III. Effects of Riparian Thinning on Marbled Murrelets and Northern Spotted Owls

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Background

Despite having different missions and mandates, the agencies share the common goal of improving ecosystem function. To that end, the ICS requests the SRT's consideration and thoughts regarding the following topics related to overall ecosystem function.

- Identify data critical in evaluating tradeoffs between short term and long term positive or negative effects of various riparian thinning treatments on fish and riparian/ stream ecosystems.
- Characterize the relationship between "no-cut" stream buffer width and management goals to accelerate recovery of forest structural conditions beneficial to federally listed terrestrial species.

Ecosystem Function

This section on ecosystem function has at least two facets to consider: (1) the effects of thinning on other (non-salmonid) threatened and endangered species (the northern spotted owl and marbled murrelet), and (2) effects on the overall system structure and composition relative to late-successional forests and related ecological goals. In the sections below we address these two areas with the knowledge that "ecosystem function" has many meanings to different people depending on their background and experience. The nature of the above questions and answers in this document do not allow for a complete coverage of all of the facets of ecosystem function. Consequently, the sections below focus on the status and habitat associations of terrestrial threatened and endangered species (i.e., northern spotted owls, marbled murrelets) which are important in the ecosystem. We also provide information on what is known about the effects of forest thinning on marbled murrelets and northern spotted owls.

Marbled Murrelet

The marbled murrelet was listed federally as a threatened and endangered species by the U.S. Department of Interior, Fish and Wildlife Service, in 1992 in the states of Washington, Oregon, and California. The species is also listed as threatened or endangered at the state (Washington, Oregon, California) and provincial level (British Columbia). The main reasons for the listings were loss of terrestrial habitat for nesting and declining populations in the marine environment. The species along with northern spotted owls and the numerous salmon stocks has been the focus of much controversy over the management and conservation of late-successional forests in the

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Pacific Northwest. The geographic range of marbled murrelets spans the nearshore marine environment from central California, Oregon, Washington, British Columbia (Canada), southeast Alaska and the Aleutian Islands, Alaska. The species is like most seabirds in that it spends most of its time in the marine environment foraging on small fish, resting, and preening. However, it is a solitary nester and flies up to 80km (50mi) inland to nest in old conifer forests. This unique behavior of nesting in conifer forests is where many of the conservation challenges arise for the species in the terrestrial environment (McShane et al. 2004).

Like most seabirds, marbled murrelets are a K-selected species. They have a low reproductive rate, with 1 egg produced per year and limited renesting attempts after nesting failures. They do not mature until they are 2-5 years old, and adult survival rates range from 80-95% per year. Effective conservation of marbled murrelets requires the ability to detect adverse changes in demography as quickly as possible, determination of the cause(s) of these changes, and early implementation of effective conservation actions. Their life history characteristics of using both the marine and terrestrial environments make conservation measures doubly challenging (McShane et al. 2004).

Terrestrial habitat for nesting is the important feature of their life history, and it includes older-aged forests, primarily mature and old-growth conifer stands within 80 km of the Pacific Ocean (McShane et al. 2004). However, they also use younger (>60 years) forests for nesting that have mistletoe, other deformities, or squirrel nests for nesting platforms (Nelson and Wilson 2001). Their nesting attempts are often unsuccessful due to forest fragmentation and the associated increase in abundance of their primary predators (jays, crows, and ravens). Eggs are laid on large lateral limbs, generally with large quantities of moss. They do not build nests but merely scratch out depressions in the moss in which to lay their egg. Consequently, large lateral limbs with large quantities of epiphytic moss seem to be the features that provide the characteristics that they need for nesting. Their nests also tend to have much overhead cover, and they have a high fidelity to nest stands and nest sites from one year to the next. They will nest in younger trees that have deformities or squirrel nests that act as nesting platforms but this is an exception to their general behavioral patterns. Most murrelet nests have been found in low elevation wet coniferous forests, apparently because of the greater abundance of moss and platforms in those areas. Although murrelets will nest throughout watersheds, fewer nests are found on ridgetops or areas with high wind, because platforms and moss cover are less abundant there (McShane et al. 2004). Murrelets are known to build nests near natural edges, such as those found along streams, wetlands, canopy gaps, forest clearings and avalanche chutes (McShane et al. 2004). However, proximity to forest edges also increases predation risk, and there are conflicting data as to whether proximity to forest edges increases or decreases nesting success (McShane et al. 2004). The main threats to marbled murrelets and their terrestrial habitat are the loss and fragmentation of habitat and predation of their nests by corvids (i.e., jay, crows, and ravens). Of the nesting attempts that fail, predation is responsible for >78% of the failures. In addition, predation rates appear to be higher in smaller more fragmented forests than in larger less fragmented stands of conifers. Threats to the species in the marine environment include oil spills, lack of prey, and entanglement in gill-nets (McShane et al. 2004). The effects of fishing by humans on prey species of murrelets are not well understood.

Currently, marbled murrelets are managed under the Northwest Forest Plan for the conservation of late-successional forests. There are also state plans and Habitat Conservation Plans for the species in California and Washington but none in Oregon, which is an important deficiency. A recent 5-year review of the species' status by the U.S. Fish & Wildlife Service (McShane et al. 2004) concluded that (1) significant improvements are needed in the amount and distribution of nesting habitat, (2) ongoing logging on state and private lands in suitable and occupied murrelet habitat is threatening nesting habitat, (3) ongoing thinning on all lands with no consideration for the effects on stand microclimate or increases in predators is a potential problem, and (4) no state conservation plan or Forest Practice Rules exist for Oregon. Populations are declining between 4-7% per year (McShane et al. 2004), so maintaining all suitable habitat and creating new habitat will be important to their long-term survival. In addition, regulation in Oregon will be mandatory for survival of the species in that state.

There are data on stand densities and other features from nest sites that have been used for nesting by murrelets but they are based on a very small sample of nests (McShane et al. 2004, Grenier and Nelson 1995), so little can be concluded about preferences or selection of these sites. They will nest in all conifer tree species, and one nest was found in a red alder. They generally nest in the middle of the live crown of a tree, so they prefer areas in the tree that provide lots of overhead cover. Most nests have >80% cover above the nest branch (McShane et al. 2004). They nest in all areas throughout a watershed but most nests are found at lower elevations often near natural forest edges, such as those found along streams. Edges may provide murrelets easier access to their nests (McShane et al. 2004:87-88), but may also increase predation risk. Also, murrelets frequently use lower elevation wet forests that provide an abundance of epiphytes as wetter areas generally have more suitable platforms based on a higher abundance of moss (Nelson et al. 2003). Very few nests are on ridgetops because they are drier (and thus less moss) and more prone to windthrow, so there are fewer nesting platforms. Most nesting sites in coastal Oregon occur < 3,400 feet.

Effects of thinning on marbled murrelet nesting habitat

Thinning of young (< 80 years old) forests is thought to accelerate the development of marbled murrelet nesting habitat because widely spaced trees extend their limbs after thinning to fill in the newly formed canopy gaps, and the limbs presumably increase in diameter as well. Thus, over the long term, thinning may increase the rate of development and density of large diameter limbs in overstory trees that are of a size ideal for marbled murrelet nesting (e.g. see Table 4.3.2 in McShane et al. 2004). However, this is an untested prediction that needs additional study, and managers also must consider the potential short-term negative effects of thinning young forests compared to the long-term potential positive effects. The negative effects of thinning appear to be the creation of forest stand characteristics (i.e., increase in forest fragmentation, shrub abundance and canopy gaps) that favor higher abundances of species (jays, crows, ravens) that prey on murrelet nests. Exact relationships between canopy gaps or understory biomass and predator abundance is not well known, so this is an area that needs further study, so all the potential effects of thinning on nesting success of marbled murrelets can be considered. Marbled murrelets nests that are near un-natural forest edges (e.g. roads and forest harvest boundaries) may be less successful than those found in forest interiors, so thinning operations designed to improve marbled murrelet nesting sites will likely be less detrimental if located >50 m from occupied or historical nesting areas (e.g. see section 4.5.6.2 in McShane et al. 2004). Because of sustained low recruitment and severe population declines of murrelet populations, thinning near occupied sites should proceed with caution until results from studies on the potential negative effects are known.

There are a number of stand characteristics consistently associated with murrelet nesting sites (Table 1). These characteristics include tall and large diameter trees, numerous nesting platforms, vertical canopy heterogeneity (e.g. canopy dominants rising above the average tree height) and canopy gaps. Basic physiological responses of conifers to increased sunlight resulting from the removal of nearby trees suggests that thinning should accelerate the development of some of these characteristics, but exact silvicultural approaches for attaining this structure have yet to be determined. In addition, there is no experimental evidence to suggest that the overall structure of thinned stands will result in higher levels of murrelet nests, nesting success, or that thinning will even increase the number of potential nesting platforms relative to unthinned stands. As such, thinning operations designed to accelerate the development of murrelet nesting habitat relative to natural processes should be considered experimental and monitored accordingly.

Guidelines from the USFWS

The USFWS does not have any specific guidelines for management of habitat for marbled murrelets (B. Tuerier, pers. comm.). The recovery plan for the murrelet states that habitat for the species is expected to be provided in the riparian reserves as specified under the Northwest Forest Plan. Consequently, management of areas proposed for thinning would be under the guidelines of the Northwest Forest Plan, and specific recommendations, if any, may be found in the recovery plan for the species (B. Tuerier, pers. commun.).

Northern Spotted Owl

The northern spotted owl was listed as a Threatened species by the U.S. Department of Interior in 1990 after two decades of debate and court proceedings over the issue. The main reasons for the listing were loss of habitat and the lack of regulatory mechanisms to protect their critical habitat. Since that time the subspecies has become the icon for management and conservation of late-successional forests throughout its geographic range in Washington, Oregon, northern California, and British Columbia. Because of its importance in this issue, it is one of the most researched and well-known owl species in the world. It has been the subject of many long-term demographic studies (Forsman et al. 1996, Anthony et al. 2006, Forsman et al. 2011). There have also been many studies on their habitat associations, home range attributes, behavior, diet and population genetics, all of which have provided valuable information about habitat needs and population stability. The subspecies preys upon medium to small-sized mammals throughout most of its geographic range. Northern flying squirrels and woodrats comprise the bulk of the diet in most localities (see below). The subspecies is long-lived, with an average life span of 8-9 years and longevity up to 23 years in the wild. Spotted owls have high survival rates as breeding adults and typically produce 1-2 young when they nest, which is about once every two years (Forsman et al. 2011). Consequently, they are a K-selected species with high site and mate fidelity. They are also highly territorial around their nesting areas and occupy these areas all year.

Northern spotted owls are associated with mature and old-growth forests throughout most of their geographic range (Thomas et al. 1990). Through radiotelemetry studies of their movement patterns it has been determined that they have very large home ranges which often overlap the home ranges of their neighbors (Forsman et al. 1984). A review of several but not all telemetry studies indicates that the subspecies selects or uses mature and old growth forests for foraging and roosting where such forests are available (Table 1). These same studies also indicated that northern spotted owls avoid young or medium aged forests in most parts of their geographic range (Table 1). Exceptions to this generality exist in northern California where the subspecies often occurs in relatively young mixed-species forests of Douglas-fir, redwood, California bay, and tanoak that have high densities of woodrats (Diller And Thome 1999). The subspecies also derives demographic fitness from its association with late-successional forests. For example, Bart and Forsman (1992) noted that spotted owls that occupied home ranges that had >40% old forest produced more young than owls that occupied home ranges with < 40% old forest. In addition, three studies that examined relationships between survival and habitat characteristics of home ranges found that survival rates of breeding adults were positively related to the amount of older forests around their core nesting areas (Dugger et al. 2005; Fig. 1) or the amount of old forests within their home ranges (Franklin et al. 2000, Olson et al. 2004: Figs. 2-3). Consequently, demographic performance and fitness of northern spotted owls are dependent on the amount of older forests around their nesting centers or within their home range. In addition, the dynamics of spotted owl populations are most sensitive to changes in adult survival rates (Noon and Biles 1990), so recent declines in survival rates have caused much concern for the status of their populations (Forsman et al. 2011).

Northern spotted owls are also associated with riparian areas, which is relevant to thinning of young forests in these areas (McDonald et al. 2006, Glenn et al. 2004). The association with riparian areas has been determined with the use of radiotelemetry studies of their movements and habitat use, which have shown that owls use riparian areas more than their proportional availability across the landscape. There have been at least three hypotheses proposed for the disproportionate use of riparian areas: (1) riparian areas provide more favorable thermoregulatory conditions (Barrows 1981); (2) prey species are more abundant in riparian areas (Carey et al. 1992 1999); and (3) fire severity has been lower in riparian areas resulting in the retention of structural complexity (Reeves et al. 2006). There is some support for all three of these hypotheses so they all likely have some influence over the use of riparian areas by northern spotted owls.

Northern spotted owls are obligate predators on medium- to small-sized mammals throughout their geographic range, and northern flying squirrels comprise the majority of the diet in most areas (Table 2). Woodrats and red tree voles are more prominent in the diet in the southern portion of the owl's range, whereas deer mice and red-backed voles are more common in the diet in the northern part of their range. These species of mammals have been studied in some detail, so there is a fair amount of information on their habitat associations and diets. Most importantly, several of the mammal species in the spotted owl's diet consume large amounts of hypogeous fungi (Maser et al. 1978), so fungi form the basis of an important food chain in coniferous forests. Hypogeous fungi form a symbiotic relationship with the roots of conifers whereby they provide a number of micronutrients to the trees that are otherwise unavailable. The food chain from fungi to small mammals to spotted owls (and many other predators) is, therefore, an important functional relationship in coniferous forests. Unfortunately, we know very little about the effect of thinning of young or old forests on this food chain and northern spotted owls. However, we do know that thinning of mature forests in the northern Coast Range of Oregon had a significant effect on species composition and biomass of hypogeous fungi (Gomez et al. 2003), hypogeous fungi and small mammals are associated with coarse woody debris (Gomez et al. 2003, McComb 2003), the abundance and survival of flying squirrels is associated with biomass of hypogeous fungi (Gomez et al. 2005, Lemkuhl et al. 2004), and thinning of a mature forest resulted in an expansion of the nonbreeding home range and a shift in the cores use areas of a male spotted owl (Meimann et al. 2003). The results of these studies suggest that this food chain is intricately tied to dead wood and hypogeous fungi in older coniferous forests. In addition, two recent studies have found that thinning in young forests virtually eliminated flying squirrels in the short term (Wilson 2010, Manning et al. 2012). Taken together, the above studies suggest that thinning in young forests has a short-term negative effect on spotted owls, but the long-term effects of thinning in young forests on spotted owls and their prey are unclear. This is an area where there needs to be a focus on monitoring and research on the effects of thinning on spotted owls and their prey.

Effects of thinning on forest structure important to spotted owls

The effects of thinning forests on habitat use of spotted owls have not been thoroughly studied, and the results of studies have not been in agreement in all cases. Historically, many of the forest management practices (i.e., clearcuts, shelterwood cuts, heavy commercial thinning) used in the Pacific Northwest have had negative effects on spotted owls (Forsman et al. 1984, Zabel et al. 1995, Buchanan et al. 1995, Hicks et al. 1999, Meimann et al. 2003). In most of these studies, the data collected on thinning were incidental to other research objectives, or there were only a few owls potentially affected by the harvest operations. Among the studies that reported spotted owl responses to thinning or other timber harvest activities, four studies (Forsman et al. 1984, King 1993, Hicks et al. 1999, Meiman et al. 2003) found spotted owls were displaced by harvest near the nest or activity center. Forsman et al. (1984) suggested that negative effects (decreased reproduction, site abandonment) of thinning or selective harvest were most likely associated with higher-intensity thinning, timber harvest close to the nesting areas, and the nest site had low amounts of suitable habitat. Similarly, Meimann et al. (2003) reported that a male spotted owl expanded his home range and shifted foraging and roosting away from a recently thinned forest, which was located close to the nest tree. They recommended that harvest operations not be conducted near nest sites. Given the small number of studies and small number of owls involved in the above studies, firm conclusions about the effects of thinning on habitat use by spotted owls are elusive, so this is an area where more monitoring and research needed.

Several studies have indicated that forest thinning can temporarily (e.g., up to 20 years) reduce the availability of hypogeous fungi, which are key foods for northern flying squirrels and other small mammals on which spotted owls depend (Waters et al. 1994, Colgan et al. 1999, Luoma et al. 2003, Gomez et al. 2003, Meyer et al. 2005). In addition, Carey (2000) found lower abundances of flying squirrels in recently-thinned (within 10 years) stands in western

Washington than in stands that were clear-cut 50 years ago. Wilson (2010) also reported that most thinning is likely to suppress populations of flying squirrels for several decades, but the long-term effects of variable density thinning on squirrels have not been studies and are unknown.

Effects of commercial thinning on spotted owl prey

Another important consideration is the effect of vegetation management on spotted owl prey species, particularly northern flying squirrels, dusky-footed woodrats, bushy-tailed woodrats, and other small mammals. Most birds of prey are limited by or influenced greatly by abundance of their prey species (Newton 1979), so this is an important consideration. There is actually a lot of published information on the effects of commercial thinning on spotted owl prey, particularly northern flying squirrels, red-backed voles, woodrats, and red tree voles. The published literature indicates that commercial thinning has negative effects on abundance of flying squirrels (Carey 2000; Manning et al. 2012; Wilson 2010; Gomez et al. 2005; Waters and Zabel et al. 1994, Waters et al. 2000) within the range of the spotted owl, and these effects may last up to 15 years or longer (Wilson 2010). Other studies in northeastern Oregon (Bull et al. 2004), southern British Columbia (Herbers et al. 2007, Ransome et al. 2004), coastal British Columbia (Ransome and Sullivan 2002), Ontario (Holloway and Malcolm 2006), and the Sierra Nevada Mountains of California (Meyer et al. 2007, Waters and Zabel 1995) have shown similar negative effects of commercial thinning on abundance of northern flying squirrels, so these negative effects on northern flying squirrels have been documented for other forest types in other U.S. states and Canadian provinces. Based on these publications, it is safe to say that commercial thinning within the range of the northern spotted owl will have a negative effect on abundance of northern flying squirrels. Northern flying squirrels are the owl's primary prey by number and biomass throughout most of their range; consequently, there is little doubt that commercial thinning will have a negative effect on abundance of flying squirrels as prey for spotted owls. In addition, commercial thinning has negative effects on the abundance of red-backed voles (Suzuki and Hayes 2003, Manning unpublished data), which is also an important prey species for the owl. There has not been as much research on the effects of commercial thinning on red tree voles because this species is extremely difficult to study because of its arboreal activity patterns. However, this species lives in the forest canopy and feeds exclusively on needles of Douglas-fir, so thinning activities will most likely have negative effects on this prey species (Forsman, person. comm.). Forests where red tree voles have been studied (Swingle and Forsman 2009) and later thinned do not support tree vole populations (E. Forsman, person comm.). Mixed results have also been reported in studies that examined effects of thinning on woodrats.

The long-term benefits of thinning in young plantations to create forests with characteristics of late-successional forests (e.g. large diameter standing and down wood) may outweigh any short-term negative effects on owls or their prey. However, as the age of forests selected for thinning increases, the short-term negative effects of such activities will likely increase and the benefits decrease. The Northwest Forest Plan specified a maximum age of 80 years for forests that are slated for thinning. The reasons for this guideline were that (1) it was unclear if thinning could actually accelerate the rate at which naturally regenerated mature forests developed old forest conditions, and (2) spotted owls forage in mature forests, and thinning of these forests will likely reduce their quality as spotted owl habitat both in the short and long term. If these young forests are not currently good foraging habitat, they are gradually developing late-successional characteristics that will provide foraging habitat in the near future. Consequently, thinning in riparian forests >80 years old or any younger forests where thinning is not likely to accelerate the development of late-successional forest structure is not recommended.

Guidelines from the USFWS

The USFWS does not have any specific guidelines for managing habitat for northern spotted owls in Riparian Reserves as designated under the Northwest Forest Plan (B. White, pers. comm.). However, there is some limited guidance on thinning in the Late-Successional Reserves in the Recovery Plan for the species (U.S. Fish and Wildlife Service 2011). Under Recovery Action 6, the Plan states: "In moist forests managed for spotted owl habitat, land managers should implement silvicultural techniques in plantations, overstocked stands, and modified younger stands to accelerate the development of structural complexity and biological diversity that will benefit spotted owl recovery". However, this prediction is speculation, and it needs to be tested with a good system of monitoring and research. Land managers should implement treatments in the Late-Successional Reserves per the Standards and Guides of the Northwest Forest Plan.

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Table 1. (A) Habitat characteristics of 10 occupied marbled murrelet nests in the Oregon Coast Range and (B) Habitat characteristics of 30 occupied marbled murrelet nests in the Siuslaw National Forest (from Grenier and Nelson 1995).

Table 1A. Stand characteristics of 10 murrelet nest sites in the Oregon Coast Range

Characteristic	mean	se	Range
TPH > 10 cm dbh	349.8	24.1	208.8-565.2
TPH > 46 cm dbh	131.9	15	10.2-269.9
TPH > 81 cm dbh	55.7	6.8	15.3-127.3
dbh > 10 cm	43.8	0.9	10-206
dbh > 46 cm	80.6	1.3	46-206
dbh > 81 cm	109.3	1.7	81-206
snag dbh (cm)	57.8	2.7	10.5-187
total snags per hectare	54	9.3	5.1-142.6
Distance to stream (m)	310	98.3	0-1000

Table 1B. Stand characteristics of 30 murrelet nest sites in the Siuslaw National Forest, Oregon

Characteristic	mean	se	Range
TPH total	253	nd	nd
TPH total, dominants	107.3	nd	nd
TPH total co-dominants	53.4	nd	nd
TPH total mid-story	92.3	nd	nd
TPH DF > 81 cm dbh	27.9	2.82	3-57
dbh all trees	60.8	nd	nd
dbh, dominants	89.7	nd	nd
dbh, co-dominants	59.2	nd	nd
dbh, mid-story	33.4	nd	nd
Canopy closure (%)	63.7	3.2	16-83
Canopy ht (m)	55.4	1.53	37-69

Table 2. Selection or avoidance of different forest types, as reported in seven different radiotelemetry studies of habitat use by northern spotted owls showing their association with mature and old-growth forests and avoidance of young forests.

	Forest Type[1]				
Data source	Non-forest	Sapling-Pole	Young	Mature	Old-growth
Forsman et al. (1984)	-	-	-/ns	-/ns/+	+
Carey et al. (1990)	-	-	-/ns	ns	+
Carey et al. (1992)	-	-	-/ns	ns/+	+
Zabel et al. 1995	-	-/ns	-/ns	ns	ns
Forsman et al. (2005)	-	-	-/ns	ns/+	+
Hamer et al. (2007)	-/ns	-/ns	-/ns	-/ns/+	ns/+
Glenn et al. (2004)	-	-	-	+	NA

[1]Meaning of symbols: "-" indicates that the forest type was avoided (i.e. used less than its proportional availability in the home range area). "NS" indicates that analyses were not statistically significant, and a "+" indicates that the forest type was selected (i.e. used more than its proportional availability in the home range area). "NA" indicates that the forest type was not available in the study area.

Table 3. Percent of different prey species in the diet of northern spotted owls in Oregon, subdivided by geographic region, 1970-2001 (adapted from Forsman et al. 2001). All values are percent of prey numbers in regurgitated pellets as opposed to percent of prey biomass.

	Coast Ranges				Interior SW		Cascade Mtns		
Species	North	Cent.	South				North	Cent.	East
Lagomorph	0.8	3.6	4.6		2.6		0.0	4.7	4.3
Flying Sqrl	48.4	49.5	36.0		28.2		52.1	34.7	41.1
Gophers	2.6	0.6	0.1		5.4		0.0	4.8	5.1
Deer Mouse	17.3	10.5	6.2		4.9		0.0	6.4	4.0
Woodrat	11.8	7.1	18.2		27.8		2.3	9.6	5.1
R-B Vole	0.0	2.2	2.8		6.8		26.9	10.7	12.0
Tree Vole	4.9	12.7	18.2		2.6		0.0	8.1	0.0
Misc Mammals	9.1	7.7	7.9		11.7		4.8	13.7	9.0
Other	5.2	6.1	6.0		10.1		13.9	7.4	19.5
Totals	100	100	100		100		100	100	100

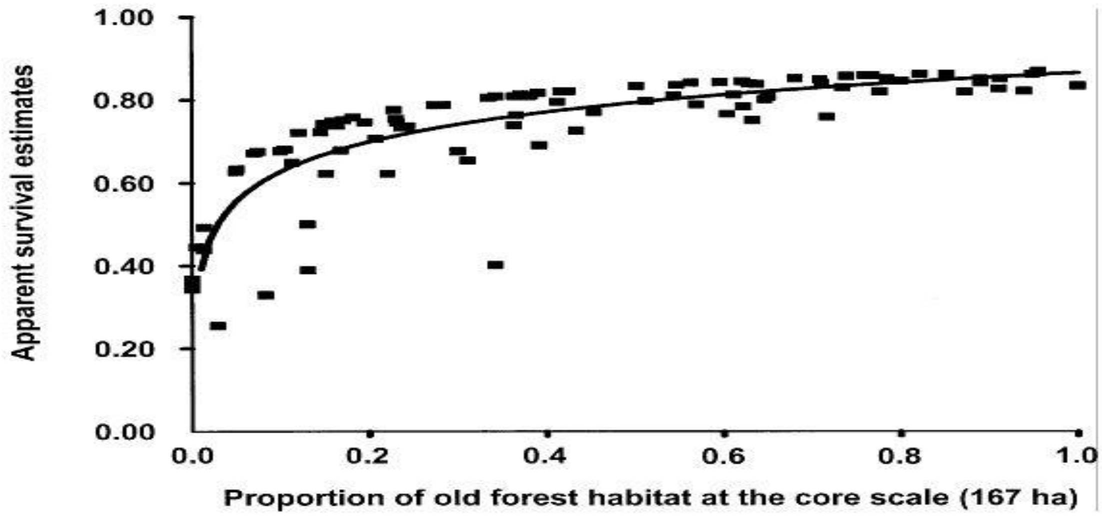

FIGURE 3. Estimates of apparent survival from the best model including the pseudothreshold structure of old forest habitat at the core scale (pt_cOFall) and the mean-centered quadratic form of nonhabitat (q_rNONall) at the ring plotted against the proportion of old forest habitat available at the core scale. Survival estimates were generated for each Northern Spotted Owl territory used in the survival analysis (n = 97) for southern Oregon (1990–1995).

Figure 1. Relationship between survival rates or northern spotted owls and the amount of old forest habitat around their core nesting areas in southern Oregon, 1990-1995 (Dugger et al. 2005).

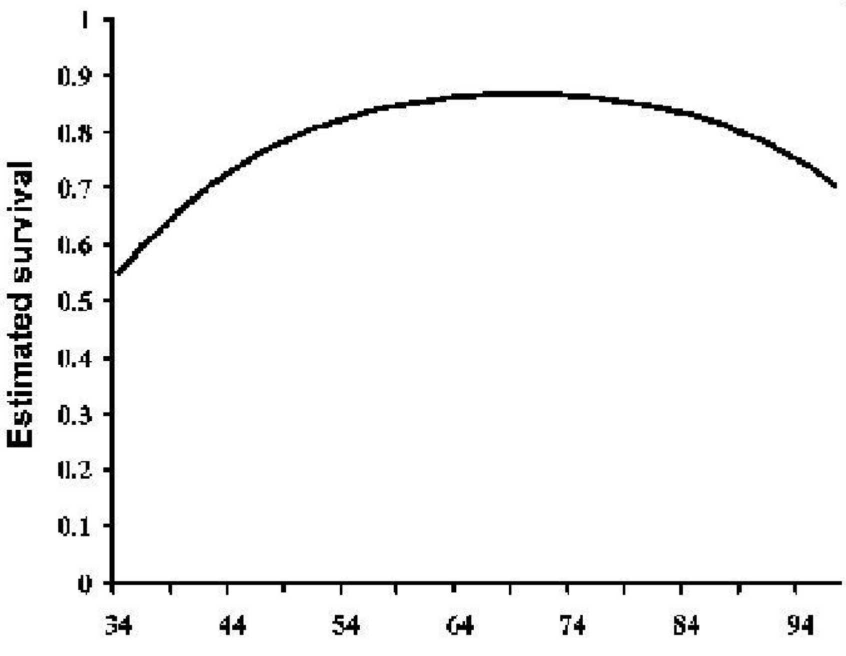

Fig. 2. Estimated survival for northern spotted owls on the Roseburg study area, Oregon, USA, 1988–1999, from the landscape pattern model with percentage of old and mid-seral conifer within a 1,500-m circle centered on owl activity centers.

Figure 2. Relationship between survival rates of northern spotted owls and the percentage of old and mid-seral conifer forests in their activity centers in western Oregon, 1988-1999 (Olson et al. 2004).

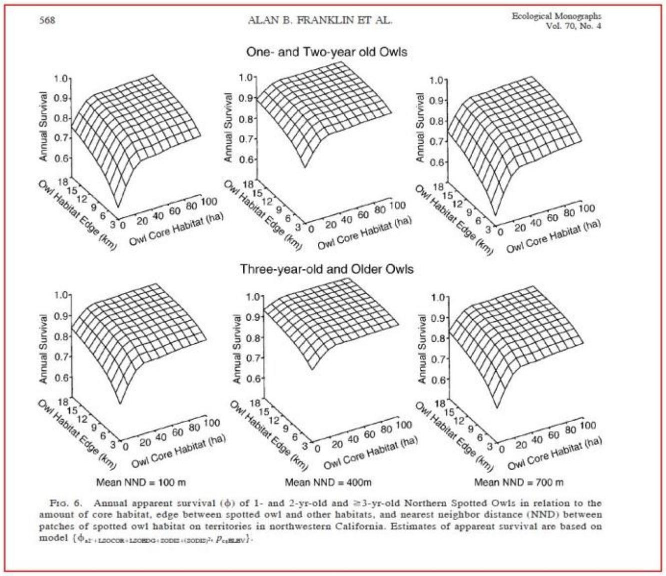

Figure 3. The relationships between survival rates of breeding spotted owls and the amount of habitat in their core nesting areas in northern California from Franklin et al. (2000).