Results

Chris Adlam

Results

Fig.2: Canopy cover in each severity category

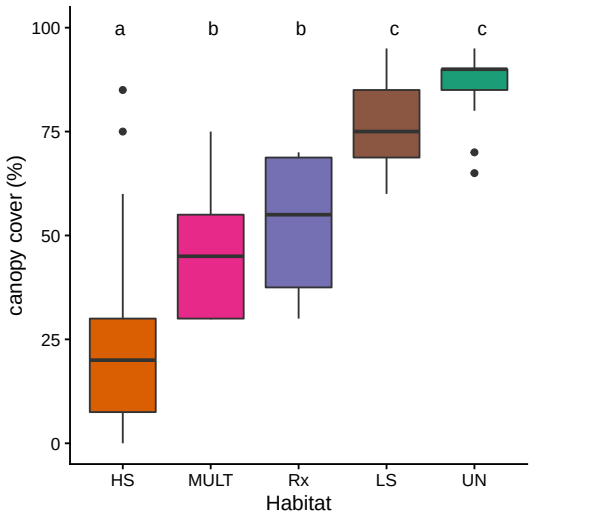


Table 1: Pairwise PERMANOVA results

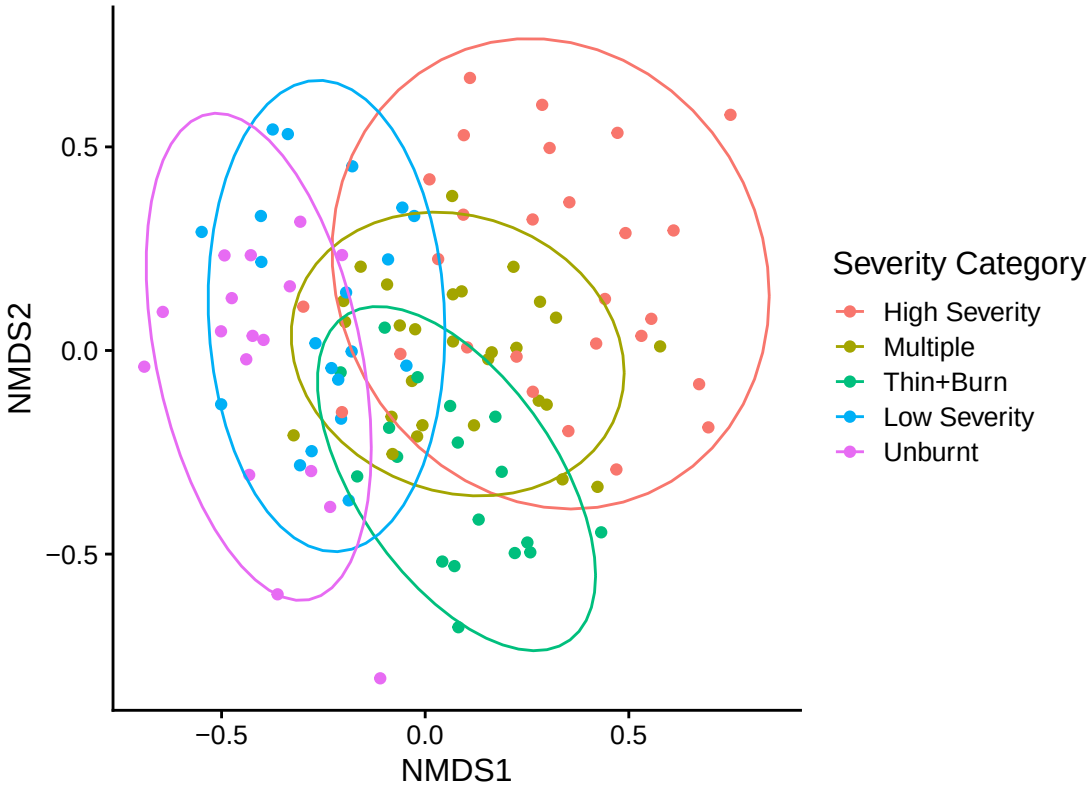
	plants		birds		lichens	
Pair	F_model	p_adj	F_model	p_adj	F_model	p_adj
HS vs LS	7.321	0.01	6.45	0.01	16.3	0.01
HS vs MULT	3.200	0.01	1.72	0.82	25.1	0.01
HS vs Rx	7.432	0.01	8.11	0.01	18.1	0.01
HS vs UN	9.946	0.01	12.06	0.01	16.5	0.01
LS vs MULT	5.986	0.01	4.52	0.01	3.4	0.02
LS vs Rx	6.849	0.01	6.53	0.01	6.6	0.01
LS vs UN	1.996	0.17	2.68	0.16	1.0	1.00
MULT vs Rx	4.152	0.01	5.90	0.01	6.4	0.01
MULT vs UN	6.984	0.01	8.79	0.01	3.7	0.01
UN vs RX	5.680	0.01	8.73	0.01	7.5	0.02

Variation in community composition across habitats

Effect of fire history on species composition

The main PERMANOVA revealed that species composition varies for all taxa in response to the severity category ($p < 0.001$). Using pairwise PERMANOVAs to compare the habitats, there is no detectable difference between plant, bird or lichen communities of low severity and unburnt stands (Table 1) (plants: pseudo-$F_{(1,35)} = 2$ and $p = 0.17$; birds: pseudo-$F_{(1,35)} = 2.68$ and $p = 0.16$; lichens: pseudo-$F_{(1,35)} = 1.0$ and $p = 1.00$). In addition, bird communities of high severity burns and multiple burns are not detectably different (pseudo-$F_{(1,53)} = 1.72$ and $p = 0.82$). For lichens, the only habitat that stands out is the HS habitat ($p < 0.02$), although it is not statistically different from the MULT habitat ($p = 1$).

Figure 3: NMDS for all species. Ellipses represent 90% CI.



Species assemblage ordination

The NMDS confirms a considerable overlap in species communities of long-unburnt and low severity burn stands. High severity stands have distinct species communities, while the communities in thinned and burnt stands and multiple burn stands appear to be intermediate between the high severity stands and long-unburnt/low severity stands. Figure 3 shows the first two dimensions of a 3-dimensional ordination that found convergent solutions with a stress of 0.176.

Alpha, Beta, Gamma diversity patterns

Alpha diversity

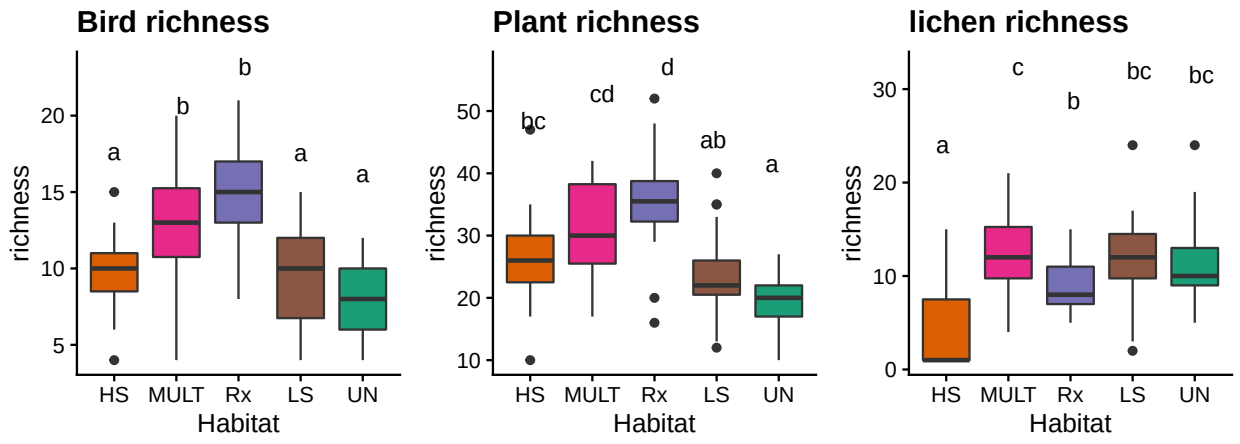


Fig.4: Bird, plant and lichen species richness

Bird and plant species richness were highest in the multiple burns and thinned and burnt stands (for plants the difference between high severity burns and multiple burns was not significant) (Figure 4). Bird and plant richness in low severity burns and unburnt plots was slightly lower than in high severity burns, but the difference was overall not significant. Lichens were predictably less diverse in the high severity stands, but richness in the other severity categories was similar.

Within the multiple burns and thinned and burnt stands, canopy cover was negatively correlated with plant richness ($F_{(1,44)} = 8.99$, $p = 0.004$) and bird richness ($F_{(1,44)} = 8.99$, $p = 0.004$). In the low severity and long-unburnt stands, canopy cover was negatively correlated with bird richness ($F_{(1,35)} = 10.482$, $p = 0.003$), but only weakly correlated with plant richness ($F_{(1,35)} = 3.133$, $p = 0.085$). In the high severity stands, canopy cover was not correlated with either plant or bird richness ($F_{(1,25)} = 2.538$, $p = 0.124$ and $F_{(1,25)} = 1.806$, $p = 0.191$ respectively).

Beta Diversity

Beta diversity was highest in the high severity burns and multiple burns for birds and plants, and lowest for the thinned and burnt stands, possibly because they were spatially clustered rather than because of an effect of treatment (figure 5). For lichens, high severity burns had the highest beta diversity, likely not because of a high level of species turnover between sites, but rather because of the variation in species richness between plots with no surviving trees and those that had surviving trees, and therefore lichens.

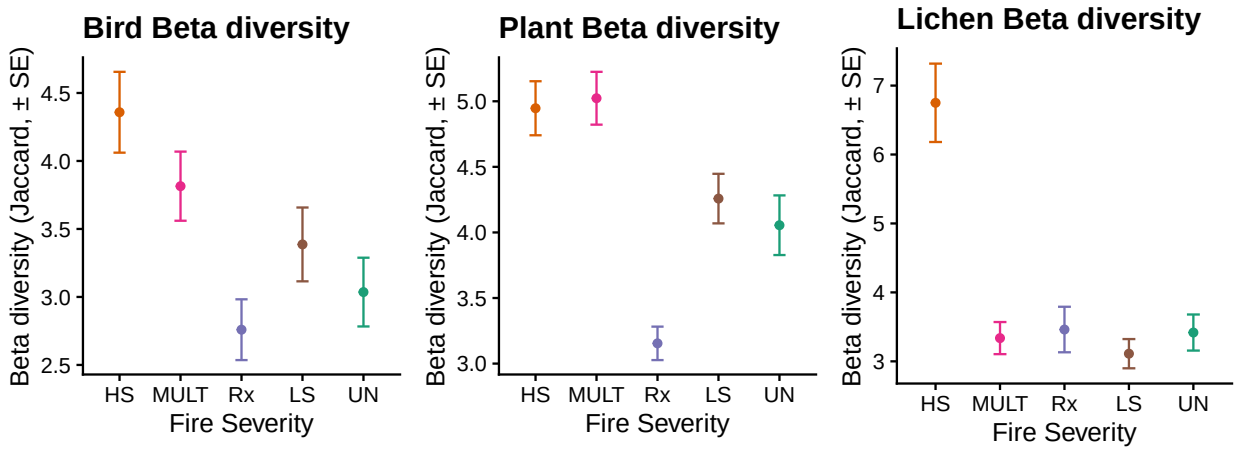


Fig.5: Bird, plant and lichen beta diversity (Jaccard)

Gamma diversity

Based on the extrapolated species richness, the total pool of species for birds appears to be largest in the multiple burns and thinned and burnt stands, intermediate in the high severity burns, and lowest in the low severity and long-unburnt stands (Fig. 5). For plants, the pattern is the same except that species pool from the thinned and burnt stands appears smaller than the high severity burns, and more similar to the low severity stands instead. High severity fire eliminates lichens and most of their substrate [@millerAlteredFireRegimes2018], and their species pool is smaller in the high severity stands than in the other severity categories, which are similar.

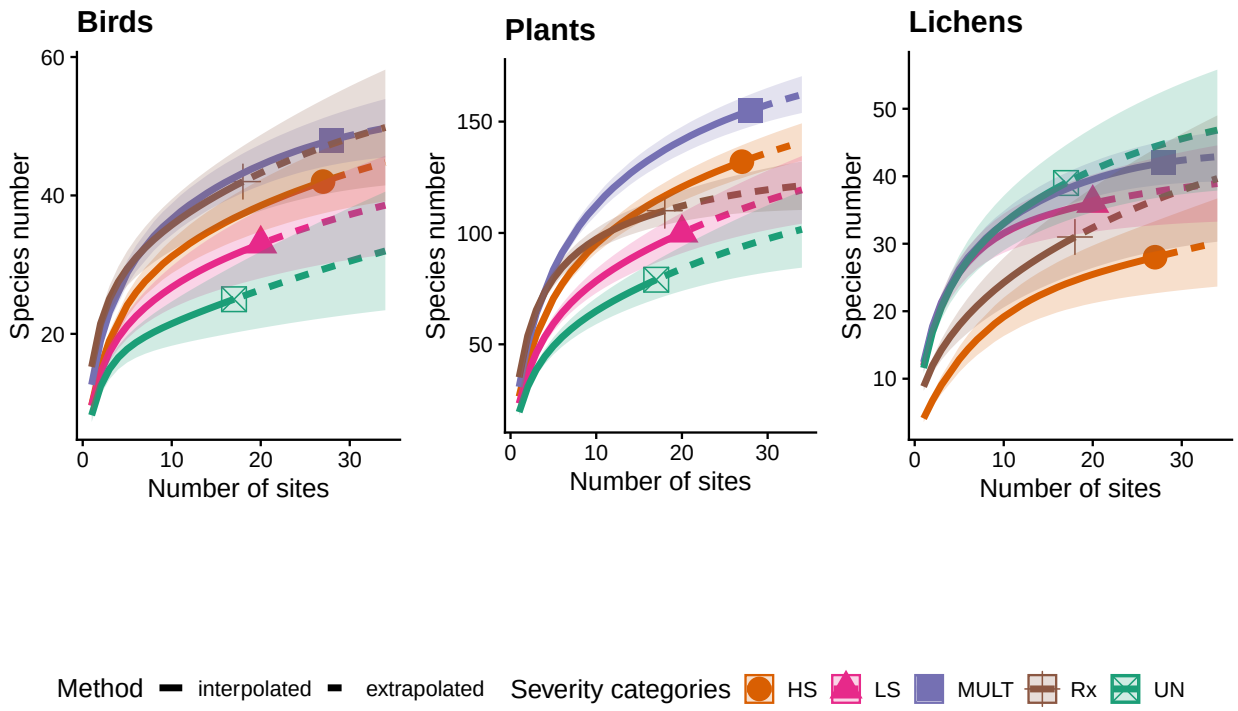


Figure 6: Gamma diversity, extrapolated based on species richness.
Shaded area represents 95% confidence intervals.

Insect Indicator Species Analysis

Six insect taxa (order or suborder) were indicators of the high severity habitats (table 2). These were mainly pollinators (Aculeata (bees/stinging wasps), Brachyceran flies, Coleoptera) and herbivores (Homoptera, Heteroptera, Orthoptera), which probably reflects the higher abundance of flowers and broadleaf shrubs/trees in high severity burns.

```
## Warning: NAs introduced by coercion
```

```
## Joining, by = "species"
## Joining, by = "species"
```

Table 2: Table 2: Insect indicators of early seral habitat

	IndVal	P-value
Homoptera	0.91	0.004
Coleoptera	0.87	0.001
Aculeata	0.86	0.005
Brachycera	0.82	0.019
Orthoptera	0.67	0.046
Heteroptera	0.64	0.012

```
## Warning: NAs introduced by coercion

## Joining, by = "species"
## Joining, by = "species"
```

Table 3: Indicator species for high severity burns and low severity/unburnt stands. Species highlighted in gray also favored multiple burns and/or thinned and burnt stands. Species in bold have a highly significant *p*-value (<0.01).

Species	IndVal	*p*-value	Species	IndVal	*p*-value
Plants			**Birds**		
Indicators of high severity burns					
Ceanothus integerrimus	**82**	**0.001**	**Spotted Towhee**	**79**	**0.001**
***Madia* spp.**	**73**	**0.001**	**Lazuli Bunting**	**69**	**0.001**
Ribes spp.	65	0.01	Nashville Warbler	62	0.012
Melica harfordii	62	0.046	**Western Wood-Pewee**	**61**	**0.001**
Elymus glaucus	**61**	**0.003**	Northern Flicker	57	0.01
Festuca microstachys	**59**	**0.001**	**MacGillivray's Warbler**	**54**	**0.008**
Rubus leucodermis	59	0.02	**Wrentit**	**54**	**0.001**
Asyneuma prenanthoides	**58**	**0.001**	House Wren	48	0.011
Solanum parishii	**56**	**0.002**	Hummingbird sp.	48	0.01
Rubus ursinus	54	0.012	Acorn Woodpecker	44	0.085
Collomia heterophylla	53	0.06	Purple Finch	44	0.082
Rubus parviflorus	51	0.08	Lesser Goldfinch	38	0.021
Agoseris spp.	48	0.012	Bewick's Wren	33	0.076
Calystegia occidentalis	48	0.011	Bushtit	33	0.067
Chamerion angustifolium	**48**	**0.005**			
Silene spp.	45	0.034			
Arctostaphylos spp.	44	0.081			
Quercus garryana	44	0.078			
Bromus carinatus	43	0.01			
Daucus pusillus	**43**	**0.005**			
Eriophyllum lanatum	**43**	**0.007**			
Achillea millefollium	40	0.072			
Dichelostemma spp.	38	0.026			
Hossackia crassicaulis	38	0.032			
Fragaria vesca	33	0.075			
Sambucus nigra	33	0.067			
Indicators of low severity/unburnt stands					
Pseudotsuga menziesii	**74**	**0.008**	Black-throated Gray/ Hermit Warbler	68	0.031
Anisocarpus madioides	**65**	**0.005**	Cassin's Vireo	66	0.033
Iris spp.	63	0.039	**Red-breasted Nuthatch**	**63**	**0.001**
Adenocaulon bicolor	**59**	**0.004**	**Chestnut-backed Chickadee**	**61**	**0.006**
Pinus lambertiana	57	0.036	**Hutton's Vireo**	**61**	**0.008**
***Pyrola* spp.**	**56**	**0.009**	**Brown Creeper**	**59**	**0.009**
Osmorrhiza berteroi	52	0.043	Hermit Thrush	40	0.025
Chimaphila umbellata	**49**	**0.004**			
Viola lobata	49	0.015			
Abies concolor	43	0.074			
Goodyera oblongifolia	43	0.04			

Early and late seral species in actively and passively managed stands

The indicator analysis for birds and plants of high severity and low severity/unburnt stands suggests distinct communities in each habitat (Table 2). Plants preferring such stands were predictably shade-tolerant species (e.g. *Goodyera oblongifolia*, *Pyrola spp.*, *Adenocaulon bicolor*, *Anisocarpus madioides*), whereas these stands were favored by bark-gleaning (Red-breasted Nuthatch and Brown Creeper) and canopy-dwelling birds (Chestnut-backed Chickadee, Black-throated Gray/Hermit Warbler, Cassin's Vireo). In contrast, species that preferred early seral conditions created by high severity fire included shrubs (e.g. *Ceanothus integerrimus*, *Rubus spp.*, *Arctostaphylos spp.*, *Solanum parishii*), grasses (e.g. *Melica harfordii*, *Elymus glaucus*, *Bromus carinatus*), annual forbs (e.g. *Madia spp.*, *Collomia heterophylla*, *Cryptantha spp.*, *Epilobium spp.*) and perennial forbs (e.g. *Asyneuma prenanthoides*, *Eriophyllum lanatum*, *Dichelostemma spp.*, *Chamerion angustifolium*, *Hossackia crassicaulis*). Birds that favored these stands tended to be species associated with shrubs and deciduous tree cover (e.g. Spotted Towhee, Wrentit, Nashville Warbler, MacGillivray's Warbler, Anna's/Rufous Hummingbirds, Black-headed Grosbeak), open habitat species (Lesser Goldfinch, Lazuli Bunting), and cavity nesters (Acorn Woodpeckers, House Wren, Northern Flicker).

```
## List of 2
##  $ plot.background:List of 5
##   ..$ fill         : chr "white"
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ linetype     : NULL
##   ..$ inherit.blank: logi FALSE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
##  $ plot.margin    : 'unit' num [1:4] 5pt 15pt 25pt 35pt
##   ..- attr(*, "valid.unit")= int 8
##   ..- attr(*, "unit")= chr "pt"
##  - attr(*, "class")= chr [1:2] "theme" "gg"
##  - attr(*, "complete")= logi FALSE
##  - attr(*, "validate")= logi TRUE
```

```
## List of 2
##  $ plot.background:List of 5
##   ..$ fill         : chr "white"
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ linetype     : NULL
##   ..$ inherit.blank: logi FALSE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
##  $ plot.margin    : 'unit' num [1:4] 5pt 15pt 25pt 35pt
##   ..- attr(*, "valid.unit")= int 8
##   ..- attr(*, "unit")= chr "pt"
##  - attr(*, "class")= chr [1:2] "theme" "gg"
##  - attr(*, "complete")= logi FALSE
##  - attr(*, "validate")= logi TRUE
```

I identified 61 species (birds, plants and lichens combined) that seemed to favor high severity burns (species found twice as frequently in that habitat compared to low severity and unburnt stands), and 45 species that favored low severity and unburnt stands (species found twice as frequently in that habitat compared to high severity burns). Additionally, most species that have a preference for either of these habitats exhibited the same affinity for multiple burns and thinned and burnt sites: 34 species (76%) preferring low severity and unburnt stands also favor multiple burns, while 31 (69%) also favor thinned and burnt sites. Conversely, 49 species (80%) that prefer high severity burns also favor multiple burns, and 41 (67%) also favor thinned and

burnt sites. Figure 7 displays graphically the proportion of plants and birds that prefer high severity burns or unburnt and low severity stands that also favor multiple burns and thin+burn sites.

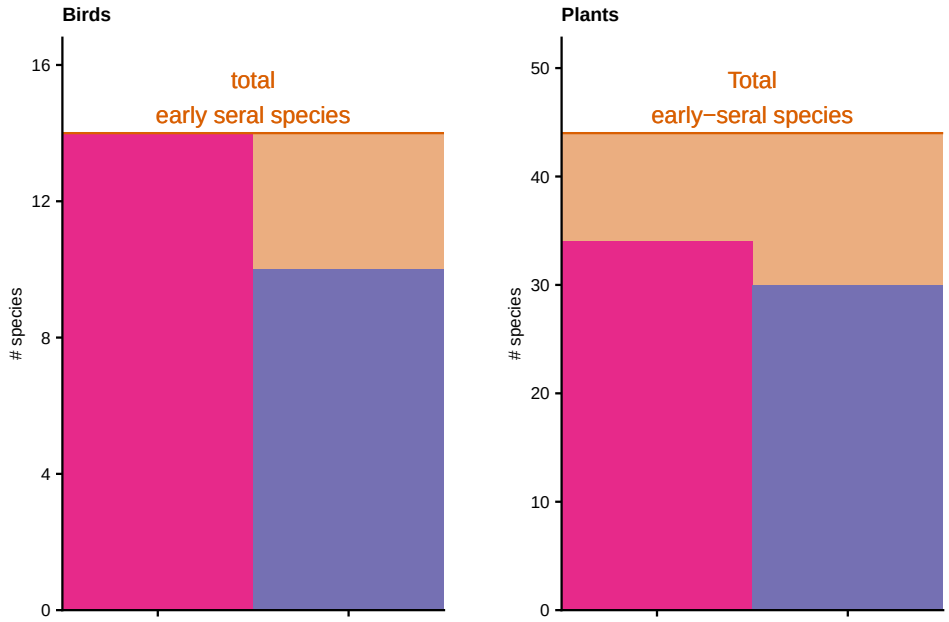


Fig. 7a: Most early −seral species favor multiple burns and thin+burn stands

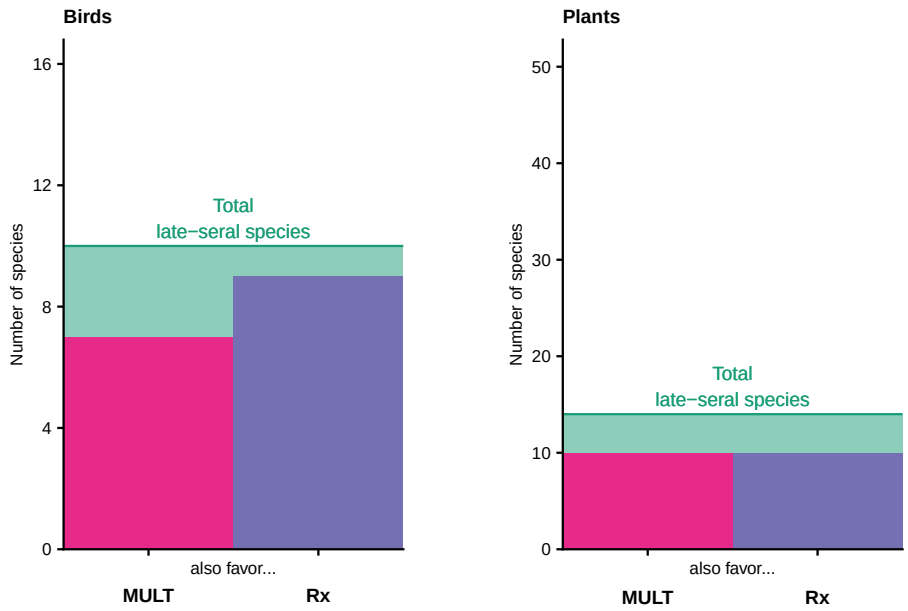


Fig. 7b: Most late−seral species favor multiple burns and thin+burn stands