ECOLOGICAL ASSESSMENT OF BIOMASS THINNING IN COASTAL FORESTS – A LITERATURE REVIEW

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SUMMARY

In the reality that is California an ecological assessment of biomass management must consider the same criteria as conventional timber harvest. Many of the same variables needing attention in timber harvest come into play when discussing biomass abundance, distribution and composition. These variables may include disturbance histories; decay rates of particular species; input (recruitment) rates; site characteristics (slope, aspect, temperature and soil moisture), ecological habitat elements and floral and faunal species needs.

Potential Biomass outcomes (products) may include posts; poles, pulp, fiberboard; pellets; bark/landscape materials; biochar; biopower/biofuels. The end product may be determined by a particular tree species or tree part. Environmental impacts of biomass removal should be considerations on a project-by-project basis.

Sources of biomass may be in the form of standing trees (both conifers and hardwoods); large and small wood; snags; non-tree species (shrubs); and agricultural waste products.

The "context" of biomass removal.

In California regulatory and financial constraints will frame the discussion as it does for conventional timber removal. On private and state forestlands, all existing regulatory constraints are applicable in the management/removal of biomass. Federal lands will be required to follow the policies of the managing resource agency. On private lands, these constraints include the California Forest Practice Act and Rules; stream zone protections (WLPZ); state and Federal species protection acts (Endangered Species). Additionally, as any other forest management operation all sites will have to consider the cost of harvesting; transportation and available processing facilities and markets.

Although the desire is to have a review paper focused strictly on the plant communities of Mendocino County the breadth and scope of the request of the Mendocino biomass group simply does not provide an opportunity to use research data generated only from Mendocino County or even California. Where possible the literature includes information from Mendocino County, northwestern California or pertinent information from other western sources.

Introduction

Demand for alternative energy sources coupled with a need to address timber stand conditions has led to increased interest in north coast biomass production. The public's interest in biomass removal can be viewed across a broad spatial landscape. Like timber production, it is widely accepted that biomass activities can affect forest structure and composition by altering species composition, nutrient cycling and subsequently biodiversity. Because both forest and fuels-treatment thinning are viewed as possible wide-spread biomass harvest options, it is important to understand what is known about forest biodiversity response to these practices. Information is needed by forest managers and policymakers to make informed decisions and management actions.

Potential Sources of Forest Biomass

Forest thinning has long been viewed as a means to reduce tree density as a way to improve tree growth, enhance forest health, or for economic reasons (Helms, 1998). Forests naturally thin through limb loss or tree mortality as a result from competition in dense stands. Forests can be thinned before competitive self-thinning to meet economic objectives as well as objectives related to biodiversity conservation and forest restoration (Hayes et al., 2003; Harrod et al., 2009; Hayes et al., 1997, 2003; Carey and Wilson, 2001). Wood products resulting from thinning operations are used in a variety of ways, often resulting in up to 60% of harvested material remaining on-site (Parikka, 2004).

Key points:

- Variable density thinning in even-aged stands can improve the light mosaic having general positive impacts to both understory vegetation and small mammals;
- Variable density thinning is generally viewed as a positive action if the reduction is generally between 24-30% reduction in basal area (Carey and Wilson, 2001) ;
- Not all wildlife species can be expected to respond identically. Some species with specific habitat element needs should be given site specific consideration;
- Thinning forest structure by reducing overall tree density by > 60% and canopy bulk density by 50% has shown to reduced susceptibility to crown fire (Harrod et al, 2009).

Given the constraints and realities of timber harvesting I assumed that biomass production will be either a by-product of commercial timber harvests or the result of timber stand improvement (TSI) actions. To reinforce this approach this literature review is following the direction of the biomass working group which is *"Past forest management practices in Mendocino County have created large tracts of overcrowded small diameter trees and brush. This excess woody biomass impacts the forest ecosystem – increasing vulnerability to catastrophic forest fire events, stunting tree growth, using more water than well-spaced forests* *and degrading terrestrial and aquatic habitat"*. Since many of the trees being considered for management are categorized as Group "A" or "B" species in the California Forest Practice Rules (FPR) existing residual stand requirements, stream zone protections, non-timber species considerations, and soil and water protections must be considered.

Consider the following two examples;

1) A source of forest biomass could be a stand identified for even-aged management in which of the regulatory constraints and expectations associated with even-aged management would apply. In this scenario forest biomass could potentially be removed from a site then sorted into timber quality logs and biomass material.

2) Similarly, in a TSI scenario, regulatory constraints would apply and would be dependent on the type of silviculture being applied. This example would require greater attention to details of residual stand attributes for cavity nesting birds, ground dwelling invertebrates and vertebrates and soil and water impacts.

In California, it is the silvicultural practices that drive the regulatory system not the end product or use of the wood.

A variable not usually associated with traditional timber harvest operations that may differ in biomass collection is the cleanliness of the harvested material. Collection and/or removal of existing downed wood may be impractical considering both the decay progression in downed wood and the amount of soil and organic debris that may be incorporated into the material. Similarly, the removal of any downed materials from stream channels would most likely be constrained given today's regulatory environment. I assumed this scenario to be impractical and is not addressed in this review.

An irregular but theoretically possible source of forest biomass could come in the form of harvested brush species, the result of fire/fuel reduction activities. Under this scenario the lack of existing regulatory guidance would require greater attention to location and the plant community being affected and the scale of the project in order to address some of the ecological considerations.

Forest Types found in Mendocino County

In conifer forests of the Pacific Northwest, the natural disturbance regime is spatially and temporally complex. In some climatic zones, frequent fires of low to moderate intensity historically led to a predominance of complex, multi-aged stands (Morrison and Swanson, 1990; Taylor and Skinner, 2003), while the fire regime in other locations was dominated by stand-replacement events (Stewart, 1986; Agee, 1993; Huff, 1995). Historically, this has resulted (in some but not all) in forests which are spatially and structurally heterogeneous. (source: California Wildlife Habitat Relationship (CWHR) Model; 1988).

Currently, CWHR recognizes 11 tree dominated communities (forest types); 4 non-tree types; and 2 developed habitat types that could potentially produce woody biomass. These include:

Tree dominated plant communities	
Hardwood types	**Conifer types**
Blue oak – Foothill pine	Closed-coned pine – Cypress
Blue oak woodlands	Douglas fir
Coastal Oak Woodland	Klamath Mixed Conifer
Montane Hardwood	Ponderosa pine
Montane Hardwood-Conifer	White fir
	Redwood
Non-tree types	
Montane chaparral	Mixed chaparral
Chamise-redshank chaparral	Coastal scrub
Developed habitats	
Orchards	Vineyards

Of the various tree dominated plant communities much more research has focused on both the ecological role and function of wood and the management of wood in the conifer types. Though a great deal of literature has been developed over the past 30 years affording a better understanding of the overall ecology of oak dominated plant communities there still is a need to better explore management scenarios for both retention and recruitment for oaks and oak woodlands being managed for biomass production.

Much the same could be said for the non-tree types (chaparral dominated) as much of the focus has been reducing fire risks in these types and how the plant community responds to the treatment. Much of the literature is both limited and unrelated to the ecological implications of biomass removal.

The two developed habitats identified in CWHR (orchards and vineyards) are truly a sustainable source of biomass and should not be dismissed. They both provide easy access to wood usually on relatively flat ground, and is now considered a waste product that is a cost for producers who have to discard the material. Additionally, the ecological concerns utilizing woody biomass from agri-based operations are much less of a concern than materials generated from forests.

Ecological Implications of Biomass Removal - *Effect of forest thinning on plant species diversity*

Disturbances such as fire and wind can have beneficial ecological effects on forest stand structure and function including nutrient cycling, modification of fuel loads, formation of cavity trees for wildlife, and promotion of complex canopy architecture (Chandler et al., 1983; Agee, 1993; Sillett and Van Pelt, 2007). Indiscriminant removal of habitat elements during biomass removal could potentially adversely impact stand biodiversity.

Key points:

- Due to the lack of fire and other constraints, air quality and T&E species, thinning in certain instances, can be considered a surrogate management strategy that should be included in forest-wide planning (Agee 1993).

Mechanical treatments can vary widely, but there are several general ways in which mechanical fuel treatments may not act as surrogates for fire. Such treatments may disturb or add to organic material on the forest floor and may lack the heat required to kill fire-sensitive tree and shrub species or to cue seed germination in some fire-dependent species. Harvesting equipment may result in damage to non-target species. However, mechanical fuel treatments, like fire, open the canopy and provide increased light to the understory and decreased competition among overstory trees. Therefore, a general pattern observed following mechanical fuel treatments is an increase in understory production and diversity similar to that seen following low to moderate intensity fire (Bartuszevige and Kennedy 2009). (From Stephens et al. 2012)

The response of plant species diversity to forest thinning is often positive, but has been less studied than faunal diversity (Halpern and Spies, 1995; Thomas et al., 1999; Nelson, C.R., et al. 2007). In the northwestern U.S. and Canada, species richness of understory vegetation in thinned stands was similar to, or greater than, uncut control stands (Deal, 2001; Thomas et al., 1999). In structurally complex temperate rain forests of the northwestern U.S., thinning increased growth of important mid-canopy layers (Comfort et al., 2010) by improving the light mosaic.

Lodgepole pine forests of the Northwest interior exhibited few differences in plant species diversity or composition between thinned and un-thinned stands (Sullivan et al., 2002).

As forest succession continued pre-commercial thinning sustained high levels of plant diversity (Weidenfalk and Weslien, 2009).

Key points:

- Following a Variable Retention harvest slash cover was 77% of the forest floor; cover on exposed mineral soil was 4%: specific plant species responses where observed with survival rates as low as 30%, with survival increasing over time.
- Thinning generally increases forest light penetration generally creating favorable conditions for plant species. Cautionary note: excessive canopy removal can lead to invasion of unwanted species (Nelson, et. al. 2007).

The results of mechanical treatments alone are mixed regarding their ability to reduce potential fire severity (Agee and Skinner 2005, Stephens et al. 2009). In this regard, whole-tree-removal systems are one of the most effective mechanical systems and may be preferred where wood-chip or biomass markets are available. Where trees are too small (less than 20 centimeters [8 inches] in diameter) for sawn products and cannot be economically chipped and transported to a processing facility, subsidizing treatment or hauling costs should be considered if the corresponding decrease in fire hazard warrants the additional expenditure. (From Stephens et al 2012.).

Coast redwood (Sequoia sempervirens), is a western North American conifer of ancient lineage with a paradoxical combination of late-successional characteristics and strong adaptations to disturbance. Like other conifer species in cool temperate forests, redwoods occur in disturbance-prone environments and have biological traits suggesting adaptation to major natural disturbances. Examples of disturbance adaptations include a requirement of exposed mineral soil for good seedling establishment, high light requirements, and rapid growth in open environments, early reproductive maturity, and thick bark on mature trees to protect against cyclic fire regimes (Rowe and Scotter, 1973; Heinselman, 1973; Chandler et al., 1983).

Plant species richness in ponderosa pine forests of the southwestern U.S. was least in unmanaged stands and increased with greater thinning intensity. However, exotic species were a large part of the increase in richness for harvested stands, and number of native shrub species decreased significantly with treatment intensity (Griffis et al., 2001).

In Sierran mixed conifer forests, canopy closure, used as a measure of thinning intensity, was shown to be negatively related to plant species richness (Battles et al., 2001). In addition, plant species composition varied significantly with intensity of thinning treatments. High intensity treatments maximized species richness but understory vegetation typical of late seral stands was more abundant in lightly thinned or control stands. In structurally complex temperate rain forests of the northwestern U.S., thinning increased growth of important mid-canopy layers (Comfort et al., 2010)

In general terms forests naturally thin through tree mortality resulting from competition in dense stands. An increase in availability of biofuels processing facilities may increase removal and use of thinned material which may partially offset harvest cost while meeting some of the increasing demand for biofuels (Page-Dumroese et al., 2010).

Key points:

- A cautionary note when working in old growth conditions, warns about the ability for both exotics and invasive plant species to take advantage of increased light and disturbed soil. Post harvest monitoring is important (Griffis et al 2001).
- Variable Density thinning experiments measured mid-canopy growth responses; when over story canopy were thinned demonstrated a positive correlated response from mid-canopy species. Thinning with skips and gaps between 20-25% of basal area while leaving 10% of the total area un-thinned; with about 15% in small canopy gaps resulted in both crown area and live crown ratio positivity correlated with changes in basal area. (Comfort et al 2010).

Effect of forest thinning on wildlife taxa diversity

Several authors have found that thinning can increase structural complexity of young forests, subsequently increasing wildlife species diversity (Spies and Franklin, 1991; Hayes et al., 1997). Thinning produces a variety of short and long-term changes to forest structure, the most obvious of which is a decrease in tree density and increase in forest canopy gaps and abundance and diversity of mid-story trees (Artman, 2003; Agee and Skinner, 2005; Hayes et al., 2003; Harrod et al., 2009). The more profound effect for wildlife species may be related to development of more complex understory vegetation due to increased light availability below the canopy (Doerr and Sandburg, 1986; Bailey and Tappeiner, 1998; Wilson and Carey, 2000; Garman, 2001; Homyack et al., 2005).

Key point:

- Thinning can increase structural complexity of young forests, subsequently increasing wildlife species diversity (Spies and Franklin, 1991; Hayes et al., 1997).

A large body of work has been developed, particularly in the last 10–15 years (Kennedy and Fontaine 2009), which has shown that many wildlife species depend on fire-maintained habitats or pyrogenic structures, such as the snags, shrubs, and bare ground created by fires of varying severity (Hutto 2008). Thinning or low-severity prescribed fire has the potential, in the short term, to create forests with similar structure and with habitat conditions favored by many wildlife species (From Stephens et al. 2012).

Most current research offers a snapshot assessment of the effect of forest thinning on species diversity and abundance. Effects of forest thinning operations on measures of diversity are often highly dependent on time since harvest, as many harvests will have a negative short-term effect on both species abundance and diversity (Wilson and Puettmann, 2007).

Key points:

- Songbird habitat evaluations on understory vegetation showed herbaceous cover consistently, but slightly, increased following thinning. Shrub cover decreased after thinning when pre-treatment cover was > 30% (Wilson and Puettman 2007).
- Thinnings between 15-63% of basal area compared to un-thinned controls of 40-60 year old Douglas fir stands tended to homogenize total shrub and tall shrub cover across studies and sites.
- Because responses to habitat manipulations can vary greatly among taxa and among species within taxa, one should not make broad assumptions about “wildlife” as key habitat elements may need consideration in certain situations.

Birds

Positive responses by many bird species to forest thinning have been well documented (Hayes et al., 1997, 2003; Hunter, 2001; Hagar et al., 2004; Kalies et al., 2010). Proposed mechanisms for increased abundance and diversity of bird species in thinned stands include increased regeneration and development of shrub and understory layers from greater light access to the canopy floor (Hayes et al., 1997) or increased horizontal or vertical variation in forest structure (McComb and Noble, 1980; Sullivan et al., 2002; Carey, 2003). Others have proposed that thinning can cause a more rapid return to conditions simulating older seral stages which in turn can increase number of species using the diversified habitat (Barbour et al., 1997; Bailey and Tappeiner, 1998).

Key points:

- No single prescription will promote habitat in all young stands for all species. Thinning stands before age 15 can be useful in addressing both wildlife considerations while addresses silvicultural objectives by increasing wind firmness and large crowns in residual trees (Hayes 1997).

- In many cases, thinning can improve foraging and nesting for ground birds through the increase of ground and mid-canopy vegetation. Some species, (Pacific slope flycatchers) may be less abundant in thinned stands validating a watershed or landscape view of management activities.
- In a second publication Hayes (2003) cites an example of different bird species responses to thinning. He cites 22 bird species in which 9 species decreased, 8 species increased relative to controls following variable thinning intensity. Control stand initial density was 410-710 t/ha (170-295 tpa). Stands were thinned to densities of 240-320 t/ha (100-133 tpa; moderate thin); and 180-220 t/ha (75-92 tpa; heavy thin). The stands were all thinned from below in stands of 35-45 year old Douglas fir.
- Tree and shrub-inhabiting birds may respond negatively to heavier thinning intensities or certain treatments or forest types.
- Impacts were considered significant for those studies where > 66% of basal area or trees per hectare were removed during thinning (Christian et al., 1996; Norton and Hannon, 1997).

Fuels treatment thinning resulted in the largest effect sizes for birds suggesting a strong positive response for avian species diversity and abundance. In stands thinned as a fuels treatment, Siegel and DeSante (2003) found canopy, cavity and especially shrub-nesting avian species in higher abundance than in comparable un-thinned stands.

Key point:

- Detections of ground nesting birds were similar on thinned and un-thinned plots. However canopy, cavity and shrub nesting species were much more frequently detected in thinned stands. Standard commercial thin with biomass thinning to a density of 1 tree/8.2 m (1 tree/27 feet). Although nests were easier to find in thinned plots, the difference in nest success was not considered significant (Siegel and Desante 2003).

One of the most interesting results was the similarity in the pattern of responses between thinning and low to moderate-severity prescribed fire (Fig. 1). Across all species of birds, the proportions of species with negative, neutral, and positive effects were quite similar (From Stephens et al. 2012).

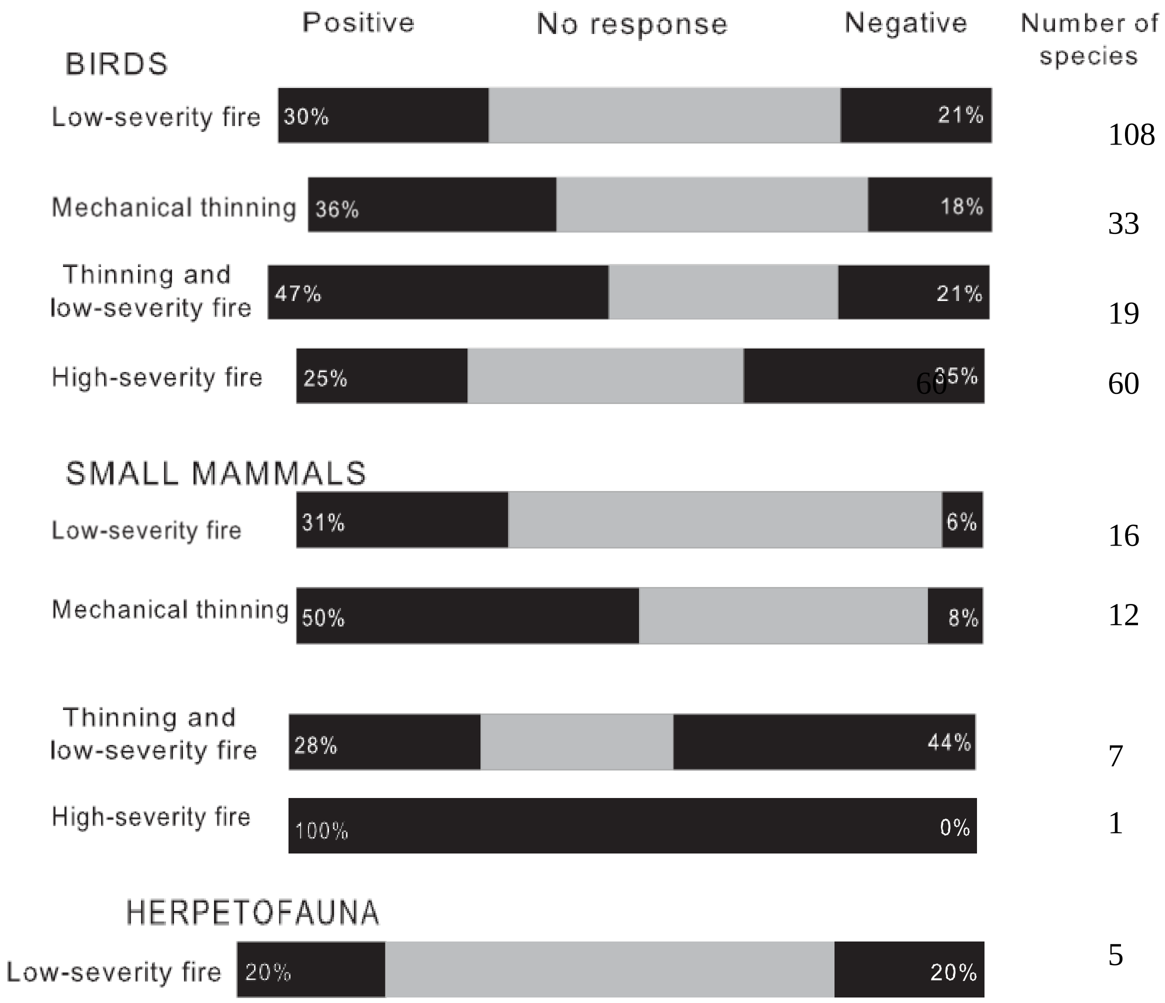

Figure 1 (from Stephens et. al. 201)2. The responses (positive, neutral, and negative; number of species with sufficient data) of birds, small mammals, and herpetofauna to fire and fire-surrogate treatments 0–4 years after fire treatment in seasonally dry forests of the United States. The response classification was based on a meta-analysis of the existing literature and the generation of cumulative effect-size estimates and their 95% confidence intervals with overlap (neutral) or not (positive, negative) with zero.

Mammals

Mammalian diversity and abundance were higher in thinned stands than un-thinned controls across most regions reviewed in the literature. However, the magnitude of the mammalian response to thinning treatments varied significantly between regions due to differing forest types and mammalian species. Reported summary effects generally suggest a strong positive response of mammalian diversity and abundance to the variety of thinning treatments applied but again a cautionary note about species specific habitat elemental requirements.

Numerous studies have revealed a positive response of small mammals to forest thinning (Zwolak, 2009). Thinning is proposed to be beneficial to open-habitat and generalist small mammal species through increased light to and productivity of understory vegetation. Increased understory shrub and herbaceous vegetation increases forage and cover for deer mouse (*Peromyscus*), jumping mice (*Zapus*) , and most vole (*Microtus*) species (Wilson and Carey, 2000; Suzuki and Hayes, 2003; Homyack et al., 2005), although response to the increase may be short-lived (Suzuki and Hayes, 2003). Zwolak (2009) found that *Myodes gapperi* (a vole) is far more susceptible to even-aged management. Giusti (unpubl. data) has observed similar results for *Myotes californicus* in coast redwood stands. *Peromyscus*, a ubiquitous species in many forest types, responded positively to clear-cuts. Impact from heavy thinning or disturbance can be species specific and the affects can be persistent for many years' even decades.

Bats are also typically favored by thinning operations across geographies through increased access to flying insects (Humes et al., 1999; Tibbels and Kurta, 2003; Loeb and Waldrop, 2008), but species-specific responses must be considered (Patriquin and Barclay, 2003). Care should be given to those habitat elements that provide roost and hibernation sites e.g. trunk hollows, both green and dead snags.

Although commercial thinning resulting in open canopies and increased understory growth may favor measures of mammalian species abundance or diversity, it may not improve habitat conditions for species associated with closed-canopy conditions (Lehmkuhl et al., 2002).

Key points:

- One species in particular, flying squirrels, are sensitive to open canopies, are dependent on understory plants, truffles and lichens. Negative thinning impacts may be ameliorated by patchy harvests and the retention of large trees, woody debris and mistletoe brooms (Lehmkuhl et al., 2002).

Although typically associated with low intensity harvest, pre-commercial thinning has been shown to reduce small mammal species diversity in some instances (Etcheverry et al., 2005). However, pre-commercial thinning can lead to late-seral conditions developing at an earlier age, which may ultimately benefit species associated with older forests.

Key point:

- Clear-cuts can provide more persisted, larger woody debris than pre-commercial thinning (PCT) One study found that overall species richness of small mammals were lower in PCT suggesting that managers should consider a mosaic of management applications (Etcheverry et al., 2005).

Reptiles

Many reptile populations are experiencing declines (Gibbon et al., 2000). However, research documenting response of reptiles to timber harvest is limited (Russell et al., 2004; Todd and Andrews, 2008). Solar radiation and thermal cover are important habitat characteristics for reptiles (Kiester, 1971). Standard clear-cutting provides ample solar radiation for morning sunning, but may not provide adequate night time thermal cover in some regions.

Key findings:

- Reptiles are most negatively impacted from even-age silvics. Maintaining ground litter for thermal cover is an important consideration for maintaining local populations.

Amphibians

Salamanders, particularly plethodontid (lungless) salamanders, are often more abundant in closed canopy forests and in later successional stages (Corn and Bury, 1989; Ash, 1997; Aubry, 2000; Semlitsch et al., 2009). Declines of up to 80% for some salamanders and species richness declines of up to 50% have been reported following even-age timber harvest in some forest types (Petranka et al., 1993). Welsh et al. (2007) working in Mendocino and Humboldt Counties did not find compelling evidence that plethodontids salamanders were in a downward trend across the northwest of California. However, in subsequent work he did write that particular attention needs to be given to 1st, 2nd and 3rd order streams to protect salamander populations. Various channel attributes provide important habitat elements for breeding, foraging and cover (Welsh 2011)

In a comprehensive review of amphibian response to forest management in North America, deMaynadier and Hunter (1995) report the short-term, stand-level response of salamanders to timber harvest is typically negative, especially for clear cutting, usually through the mechanisms of reduced leaf litter, canopy cover and soil moisture (deMaynadier and Hunter, 1995; Pough et al., 1987; Ash, 1997; Semlitsch et al., 2009). Ashton et al. (2006) reported that some amphibian populations had not recovered 34-50 years following traditional clear cut silviculture in redwood stands. They cite fine sediments entering stream channels as the principle impediment to population recovery. Pough et al. (1987) showed a strong linear relationship of understory vegetation and leaf litter depth with above-ground salamander activity, and Ash (1997) reports the timing of amphibian return to previously harvested stands closely follows re-development of the litter layer.

Less information is available on amphibian response to partial harvest or thinning. Some suggest that detrimental effects of stand disturbance (e.g. soil compaction, stream sedimentation) on amphibian populations persist even when the disturbance is a less severe partial cut (Harpole and Haas, 1999; Semlitsch et al., 2009). However, Brooks and Kyker-Snowman (2008) found forest floor temperature and humidity to be similar between partial, selection-based timber harvests and un-harvested control stands. Several studies report mixed or even positive effects of thinning on amphibian populations (Pough et al., 1987; Grialou et al., 2000; Renken et al., 2004; McKenny et al., 2006) suggesting that thinning harvests can maintain forest amphibian populations.

Key findings:

- Amphibians generally respond negatively to even-aged management;
- thinning harvests can maintain forest amphibian populations if adequate attention is given to retaining forest floor litter and woody material;
- "operational biomass harvest may not change CWD levels enough to appreciably influence forest biodiversity, especially if biomass harvest guidelines are used that require leaving a portion of harvest residues. (Riffell et al. 2011).

Forest Invertebrates

Insects are affected in a variety of ways by changes to the forest canopy, understory, and litter layers, and can themselves be significant drivers of forest productivity and nutrient cycling (Hunter, 2002). Effects of forest thinning on invertebrates are not well understood (Duguay et al., 2000; Schowalter et al., 2003; Yi, 2007). Depending on their life history characteristics, invertebrate communities have been shown to respond positively (Yi, 2007), negatively (Niemela et al., 1993), or minimally (Schowalter et al., 2003; Apigian et al., 2006) to forest thinning and other canopy opening disturbances.

Soils

Although considerable mineral soil exposure may be observed in skid trails and other areas of intensive vehicle activity during mechanical treatments, such treatments typically have limited site impacts of less than 2% of the forest floor, and therefore had little effect on soil exposure. In one study, increases in mineral soil exposure persisted through later years (to the second or fourth year, depending on the site) only after the prescribed-fire-only treatment. (From Stephens et al. 2012).

Carbon

One study by Nave et al. 2010 demonstrated that harvesting caused forest floor C storage to decline by a consistent 30%, but losses were significantly smaller in coniferous/mixed stands (20%) than hardwoods (36%).

One of the most important overall findings of the Nave report was that C stored in forest floors is more vulnerable to harvest-induced loss than mineral soil C. The overall effect of harvest on forest floor C storage was remarkably consistent among studies, with little variation due to differences in soil taxonomic order, time since harvest, or harvest intensity. The principal predictor of variation in harvest impacts on C storage was tree species composition, with coniferous/mixed forests losing less forest floor C than do hardwood forests.

The effects of species composition and soil taxonomic order on harvest-induced changes in forest floor and mineral soil C storage suggest that further research may allow development of predictive maps of forest management effects on soil C storage.

Nitrogen

Nitrogen (N), like Carbon, is an element with a complex role in the forest environment. The subject could easily be the subject of an extensive review producing volumes of information. To help the reader I have selected a paper by Fenn et. al. (2003) that identifies many of the important aspects of nitrogen's role in forests.

Key points:

- Human activities have doubled N inputs to the environment between 1961 to 1997, mostly from N fertilizers and fossil fuel emissions (NOx) (Howarth et al. 2002);
- Chronic N deposition in forests causes a syndrome called "N saturation hypothesis" a condition resulting in the long-term removal of N limitations on biotic activity accompanied by a decrease in the capacity for N retention (Aber 1989);
- Biological studies demonstrate that some aquatic and terrestrial plant and microbial communities significantly altered by N deposition.
- Atmospheric deposition of N is greatest near large metropolitan areas often witnessed by impaired visibility (Fenn 2003a);
- Chronic N deposition in the west is implicated in increased fire frequency and habitat alterations in some areas.

Nitrogen is quickly becoming recognized as a major environmental pollutant, an artifact of modern society. Though a relatively minor issue in the coastal forests of Mendocino, N deposition is occurring. N plays a huge role in the ammonification of soils and along with the decay of leaf litter is an important factor in sustaining microbial biomass.

SYNOPSIS

Although pilot and experimental biomass harvests have been conducted across North America (Arnosti et al., 2008; Evans and Finkral, 2009), knowledge of how biodiversity responds to forest thinning is incomplete. Although the Southeastern U.S. is the leading timber-producing region of the United States (Prestemon and Abt, 2002), and thinning is a common silvicultural practice in all regions, most research on effects of thinning on wildlife species has been conducted in the Northwest. Reviews of forest thinning effects to date have been regional or local in geographic scope and primarily qualitative in their assessment (Hayes et al., 1997; Harrison, 1999; Muir et al., 2002; Thompson et al., 2003). However, detailed information about biodiversity response to forest thinning has recently been assessed quantitatively for the Southwestern United States (Kalies et al., 2010).

Most current research offers a snapshot assessment of the effect of forest thinning on species diversity and abundance. Effects of forest thinning operations on measures of diversity are often highly dependent on time since harvest, as many harvests will have a negative short-term effect on both species abundance and diversity (Wilson and Puettmann, 2007).

Though harvesting live trees for biofuels production as part of a sustainable forest management program disturbs ecological processes to some extent, such disturbances do not negatively affect biological diversity in most cases (Janowiak and Webster, 2010). Figure 2 provides a graphic representation of how % of retained habitat elements can optimize biodiversity quality over time. This captures the essence of what the ecological literature is collectively attempting to address through the retention of both structural and compositional elements at the harvest site.

It is important to recognize that some species of higher conservation concern may be either positively or negatively affected by thinning and that simple diversity and richness measures may not be sufficient for fully understanding the effects of thinning on biodiversity.

Disturbance intensity and biophysical setting are likely to be strong determinants of response by wildlife and vegetation to biomass thinning harvests (Greenberg et al., 2007a, b). Thinning designed to promote species diversity will likely need locally tailored prescriptions of intensity and pattern (Hagar et al., 2004).

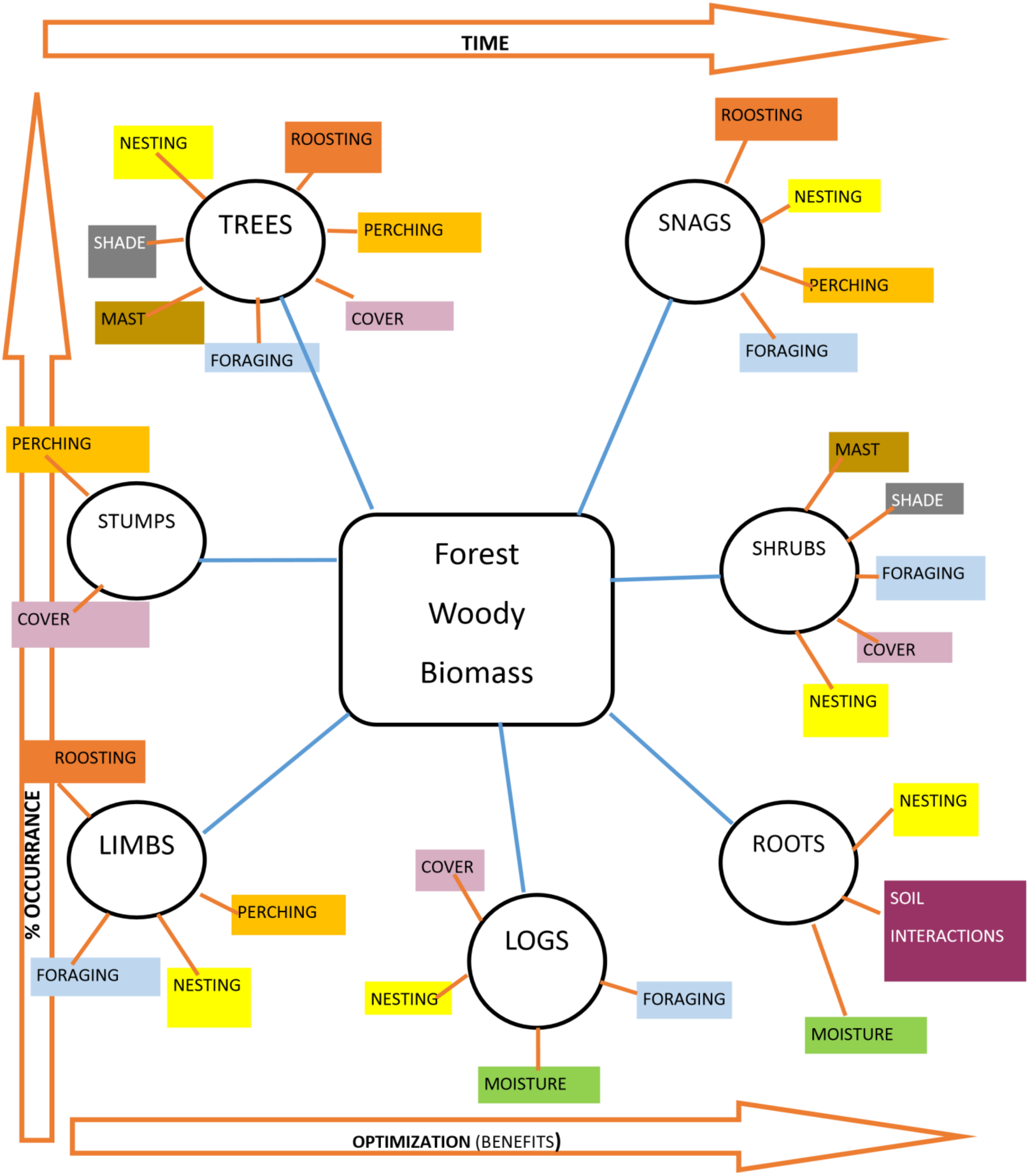

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Fig. 2. Simplified schematic of forest woody biomass components and their ecological function(s) showing optimization of habitat quality as a function of both % occurrence of elements and time for both vertebrates and invertebrates. Colors identify over-lapping functions among the different elements.

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