarse woody debris in British Columbia

Species	Life history role	Management status
Northern Flicker (<i>Colaptes auratus</i>)	foraging	Yellow-listed
Pileated Woodpecker (<i>Dryocopus pileatus</i>)	foraging	Yellow-listed
Ruffed Grouse (<i>Bonasa umbellus</i>)	drumming	Yellow-listed

Aubry et al. (1988) found that some species of salamander were most abundant around CWD. Dupuis (1993) concluded that salamander populations in logged areas were limited by available moist microhabitats, primarily because of a lack of large logs in intermediate and advanced stages of decay. Salamanders use logs as reproduction sites, as foraging sites, and for cover, and also lay their eggs in them (Table 7.5) (Samuelsson et al. 1994).

Coarse woody debris functions as seed beds or nurse logs for some tree species and many species of bryophytes, fungi, and lichens, and some flow-



Fur-bearers such as marten select habitats partly on the basis of thermal micro-habitats such as those provided by coarse woody debris. (Courtesy B.C. Ministry of Environment, Lands and Parks)

ering plants (Table 7.6) (Samuelsson et al. 1994; D.F. Fraser, pers. comm., 1995; E.C. Lea, pers. comm., 1995). CWD, and the associated epiphytic bryophytes, act as both nutrient and moisture buffers for the ecosystems (FEMAT 1993). This buffering allows the slow release of water and nutrients to surrounding plants. In mature and old-growth coastal forests, a large proportion of western hemlock and Sitka spruce seedlings germinate and grow on CWD substrates (Harmon and Franklin 1989; G. Davis, pers. comm., 1994). In the Crowsnest Forest, 40-70% of natural seedlings were rooted in decayed wood in old growth and 24% were rooted in decayed wood in cutblocks (S. Berch, pers. comm., 1995). CWD may be important to the establishment of vascular plants around wet sites such as ponds and bogs (D.F. Fraser, pers. comm., 1995). Red huckleberry (*Vaccinium parvifolium*) is likely an obligate CWD user (D.F. Fraser, pers. comm., 1995; E.C. Lea, pers. comm., 1995).

Other species are either associated with CWD or perhaps with the fungi that use CWD as their parasitic intermediate, such as the gnome plant (*Hypopitis congestum*), candystick (*Allotropa virgata*), and other ericaceous species. Ryan and Fraser (1993) reported that cryptogam species richness in coastal Douglas-fir forests was strongly influenced by available substrate. In forested sites, the presence of CWD and rock substrates resulted in substantial increases in species richness. The review of Samuelsson et al. (1994) of CWD states that distinct succession of bryophyte and lichen communities occurs as trees die, fall, and decay. In B.C., known decomposer macrofungi

Table 7.5

Herpetofauna closely associated with coarse woody debris in British Columbia

Species	Life history role	Management status
Pacific Giant Salamander (<i>Dicamton tenebrosus</i>)	reproduction	Red-listed
Clouded Salamander (<i>Aneides ferreus</i>)	cover, reproduction	Yellow-listed
Coeur d'Alene Salamander (<i>Plethodon idahoensis</i>)	cover, reproduction	Red-listed
Western Red-backed Salamander (<i>Plethodon vehiculum</i>)	cover	Yellow-listed
Western Skink (<i>Eumeces skiltonianus</i>)	cover	Yellow-listed
Rubber Boa (<i>Charina bottae</i>)	cover	Blue-listed
Sharp-tailed Snake (<i>Contia tenuis</i>)	cover	Red-listed

Table 7.6

Vascular plants closely associated with coarse woody debris in British Columbia

Species	Life history role	Management status
Western Hemlock (<i>Tsuga heterophylla</i>)	germination	Commercially harvested
Sitka Spruce (<i>Picea sitchensis</i>)	germination	Commercially harvested
Red Huckleberry (<i>Vaccinium parvifolium</i>)	germination, growth	-
Gnome Plant (<i>Hypopitis congestum</i>)	growth	-
Candystick (<i>Allotropa virgata</i>)	growth	Blue-listed

that are dependent on CWD include 162 species of bracket or shelf fungi/conks, 364 species of other macrofungi, and some commercially harvested mushrooms, such as oyster mushrooms (S. Berch, pers. comm., 1995). These communities play roles in the germination and growth of other epiphytic and quasi-epiphytic communities. Climatic factors influence epiphytic communities, with lichens dominating drier ecosystems and bryophytes replacing them as conditions become wetter.

The longevity of individual pieces of CWD is critical to the persistence of many species with poor dispersal abilities. Dispersal in many species is from one log to the next, so logs close to each other are required. Samuelsson et al. (1994) note that large logs play a more important role than small logs in the ecology of bryophytes and lichens. Large logs last longer, have greater surface area, and have higher, steeper sides that prevent ground-dwelling species from invading. They may also be important in providing a relatively litter-free substrate for the establishment of some species of cryptogams (D.F. Fraser, pers. comm., 1995).

Ecological Roles of Large Organic Debris

The value of woody debris in providing habitat for anadromous and other game fish in aquatic ecosystems has been well documented (Thomson 1991). Large organic debris (LOD) increases aquatic habitat diversity by acting as a physical barrier to water, retaining or detaining sediment and controlling gravel movement (Miller 1987); helping to create and maintain ponds, back channels, and side pools (Bustard and Narver 1975a; Bisson et al. 1987; Sedell et al. 1988); increasing pool size, frequency, and stability; and helping to form complex habitats such as riffles and plunge pools (Hamilton 1991);

Table 7.7

Fish closely associated with large organic debris in British Columbia		
Species	Life history role	Management status
Coho Salmon (<i>Oncorhynchus kisutch</i>)	cover; facilitates deposition of spawning gravel	Yellow-listed
Chinook Salmon (<i>Oncorhynchus tshawytscha</i>)	cover; facilitates deposition of spawning gravel	Yellow-listed
Cutthroat Trout (<i>Oncorhynchus clarkii</i>)	cover, foraging; facilitates deposition of spawning gravel	Yellow-listed
Rainbow Trout (<i>Oncorhynchus mykiss</i>)	cover, foraging; facilitates deposition of spawning gravel	Yellow-listed
Brown Trout (<i>Salmo trutta</i>)	cover, foraging; facilitates deposition of spawning gravel	Yellow-listed
Bull Trout (<i>Salvelinus confluentus</i>)	cover, foraging; facilitates deposition of spawning gravel	Blue-listed
Brook Trout (<i>Salvelinus fontinalis</i>)	cover, foraging; facilitates deposition of spawning gravel	Yellow-listed
Dolly Varden (<i>Salvelinus malma</i>)	cover, foraging; facilitates deposition of spawning gravel	Yellow-listed
Mountain Whitefish (<i>Prosopium williamsoni</i>)	cover, foraging; facilitates deposition of spawning gravel	Yellow-listed
Arctic Grayling (<i>Thymallus arcticus</i>)	cover, foraging	Blue-listed; Williston stock Red-listed Yellow-listed
Northern Pike (<i>Esox lucius</i>)	foraging, cover	Yellow-listed
Lake Chub (<i>Caesius plumbeio</i>)	cover	Yellow-listed
Redside Shiner (<i>Richardsonius balteatus</i>)	cover	Yellow-listed
Burbot (<i>Lota lota</i>)	cover	Yellow-listed
Brook Stickleback (<i>Culaea inconstans</i>)	cover	Yellow-listed
Threespine Stickleback (<i>Gasterosteus aculeatus</i>)	cover	Yellow-listed
Ninespine Stickleback (<i>Pungitius pungitius</i>)	cover	Yellow-listed
Smallmouth Bass (<i>Micropterus dolomieu</i>)	foraging, cover	Yellow-listed
Largemouth Bass (<i>Micropterus salmoides</i>)	foraging, cover	Yellow-listed

Table 7.8

Mammals closely associated with large organic debris in British Columbia		
Species	Life history role	Management status
Beaver (<i>Castor canadensis</i>)	dam construction	Yellow-listed
River Otter (<i>Lutra canadensis</i>)	cover, foraging	Yellow-listed
Mink (<i>Mustela vison</i>)	cover, foraging	Yellow-listed

and providing a substrate for biological activity (Sedell et al. 1988). LOD helps regulate local water flow and depth, and increases water depth variability, providing preferred habitat for some species (Bustard and Narver 1975b).

LOD provides important cover for fish for hiding and resting (Hamilton 1991). Table 7.7 lists fish species in B.C. that are closely associated with LOD for all or part of their life history. LOD also acts as a food source and habitat for many types of aquatic invertebrates (Harmon et al. 1986). Dudley and Anderson (1982) documented 56 taxa of invertebrates closely associated with wood, and an additional 129 taxa that were dead-wood facultatives in stream ecosystems in the U.S. Pacific Northwest. Cummins and Klug (1979) and Maser and Trappe (1984) identified 5 functional groups of aquatic invertebrates reliant on LOD: borers/tunnellers; wood ingesters and shredders; algae scrapers; those that attach to wood or hide in its grooves; and piercers and predators. LOD provides substrate for algae and microbes, which in turn provide food for aquatic invertebrates (Maser and Trappe 1984). The state of decay of LOD is a critical factor in determining the biotic community that may take advantage of it as growing substrate, burrowing substrate, or food source. Aquatic invertebrates are a major food source for aquatic vertebrates. LOD also provides habitat for mammals, particularly beavers, mink, and otter (Table 7.8), and long-toed salamanders. LOD is used by some birds (Kingfisher, American Dipper, Wood Duck, Hooded Merganser), but is likely less critical to them.

Pools formed by LOD act as collection basins for finer organic matter. The size and position of debris is correlated with the size and amount of pool habitat formed (Sedell et al. 1988). Trapped organic matter, such as leaves and needles, forms much of the energy input into stream ecosystems and may be the dominant regulator of ecosystem organic 'output' (Bilby and Liker 1980; Bilby 1981, 1984). Stream rehabilitation after major floods, debris events, or massive landslides is accelerated by large, woody debris

along and within the channel (Sedell et al. 1988). Plant species diversity on river bars is related to the area, sediment, and woody debris of river bars (Malanson and Butler 1990).

Dead Wood and Ecosystem Processes

Dead wood is a critical component of many ecosystem processes. It supports physical, chemical, and biological functions in forested ecosystems. These functions include nutrient cycling, carbon storage, erosion control and slope stabilization, water cycling, soil formation, and stream movement processes (Harmon et al. 1986; Maser et al. 1988; Caza 1993; Samuelsson et al. 1994).

Coarse woody debris is a significant factor in nutrient cycling processes (Harmon et al. 1986; Caza 1993). Although the relative concentration of nutrients in wood and bark is low, much of the nutrient capital and carbon are stored here because of the large biomass involved (Harmon et al. 1986; Caza 1993). Dead wood facilitates a slow release of nutrients, ameliorates leaching, and provides a growing substrate for bryophytes. These buffer water and nutrient release from litterfall and above-ground processes, especially processes such as nitrogen fixation in above-ground plants such as hepatics (Harmon et al. 1986; FEMAT 1993; Samuelsson et al. 1994). Free-living bacteria in woody residues and soil wood fix 30-60% of the nitrogen in the forest soil. In addition, 20% of soil nitrogen is stored in these components (Harvey et al. 1987). Harmon et al. (1986) reported that CWD accounted for as much as 45% of above-ground stores of organic matter.

Dead wood in terrestrial ecosystems is a primary location for fungal colonization and often acts as refugia for mycorrhizal fungi during ecosystem disturbance (Triska and Cromack 1979; Harmon et al. 1986; Caza 1993). Colonization of dead wood by fungi and microbes may be one of the most important stages in nutrient cycling (Caza 1993); however, these processes are still relatively poorly understood. Soil wood contains a disproportionate amount of the coniferous feeder roots or ectomycorrhizae in forests (Harvey et al. 1987). As one of the dominant sources of organic matter, dead wood is an important determinant in soil formation and composition (Caza 1993).

Dead wood is also the dominant store of organic matter in stream ecosystems (Harmon et al. 1986); as such, it is an important source of nutrient and organic matter input. Dead wood traps leaf and litterfall within aquatic systems, which extends the length of time this material remains and provides nutrients through decomposition (Triska and Cromack 1979; Harmon et al. 1986).

Dead wood provides physical structure to the ecosystem and fills such roles as sediment storage (Wilford 1984), protecting the forest floor from

mineral soil erosion and mechanical disturbance during harvesting activities. It ameliorates the effects of cold air drainage on plants, helps stabilize slopes, and minimizes soil erosion (Maser et al. 1988). Dead wood provides elevated germination platforms with reduced litterfall accumulation and relatively consistent moisture regimes (Harmon et al. 1986; Maser et al. 1988; Caza 1993; D.F. Fraser, pers. comm., 1995). In stream ecosystems it protects stream banks from erosion and maintains channel stability (Triska and Cromack 1979; Sedell et al. 1988). Features that influence the ability of LOD to fulfil these functions include size (length and diameter), whether roots are still attached, orientation, degree of burial, and proportion of the piece that remains submerged (Sedell et al. 1988).

In both terrestrial and aquatic ecosystems, dead wood functions as a reservoir of moisture, ameliorating drought conditions and providing a 'perched water table' (Triska and Cromack 1979).

Management of the Dead Wood Cycle

Almost all aspects of forest management affect the dead wood cycle. Harvesting initially increases CWD amounts except where utilization is very high. CWD may be harvested where utilization standards influence the amounts of waste and avoidable waste retained in second-growth forests. Site preparation (such as broadcast burning, windrowing, or piling and burning) leave structurally simpler forest floor ecosystems. These ecosystems lack or have significantly reduced amounts of CWD, and recruitment of new CWD from the regenerating stand may not occur until after the projected rotation age is reached.

Public perception of CWD as messy logging that wastes wood has influenced CWD management. This has led to a policy of 'zero waste tolerance.' The importance of LOD in stream ecosystems and the role of snags are more widely accepted. Management of CWD requires increased understanding of its importance in the forest management arena, the environmental community, and the general public.

Management of the dead wood cycle must ensure continued input of material into forested ecosystems (terrestrial and aquatic) so that the important biological, chemical, and physical functions are fulfilled. The previous sections point out the need to address a variety of attributes or characteristics of dead wood to achieve this goal.

The value of snags, CWD, and LOD as a supply of habitat and as components of ecosystem processes is correlated to a large extent with the amount of material and the piece size. As with most attributes, however, there is a succession of biota and ecosystem functions with increasing piece size. Decay characteristics are another important consideration in managing the dead wood cycle. Distinct biotic communities are associated with different

decay states, and the role of dead wood in ecosystem function changes considerably as decay progresses (i.e., from sediment storage and aquatic pool formation to nutrient cycling). Species composition of dead wood is another attribute that must be addressed.

Use by biota, input and decay processes, and nutrient and moisture storage functions may all be species-dependent. Orientation, distribution, and structural arrangement in the terrestrial and aquatic landscape influences the value of dead wood in the ecosystem, particularly in processes such as slope stabilization, sediment control, stream bank stabilization, fungal recolonization, and habitat value for some species.

Management of the dead wood cycle requires an ecosystem approach because of the dead wood's ecological variability. Management regimes need to be designed to ensure the persistence of the full range of natural variation for each of the following characteristics of dead wood: amount, size, species, decay class, orientation, distribution, and structural arrangement. Currently little information is available for effective management. The next section outlines the types of information still needed.

Because wildlife trees and snags are an important source of input to the dead wood cycle, appropriate management of these components is critical. A system is in place in British Columbia to guide the management of wildlife trees and snags at the landscape and stand scales (Province of British Columbia 1995). There is a sanctioned (B.C. Ministry of Forests and B.C. Workers' Compensation Board) process for assessing and maintaining snags in silviculture operations with low ground vibration, such as tree planting and juvenile spacing, and in certain harvesting scenarios (Guy and Manning 1995). Currently there are no ecosystem management systems or prescriptions in place for the management of CWD and LOD. Management regimes must be designed to ensure that dead wood input and decay processes satisfy the criteria for the factors discussed above, and are explicitly addressed by harvesting and silviculture plans and operations.

Research Needs

Information needs for ecosystem-based management would best be met by a combination of research and inventory tasks that address the following topics:

Dynamics of wildlife trees and snags: natural mortality rates of trees by species and size class, and the development of life tables for snags to assess longevity in the ecosystem.

Dynamics of CWD: rates of input, decay, size and species distribution, orientation, and distribution in natural and managed stands.

Dynamics of LOD, particularly input characteristics of size, species, orientation, and relative rates of loss through decay and downstream transport.

Development of models for dead wood cycle dynamics that could be integrated with tree growth and timber supply models.

The nature of relationships between dead wood and dead wood-obligate species, particularly taxa that are still poorly understood and undescribed, such as bryophytes, hepatics, lichens, and invertebrates.

Importance of dead wood in ecosystem processes in different ecological conditions in B.C.

Pre- and post-assessments of the nature of dead wood during forest-harvesting operations in a variety of ecological conditions. This information will highlight attributes and ecological areas that need immediate management attention.

Examination of the effect of a range of silvicultural treatments on the dynamics and ecosystem value of dead wood.

Relationships between CWD dynamics and Ministry of Forests waste and residue assessment procedures in order to clarify the potential overlap between these.

Assessment of the extent to which wildlife tree and snag management will ensure an adequate input of dead wood to the forested ecosystem.

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8

Managing for Edge Effects

Joan Voller

Definitions

An *edge* is the interface between two types of habitat: the boundary where two communities meet (Giles 1978; Thomas et al. 1979; Forman and Godron 1986). An *ecotone* is the area of habitat affected by the meeting of the two communities (Thomas et al. 1979).

Edge effects: Edge effects were originally defined by Leopold (1933) as the tendency for boundaries between two habitat types to support a greater variety of species and number of individuals than either adjacent habitat. More recently, the term *edge effect* has come to describe the diverse phenomena that occur in the ecotone, and either positive or negative connotations may be associated with it (Angelstam 1992). For example, *edge effect* is now used to describe such phenomena as the modified environmental conditions found at the boundary between two habitats (Olympic Learning Center 1991; FEMAT 1993). In addition, the term may be used to describe the effects of edges on various processes, such as increased predation and parasitism of vulnerable species in the vicinity of the ecotone (Alverson et al. 1988).

Edge orientation: Edge orientation has recently been shown to play an important role for all variables of microclimate, and thus will affect vegetation growth and wildlife use (Chen et al. 1995). This is especially true in high-latitude areas such as British Columbia, where solar altitudes are high. Edge effects at high latitudes are strongest at southwest-facing edges and weakest at northeast-facing edges (Chen et al. 1995).

Inherent versus induced edge: There are two types of edge: inherent and induced (Yahner 1988). An inherent or natural edge is a long-term, natural feature of the landscape, such as the boundary between a riparian area and upland habitat. Inherent edges may be caused by topographic differences, changes in soil type, microclimate changes, or geomorphic features (Thomas et al. 1979). An induced edge is usually a relatively short-often man-made feature such as that found between an old-growth and a