Response of Canada Lynx and Snowshoe Hares to Spruce-Beetle Tree Mortality and Wildfire in Spruce-fir Forests of Southern Colorado

Progress Report - 2016

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Purpose of Document

In this document, we first provide a brief annual report to meet reporting requirements for existing university agreements. Second, we conducted preliminary analyses of vegetation data collected within lynx home ranges (beginning page 9). These preliminary understandings were requested by the Rio Grande National Forest to inform forest management until final results are available later this year (2017).

Background Information

In March 2013, the Rio Grande National Forest (RGNF) contacted the Rocky Mountain Research Station (RMRS) Science Application & Integration Staff to ask for assistance in answering some key science questions related to an ongoing spruce-beetle outbreak on the forest. RMRS and RGNF staff worked together to define some of the key issues and questions, which fell into four broad categories of concern: vegetation, fuels, watershed, and wildlife. The group convened in November 2013, with representatives from the RO, RMRS, and all three districts of the RGNF.

The focus of the visit involved the rapid ecological changes occurring in the high-elevation spruce-fir zone on the RGNF due to an outbreak of the spruce bark beetle. The outbreak has influenced approximately 480,000 acres of spruce-fir on the Forest, and continues to spread at a rate of about 100,000 acres annually. The West Fork Fire Complex of 2013 added another ecological perspective to the landscape by burning approximately 110,000 acres of spruce-fir/aspen mix on the San Juan and Rio Grande National Forests. Initially starting on the west (San Juan NF) side of the Continental Divide, the fires involved about 88,000 acres on the RGNF. Much of the burn occurred in spruce-fir cover types that had significant rates of tree mortality due to the spruce beetle. The West Fork Complex offers an additional ecological research opportunity as well as discussion topics on disturbance regimes and bark beetles, future forests, and influences on other resource values such as wildlife habitat.

Issue

The Rio Grande National Forest (RGNF) includes some of the most important lynx habitat in Colorado. Approximately 85% of the 218 lynx reintroduced to Colorado from 1999-2007 were released on the RGNF. Although lynx have established home ranges in other parts of the state, most lynx remain and reproduce in the high-elevation spruce-fir zone of southwestern Colorado, including the RGNF. Lynx depend on spruce-fir forests with dense understories across their distribution. However, by 2013, a spruce beetle outbreak killed approximately 85% of mature spruce in the subalpine cover types on the RGNF. There is a strong desire by the US Forest Service and industry to salvage beetle-killed trees across broad landscapes in southern Colorado. However, the consequence of timber salvage to lynx or even what constitutes suitable lynx habitat in beetle-impacted forests is unknown. Biologists are therefore in the untenable position of being required to evaluate the impact of timber salvage to lynx without a scientific basis to support their decisions. ESA requires that agencies consider the impact of timber salvage to lynx as federally listed species.

Key Management Questions

1. How do spruce-beetle outbreaks affect the suitability of lynx habitat within the core use area of southern Colorado?
2. What forest structures and compositions are used by lynx in landscapes heavily influenced by spruce-beetle outbreaks?
3. How does forest structure and composition of insect impacted forests affect the relative density of snowshoe hares?
4. What areas and types of forest structure in the post-beetle landscape on the Rio Grande National Forest are most conducive to landscape restoration activities, including timber salvage, while minimizing potential impacts to lynx and snowshoe hare populations?

The Rocky Mountain Research Station, in cooperation with the RGNF, Region 2- USFS, Colorado Parks and Wildlife (CPW), and Montana State University initiated an administrative study in 2014 that investigates resource selection and movements of lynx that occupy spruce-beetle impacted forests. The purpose of the study is to address the key management questions associated with the maintenance of suitable habitat for lynx and primary prey species in relationship to spruce-bark beetle related forest disturbance, and to an expected increase in post-beetle forest management activities, such as timber salvage. We are studying what types of forest structure constitute the best habitat available for snowshoe hare and lynx in a post-spruce beetle epidemic landscape. Study objectives include: **1)** determine if Canada lynx exhibit seasonal changes in resource use of insect-impacted spruce-fir forests in the San Juan Mountains, CO; **2)** Map suitable lynx habitat in spruce-beetle impacted forests relative to proposed timber salvage; and **3)** determine how the relative abundance of snowshoe hares, the primary prey of lynx, is affected by spruce-beetle outbreaks in terms of forest structure.

Preliminary Results

Lynx Capture and Handling.

In 2015-2017, we instrumented lynx with GPS collars to plot their movements and resource-use patterns in beetle-impacted forests. In 2015 through 2017, we captured and/or handled a total of 19 lynx (6 adult females, 6 adult males, 7 kittens) in Colorado (Table 1); the 1 month-old kittens were handled at den sites. Of these animals, we instrumented and monitored the movements and resource-use patterns of 11 lynx (6 males, 5 Females) with GPS collars on the Rio Grande National Forest (Table 2). There were no injuries to any lynx as the result of trapping and/or handling. Of the 5 instrumented females, 2 denned in 2015 and produced 2 kittens each, and 1 female denned in 2016 and produced 2 kittens; denning of the 2017 female is not yet known. Preliminary results indicated that lynx continued to occupy home ranges in spruce-beetle impacted forests (Figure 1 and 2). In 2015 and 2016, we sampled vegetation at winter and summer GPS and random locations to determine the forest structure and composition that lynx selected within beetle impacted forests (Table 3). The majority of this progress report is the preliminary assessment of these field data.

Table 1. Total lynx captured and/or handled on the Rio Grande National Forest, Colorado from 2015-2017.

LynxID	Nickname	Gender	Estimated Age	ShoulderPIT
CO15F01	Ivy Female	Female	4 years	985120028461524
CO15M01	Ivy Male	Male	3	985120028460313
BC04F04	Love Lake Female	Female	12	985120021530398
CO15M02	Love Lake Male	Male	2	985121012392677
CO15F02	Love Lake Female 2	Female	2	985120028455351
CO15K01	Ivy Kitten 1	Unknown	1 month	not tagged
CO15K02	Ivy Kitten 2	Unknown	1 month	not tagged
CO15K03	Red Mountain Kitten 1	Unknown	1 month	985121009939252
CO15K04	Red Mountain Kitten 2	Unknown	1 month	985121009933845
CO16M01	Rio Grande Male	Male	5	985120028453055
CO04F15	Finger Mesa Female	Female	12	985120017855833
CO16K01	Thirty Mile Kitten	Unknown	9 month	
CO16F01	Squaw Creek Female	Female	6	985120028460384
	Squaw Creek Kitten1	Unknown	1 month	985121009786377
	Squaw Creek Kitten 2	Unknown	1 month	985121009801537
CO16M02	Hunter's Lake Male	Male	6	985121012575153
CO17AM01	Wager Gulch Male	Male	6	985120027224555
CO17AF01	Conejos Peak Female	Female	3	985120028456346
CO17AM02	Conejos Peak Male	Male	4	985120028179240

Table 2. Captured lynx instrumented with GPS collars on the Rio Grande National Forests in southern Colorado

Lynx	**LynxID**	**StartDate**	**EndDate**	**# Pts**
Rio Grande Male	CO16M01	1/24/2016	8/9/2016	3178
Finger Mesa Female	CO04F15	2/16/2016	8/10/2016	2466
Squaw Creek Female	CO16F01	2/19/2016	8/10/2016	2246
Hunter's Lake Male	CO16M02	3/1/2016	8/9/2016	2408
Love Lake Female	BC04F04	2/18/2015	8/1/2015	2219
Love Lake Male	CO15M02	2/20/2015	8/1/2015	2159
Ivy Female	CO15F01	2/13/2015	7/13/2015	2021
Ivy Male	CO15M01	2/17/2015	8/1/2015	2313
Conejos Peak Male	CO17AM02	2/23/2017		
Conejos Peak Female	CO17AF01	4/11/2017		
Wager Gulch Male	CO17AM01	1/28/2017		

Table 3. Number of used and random locations for each lynx sampled in the field during 2015 and 2016. Total sample currently is 413 locations.

Lynx	Summer (Used/Random)	Winter (Used/Random)
F01	25/22	24/22
F03	11/17	18/17
F05	13/15	8/9
F07	5/10	8/5
M02	23/16	24/14
M04	8/14	16/13
M06	NA	13/11
M08	NA	19/13

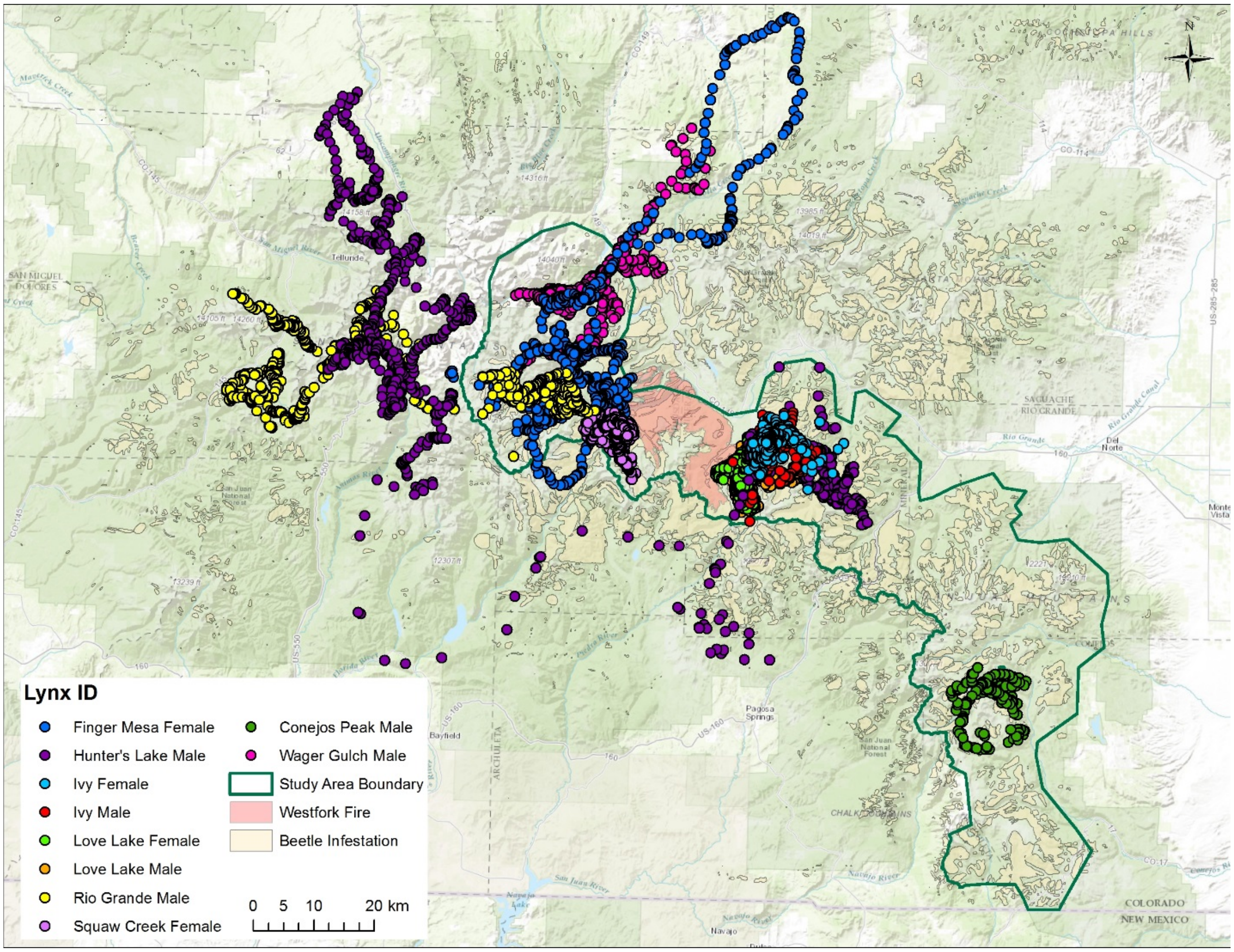


Figure 1. Lynx use of spruce-beetle impacted forests as documented with GPS telemetry for 10 different individuals, 2015-2017.

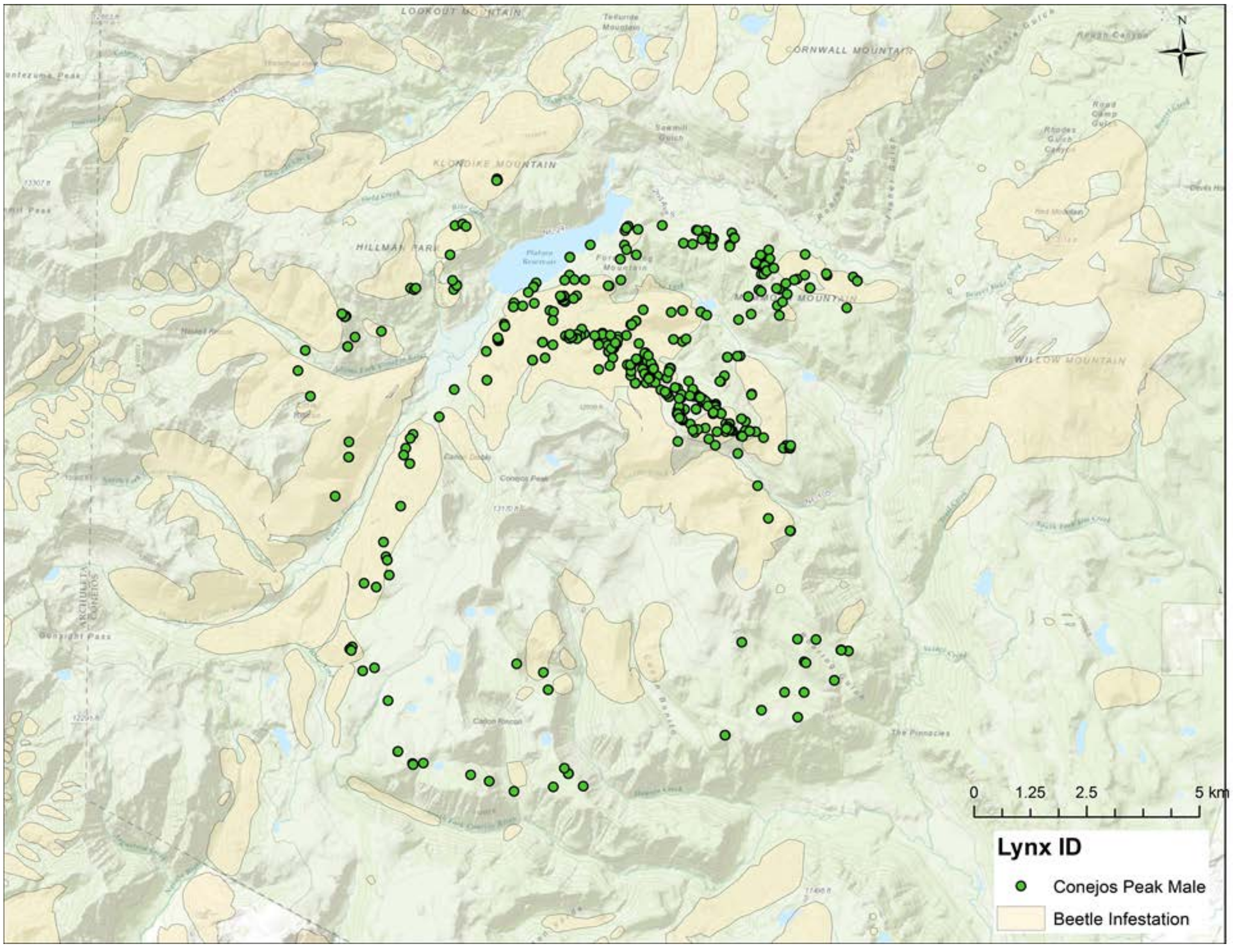


Figure 2. Conejos Peak Male using beetle-killed forests adjacent to Platoro Reservoir.

Forest Mapping

Forest mapping is a central aspect to the study given the need for accurate spatial layers of spruce-beetle kill for lynx resource-use modeling. A detailed account of mapping results are provide in the attached report by Savage et al. (2016) entitled "Lynx Habitat Use in Post-Beetle, Post-Fire Landscapes in the Rio Grande National Forest in southwestern Colorado." To identify forest types in southwestern Colorado that are favored by Canada lynx (*Lynx canadensis*), we (1) successfully utilized current Landsat satellite imagery and zero-inflated classification models to map forest types within a 303,587 ha study area covering portions of the Divide and Conejos Peak ranger districts of the Rio Grande National Forest and (2) successfully mapped sub-canopy species counts within the same study area. The results demonstrated that our new zero-inflated models are able to map percent canopy cover and sub-canopy counts with fairly high accuracy (pseudo medians ranged from -1.08% to 2.47% and 95% confidence interval widths ranged from 3.27% to 13.11%; RMSEs ranged from 9.51% to 16.98% for percent canopy cover maps; mean differences ranged from -0.88 to 0.12 and 95% confidence interval widths ranged from 1.11 to 6.48; RMSE's ranged from 2.99 to 16.89 for the sub-canopy count maps). A total of 11 predicted maps were created for the project – all with 30-m pixels: 4 PCC-by-species maps, 1 percent mortality map, 1 percent total sub-canopy cover map, 4 species count maps, and 1 total sub-canopy count map.

Schedule

Date	Activity
October 2014 – March, 2015	Trap and fit lynx with GPS collars in known areas of activity in or adjacent to insect impacted forests. In addition, conduct snow-track based surveys for lynx to locate additional activity areas in or adjacent to insect-impacted forests
June – September 2015	Conduct pellet-based surveys for hares in insect-impacted forests. Technicians will also sample vegetation plots used to "train" a map of forest structure and composition from remote sensing of insect-impact zones
October 2015 – March, 2016	Trap and fit lynx with GPS collars in known areas of activity in or adjacent to insect impacted forests. During this period, the SSC at MSU will develop a map (GIS data layer) of forest structure and composition of insect-impacted forests on the RGNF.
July 2016 – September 2016	Sample forest structure and composition at lynx-use and random locations for each collared lynx.
December 2016 – March 2017	Trap and instrument additional lynx in spruce-beetle impacted forests to improve sample size.
June – September 2017	Sample forest structure and composition at lynx-use and random locations for each collared lynx.
October – December 2017	Develop statistical models and spatial use surfaces of lynx and snowshoe hares in spruce-beetle impacted forests.

Research Activities – 2017-2018

We will search for dens in June 2017 to document kitten productivity for any collared females; kittens are marked on-site with a pit tags by Colorado Parks and Wildlife and immediately returned to the den. From June – August 2017, we will sample the structure and composition of forest vegetation present at lynx and random locations within home ranges. These data are needed to build resource selection models for lynx and snowshoe hares using spruce beetle-impacted forests. This information is needed to inform forest management such as tree harvest and timber salvage on the Rio Grande National Forest with direct application and relevance to national forests across western Colorado.

Habitat Use and Selection by Canada Lynx in Beetle-killed Forests within Southern Colorado: A Preliminary Assessment on Forest Structure and Composition

Summary

In this summary, we provide a general overview of preliminary analyses of vegetation data collected at used and available locations within Canada lynx home ranges. We will continue sampling this summer (2017) to augment these preliminary data. Therefore, we stress that these data should be viewed as "preliminary" and some understandings may change when we evaluate the complete dataset in September, 2017. That said, these preliminary understandings represent our best attempt to understand how lynx use beetle-impacted forests at the stand-level. In the final analysis, we will complement these stand-level understandings with landscape-level resource-use evaluations based on remotely-sensed environmental data. Both stand- and landscape-level evaluations are needed to fully understand the intersection of lynx habitat conservation and timber salvage.

For these preliminary analyses, we evaluated habitat use and selection for 8 different lynx (4 males and 4 females) using 413 field plots collected during 2015 and 2016 (Table 3). It is important to note that we expect to nearly double this sample during the 2017 summer field season. We examined differences in mean values of metrics between used GPS locations in home ranges to locations randomly available (both winter and summer) for each lynx. Winter was defined as January-April and summer as May-July. We recorded many different metrics at each plot, but this assessment focused on 1) horizontal cover, 2) pellet density of snowshoe hares, 3) stem density of understory, 4) canopy cover, and 5) tree density of larger-sized trees (i.e., ≥3 inches DBH). We used the Forest Vegetation Simulator to calculate stem density metrics. Below we have provided a brief synopsis of what we learned from each metric. We did not provide tables of specific values because, as aforementioned, we will be sampling many more plots over the 2017 field season, which will likely change the values. Instead, we provide many figures to capture our preliminary insights regarding the forest attributes that lynx select disproportionate to their availability.

Horizontal Cover

Horizontal cover was measured in 4 cardinal directions at a distance of 10 m from plot center at used and available locations.

Across both summer and winter nearly all lynx exhibited selection (i.e., use is greater than availability) for horizontal cover (Figure 3). However, this is not a static relationship. The differences between use and availability increases as available decreases; in other words, selection for horizontal cover becomes stronger as availability of horizontal cover decreases (Figure 4). Finally, lynx tended to use areas with ≥50% horizontal cover in the summer and ≥40% in the winter.

Snowshoe Hare Pellet Density

Pellet density of snowshoe hares was recorded at 5 subplots (1 m^2) evenly spaced along a north-south transect at used and available locations.

Similar to horizontal cover, nearly all lynx exhibited selection (i.e., use is greater than availability) for areas with higher snowshoe hare pellet densities (Figure 5), and selection remained relatively constant across changing availabilities (Figure 6). In the winter, when environmental conditions are most limiting, all lynx demonstrated selection for areas with higher snowshoe hare pellet densities relative to random expectation.

Stem Density of Understory Saplings

We hypothesized that forest understory was critical to lynx. Understory stem density was sampled across a 73 ft x 3.28 ft belt transect in a north-south orientation at used and available locations. All **LIVE** trees that comprised forest understory (i.e., generally between 4 – 10 ft tall) were included in the assessment. We documented subalpine fir (ABLA), bristlecone pine (PIAR), Engelmann spruce (PIEN), blue spruce (PIPU), Douglas fir (PSME), and quaking aspen (POTR) in the understory, however, ABLA, POTR, PIEN, and PIPU captured 98% of the trees we sampled. Thus, we focused on these species.

In summer, all lynx exhibited selection for higher total stem densities in the understory, however, during winter we observed an even split of avoidance (use less than availability) and selection (use greater than availability; Figure 7). We observed substantial individual variation across lynx for species-specific relationships with understory stem densities (Figures 8-11). However, across both summer and winter, nearly all lynx exhibited selection for higher stem densities of ABLA (Figure 8), which suggests that ABLA is an important understory species. This is particularly true when the availability of ABLA understory was low.

Canopy Cover at the Top Layer

We sampled forest canopy cover at the top layer across 25 points arranged in 66 ft x 66 ft grids centered at used and available locations. Similar to the understory aforementioned, we focused on the dominate species: ABLA, PIEN, PIPU, and POTR. We examined live canopy cover for all species, and calculated dead canopy cover for PIEN. We also combined live and dead canopy cover for a total overall examination of canopy cover.

In winter, most lynx exhibited selection for higher live-tree canopy cover, but in summer selection was more variable (Figure 12). When combining live and dead canopy cover, nearly all lynx exhibited selection for higher canopy cover during winter (Figure 13). The most consistent species-specific relationships we observed was selection for **LIVE** ABLA and PIEN canopy cover (Figures 14 and 16), despite the absolute values of canopy cover being low (e.g., ABLA = 1-10%, PIEN = 1-3%). In addition, 6 out of 8 lynx exhibited selection for **DEAD** PIEN canopy cover during winter (Figure 18). All other relationships were quite variable (see Figures 14-18).

Tree Density of Large (≥3 inch DBH) Trees

Tree density was sampled across a 1/10 acre plot at used and available locations. Similar to the understory metrics, we focused on the dominate species: ABLA, PIEN, PIPU, and POTR. We examined tree density of live and dead trees as well as snags. In addition, we evaluated selection for tree density by size class using cut points of 3-4.9 inches (small), 5-8.9 inches (medium), 9-15.9 inches (large), and ≥16 inches (very large) DBH; we examined this for both live and dead trees. These size-class breaks were consistent with those used by foresters on the Rio Grande National Forest. Finally, we assessed live tree density by species and dead tree density for PIEN.

Lynx consistently selected forest stands with higher than random densities of **DEAD** trees (Figures 19-21), however, selection for **LIVE** tree density increased as availability of **LIVE** trees decreased (Figure 19). In other words, the selection that lynx exhibited for live trees increased as these trees became rarer in their home ranges. Density of snags was generally avoided by lynx (Figure 21). Lynx most consistently selected higher densities of large **LIVE** trees in the winter relative to small, medium, and very large trees (Figures 23-26). Similarly, tree density of medium, large, and very large **DEAD** trees were the most consistently selected by lynx, particularly as they become rarer on the landscape (Figures 27-30). Finally, lynx exhibited selection for **LIVE** ABLA and **DEAD** PIEN tree densities (Figures 31 and 35), however, when availability was low lynx exhibited selection for high **LIVE** PIEN tree densities as well (Figures 33). All other relationships were quite variable across individual lynx (see Figures 31-35).

Preliminary Take-Home Messages

1) Lynx actively selected forest stands with high horizontal cover and high snowshoe hares density.
2) Lynx selected forest stands with abundant ABLA in the understory. Total understory was less important largely because the very high density of POTR in home ranges during the winter tended to “swamp” the analysis of conifers. This could be due to heterogeneity of sampling across individual lynx, so the final analyses might indicate a more refined understanding.
3) Canopy cover (live + dead) is higher in stands selected by lynx relative to random; generally >40% in the winter. Live ABLA and PIEN as well as beetle-killed PIEN appear to be important components of lynx resource selection at the stand level.
4) Lynx selected forest stands with high tree (i.e., ≥3 inches DBH) densities; generally >400 trees/acre; this selection included both live tree density and dead tree density.
5) Abundant large live trees, and medium, large, and very large dead trees appear to be important forest components selected by lynx.

6) Live ABLA and PIEN tree (i.e., ≥3 inches DBH) densities as well as beetle-killed PIEN tree densities appear to be the species-specific components selected for by lynx.
7) Collectively, the forest metrics selected by lynx based on these preliminary analyses suggest they depend on stands in beetle-impacted forests that are also valuable for timber salvage. Therefore, an important strategy for facilitating timber salvage and lynx conservation will require careful consideration to the spatial configuration of harvest within designated lynx habitat as will be defined through landscape-level evaluations based on remote sensing. However, we stress that our analyses are preliminary and we will be completing more detailed results in the near future. Additionally, after data collection is complete (i.e., August 2017), we will working to develop spatial maps highlighting high and low probabilities of use by lynx, which should be highly valuable to inform mitigation strategies and to spatially prioritize salvage.

Figures

Horizontal cover and snowshoe hares

Figure 3. Mean horizontal cover at used and available locations for each lynx by season.

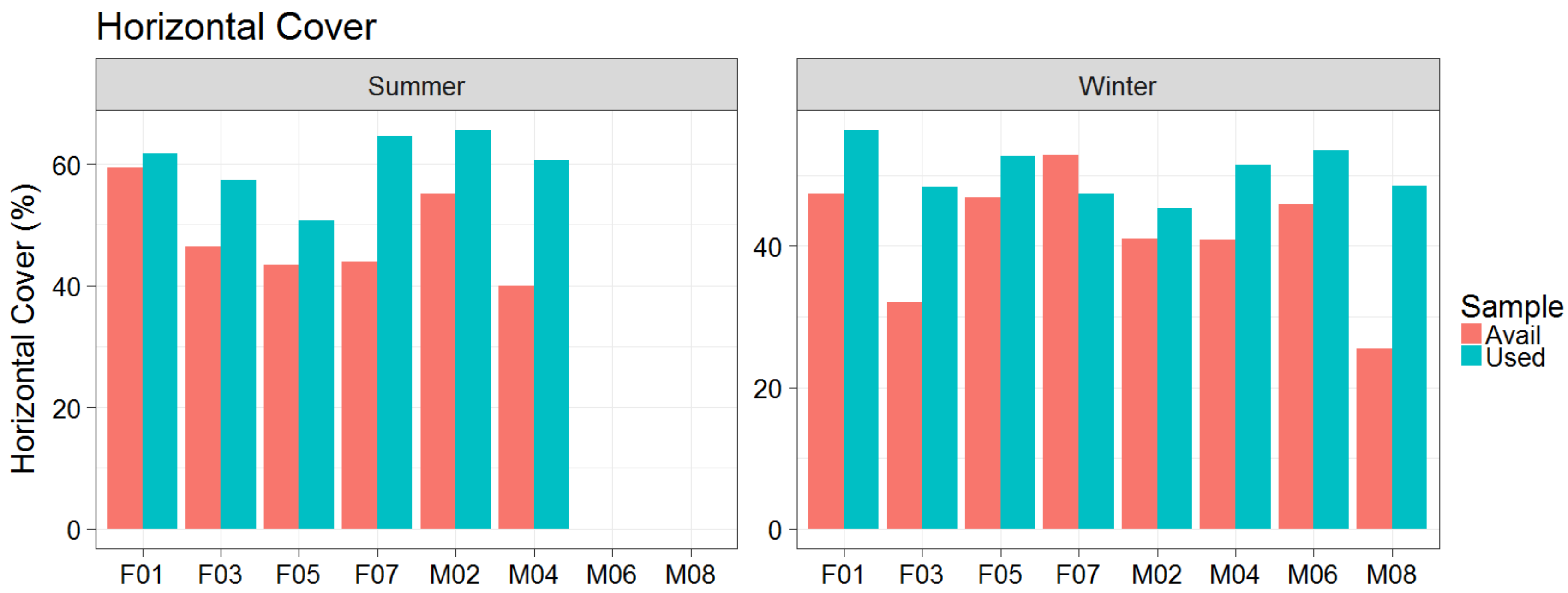


Figure 4. Mean horizontal cover (%) at used and available locations for each individual lynx by summer and winter. Dashed line (i.e., black) indicates ***Random Use***, whereas data above the line indicate selection and data below the line indicate avoidance. Black dots represent each lynx.

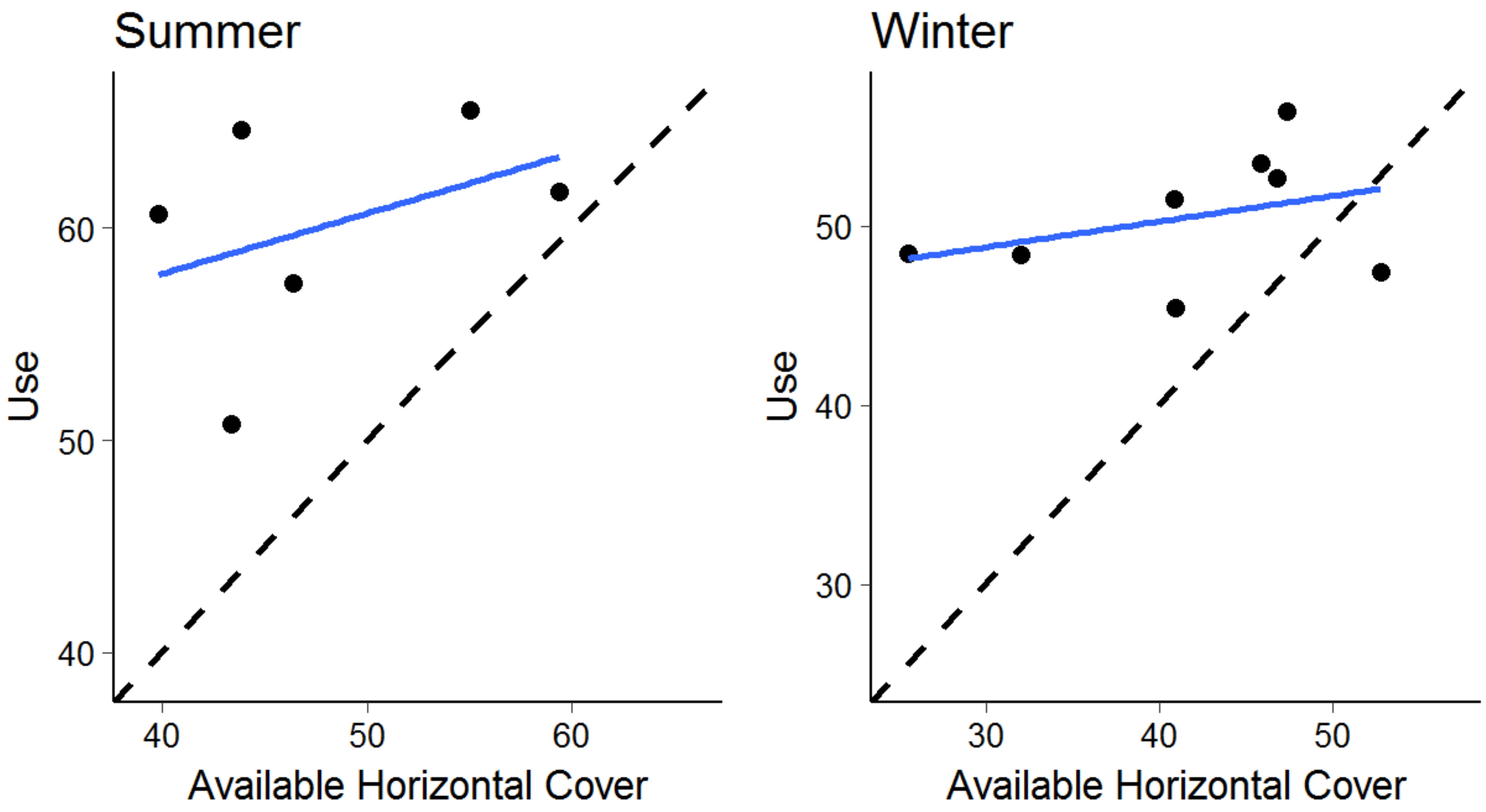


Figure 5. Mean pellet density per 1 m^2 plot at used and available locations for each lynx by season.

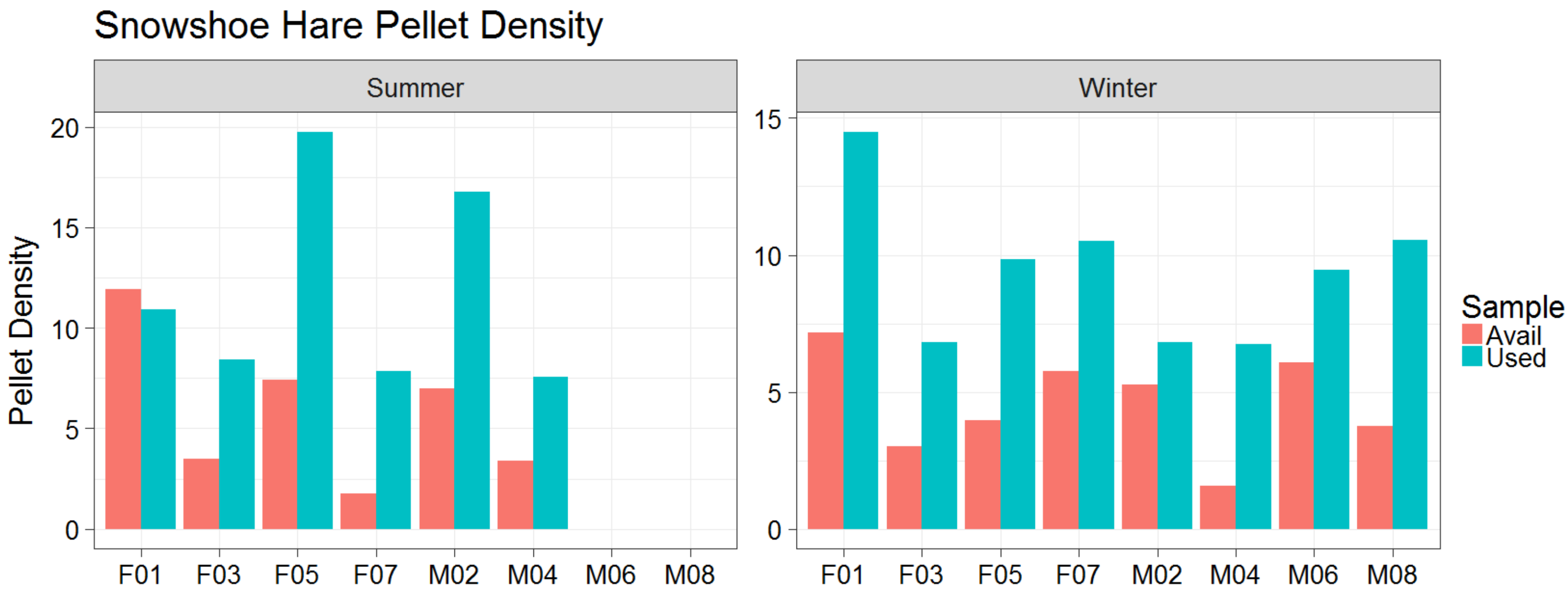
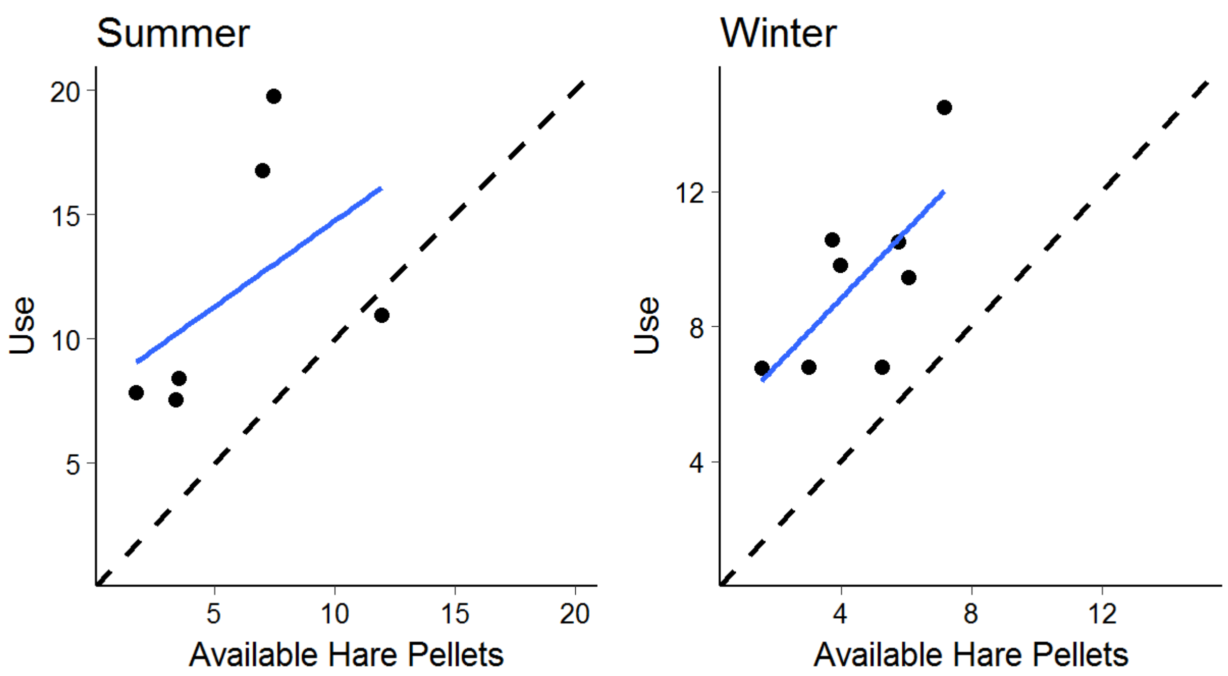


Figure 6. Mean pellet densities per 1 m^2 plot at used and available locations for each individual lynx by summer and winter. Dashed line (i.e., black) indicates ***Random Use***, whereas data above the line indicate selection and data below the line indicate avoidance. Black dots represent each lynx.



Stem density of understory trees

Figure 7. Mean understory stem density (tree/ft^2) for all live trees at used and available locations for each lynx by summer and winter.

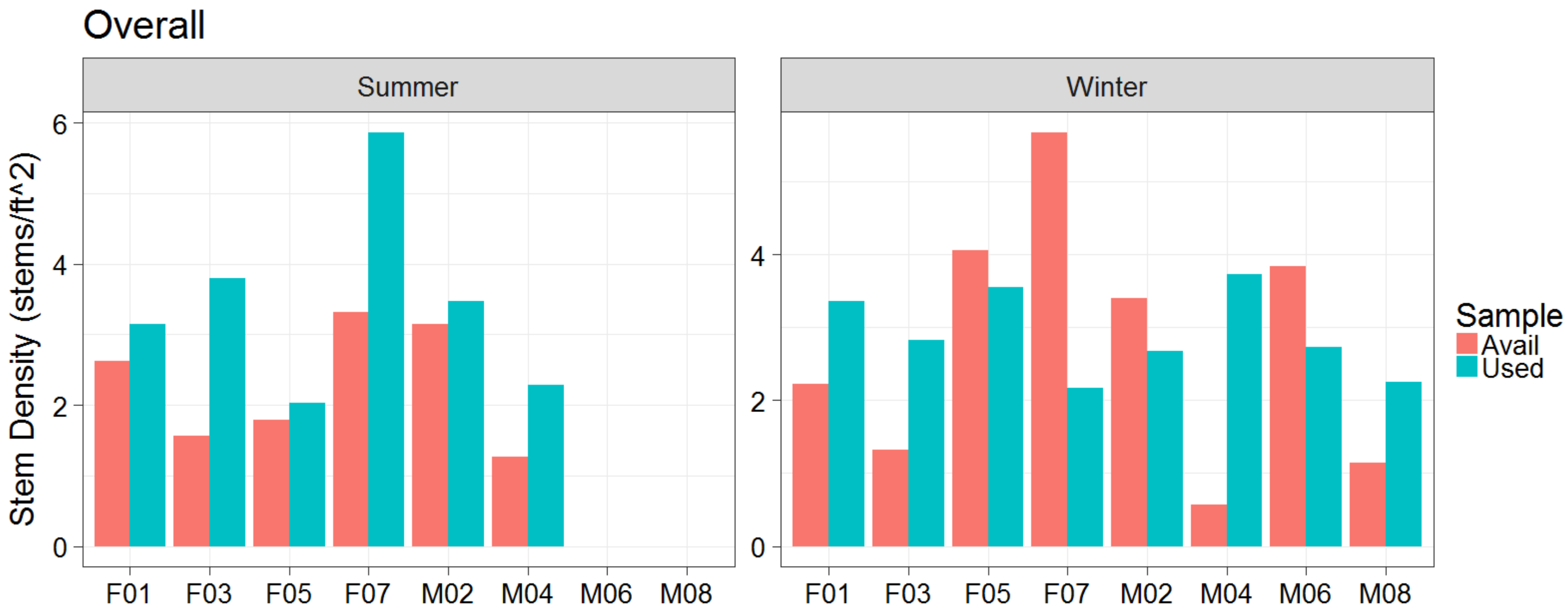


Figure 8. Mean understory stem density (tree/ft^2) for live ABLA trees at used and available locations for each lynx by summer and winter.

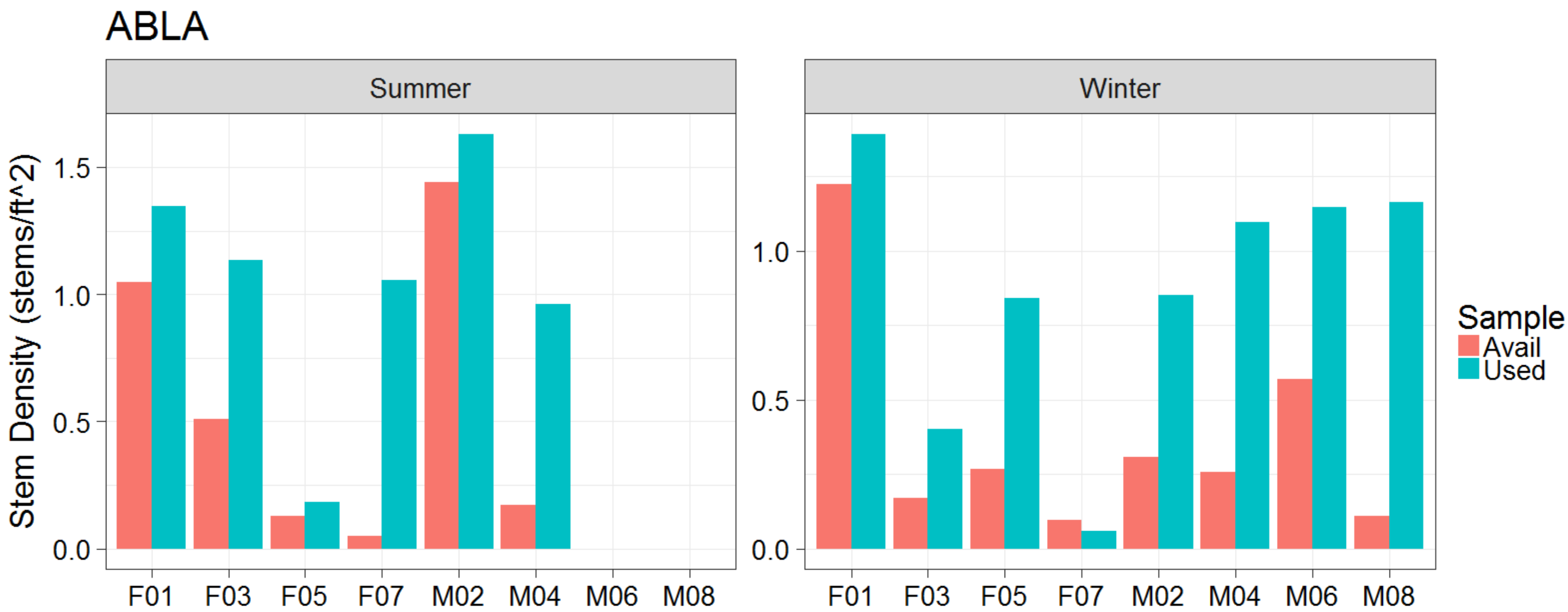


Figure 9. Mean understory stem density (tree/ft^2) for live PIPU trees at used and available locations for each lynx by summer and winter.

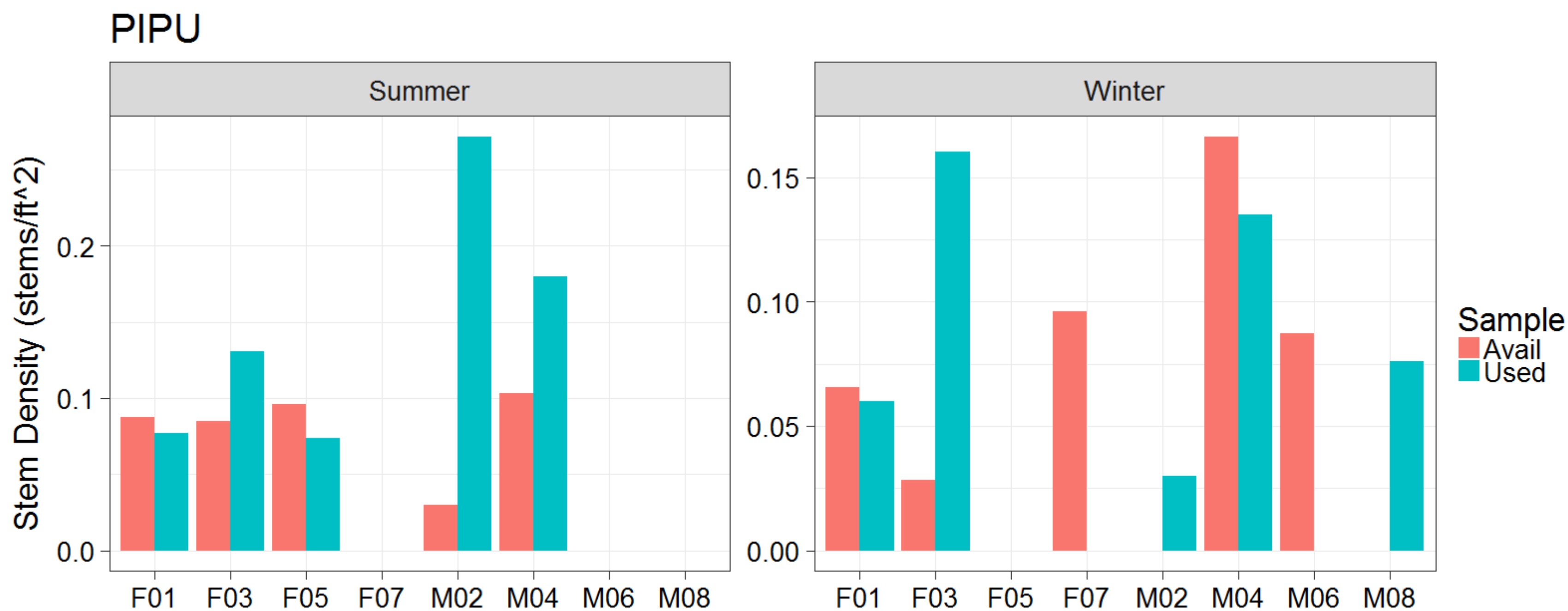


Figure 10. Mean understory stem density (tree/ft^2) for live PIEN trees at used and available locations for each lynx by summer and winter.

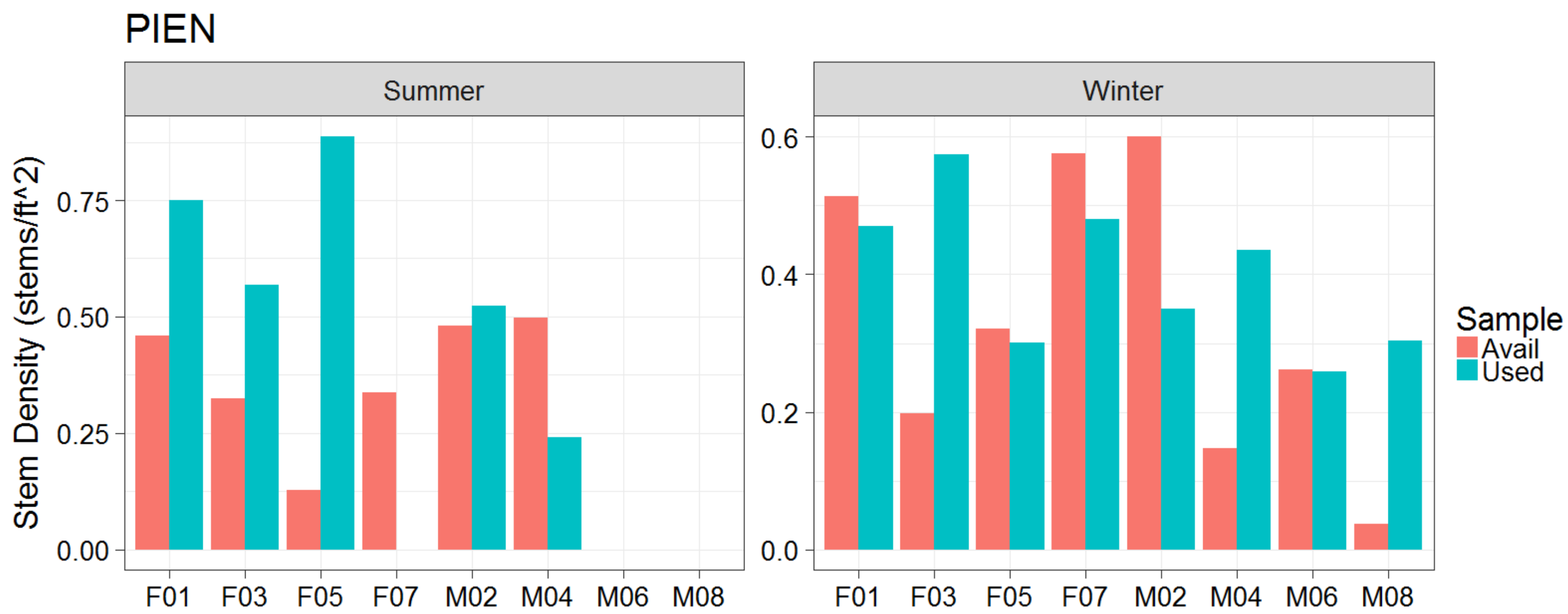
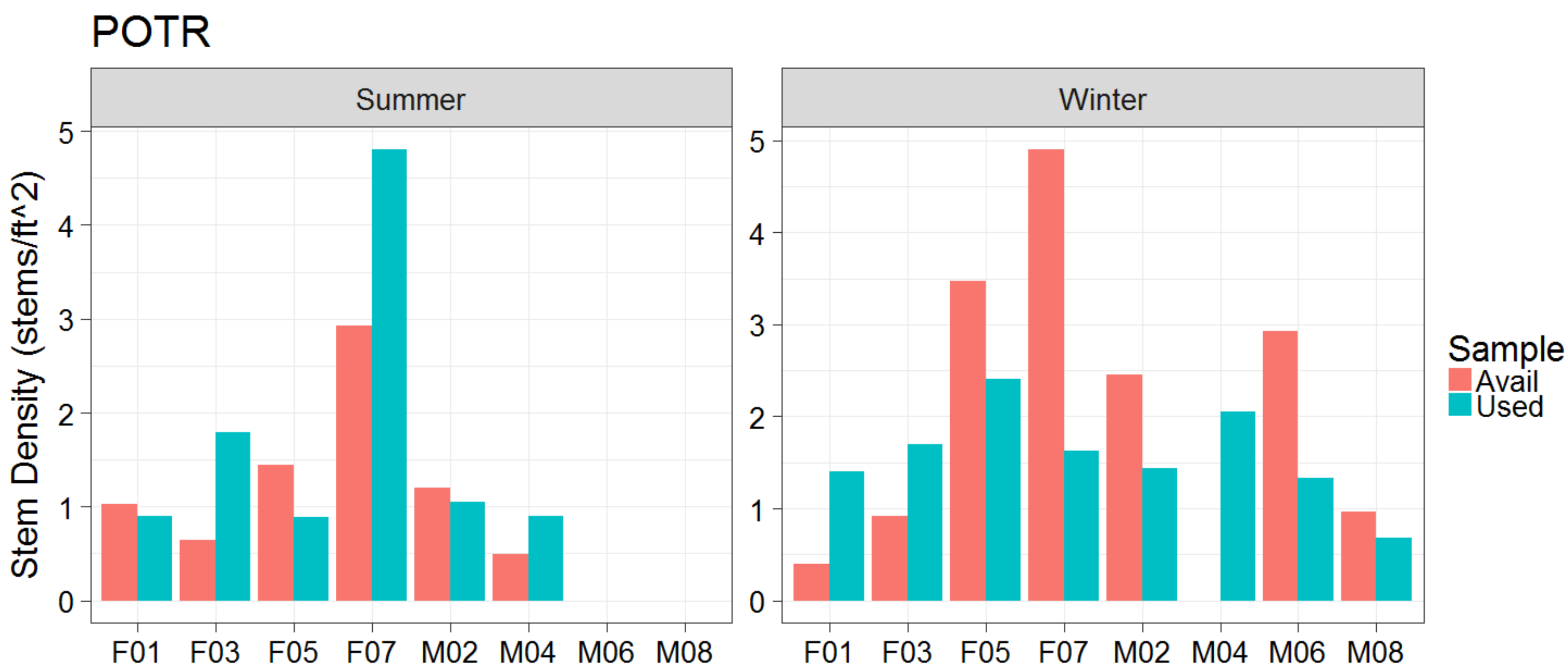


Figure 11. Mean understory stem density (tree/ft^2) for live POTR trees at used and available locations for each lynx by summer and winter.



Canopy cover at the top layer

Figure 12. Mean canopy cover at the top layer for live trees at used and available locations for each lynx by summer and winter.

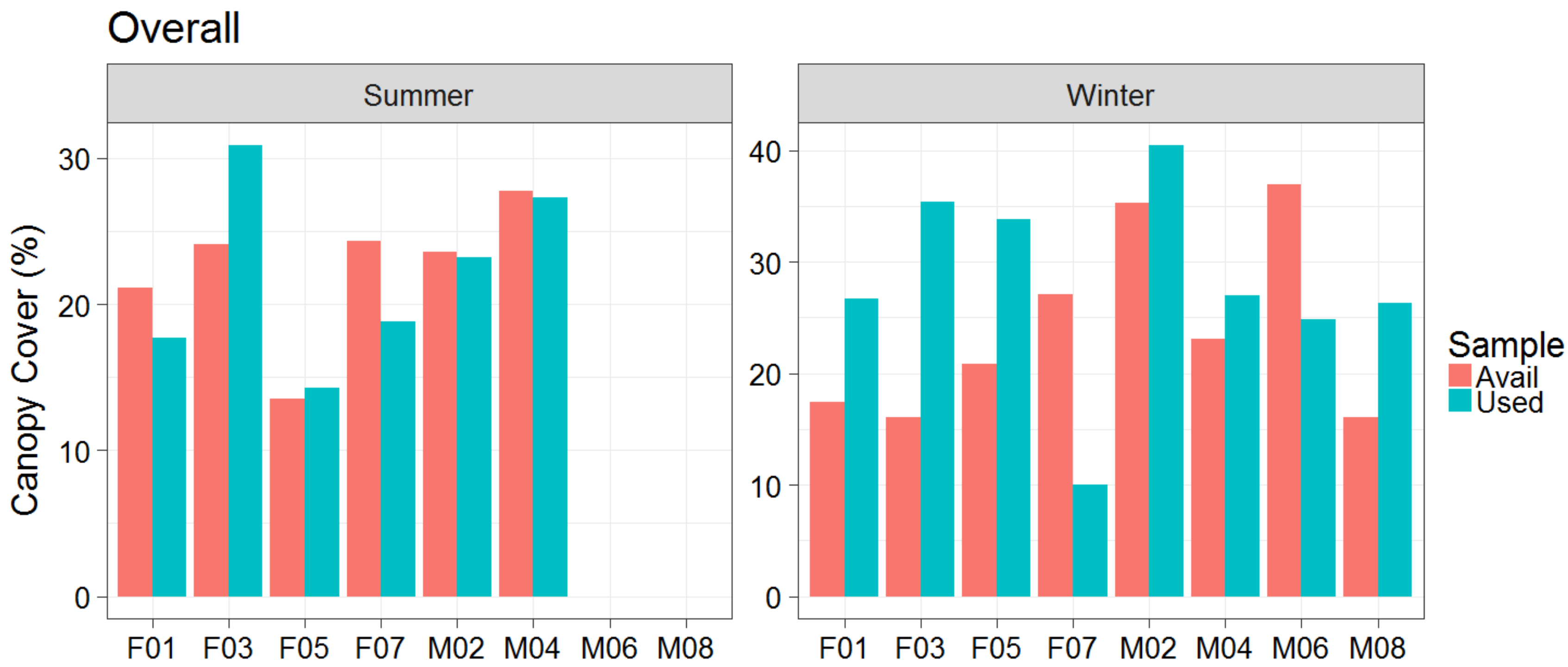


Figure 13. Mean canopy cover at the top layer for both live and dead trees at used and available locations for each lynx by summer and winter.

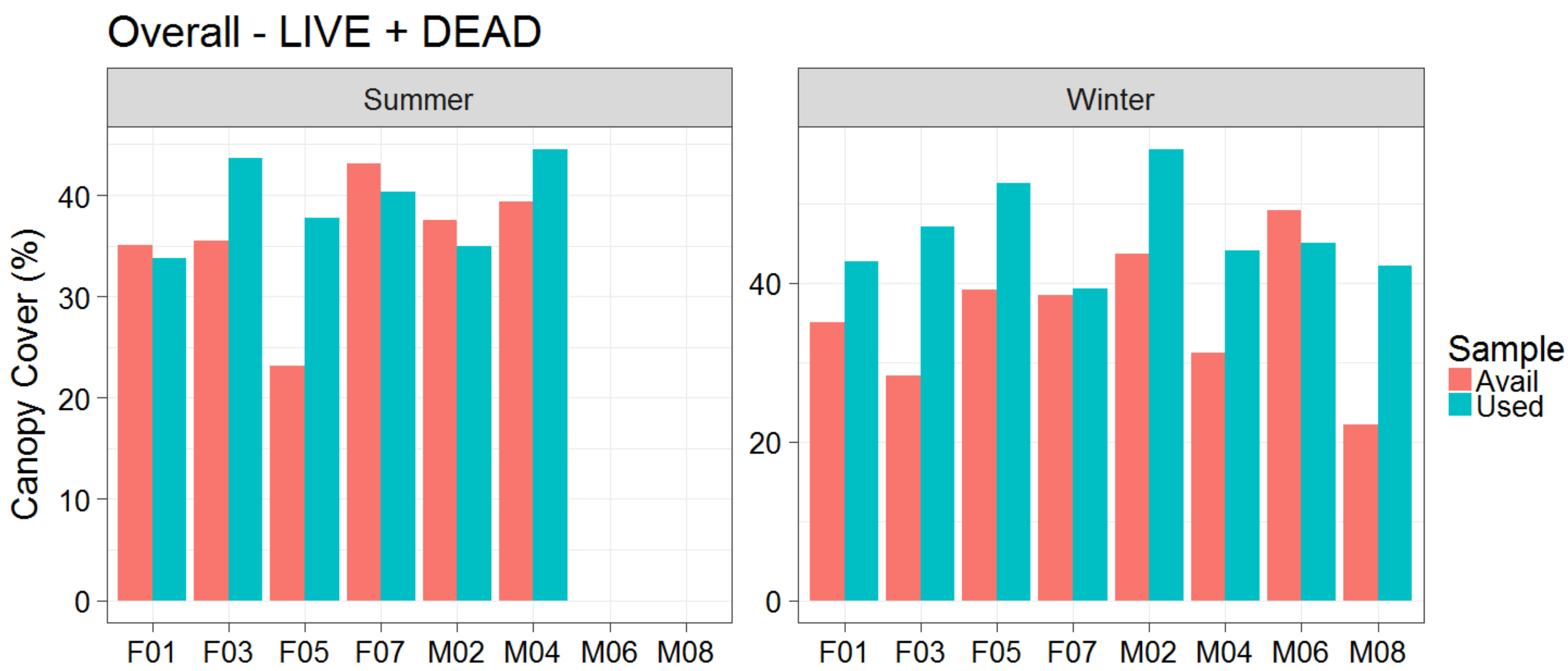


Figure 14. Mean canopy cover at the top layer for live ABLA trees at used and available locations for each lynx by summer and winter.

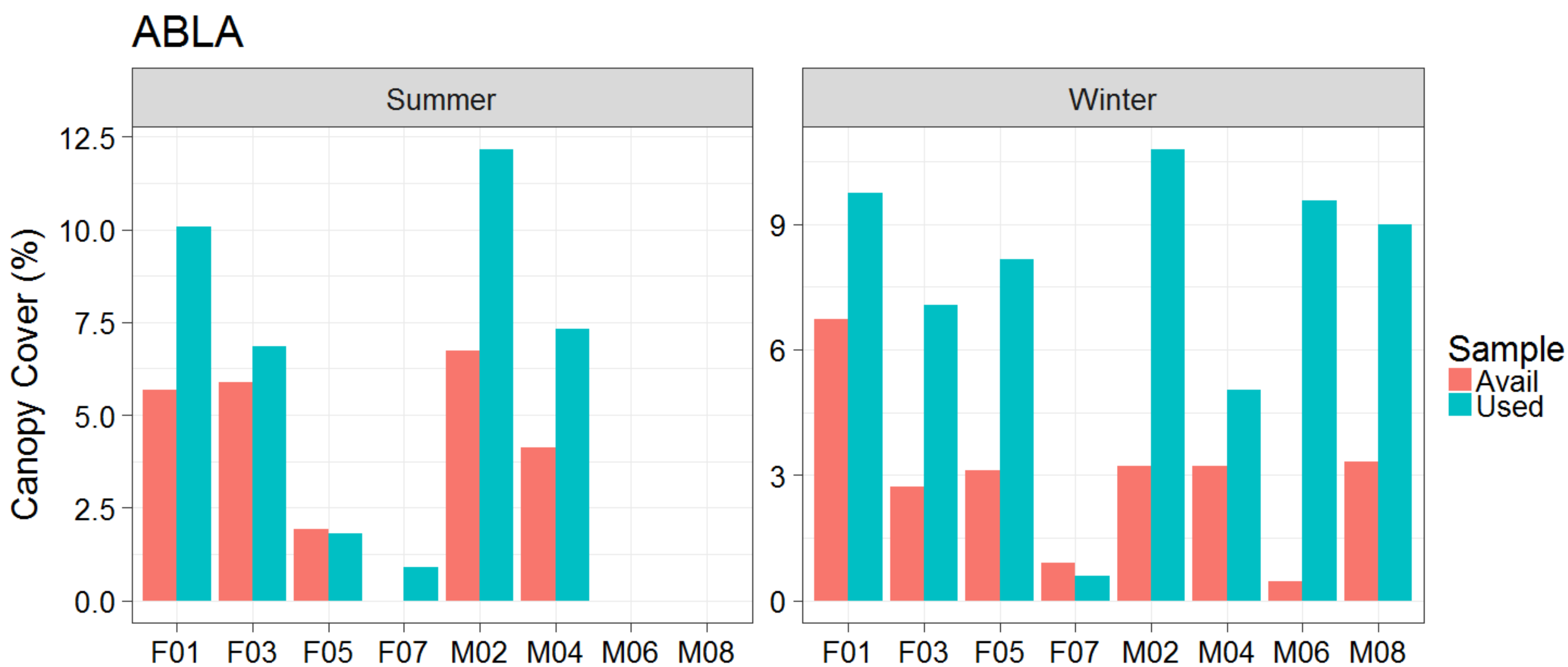


Figure 15. Mean canopy cover at the top layer for live PIPU trees at used and available locations for each lynx by summer and winter.

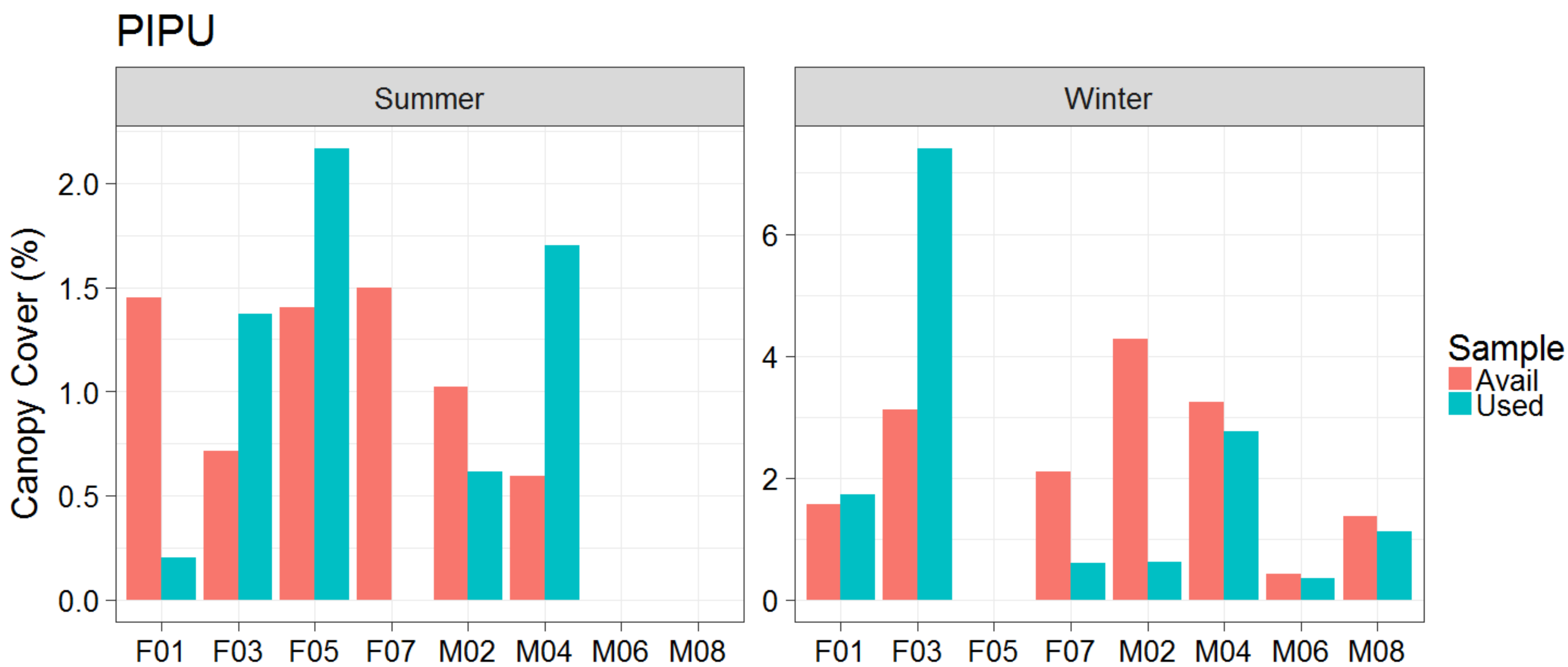


Figure 16. Mean canopy cover at the top layer for live PIEN trees at used and available locations for each lynx by summer and winter.

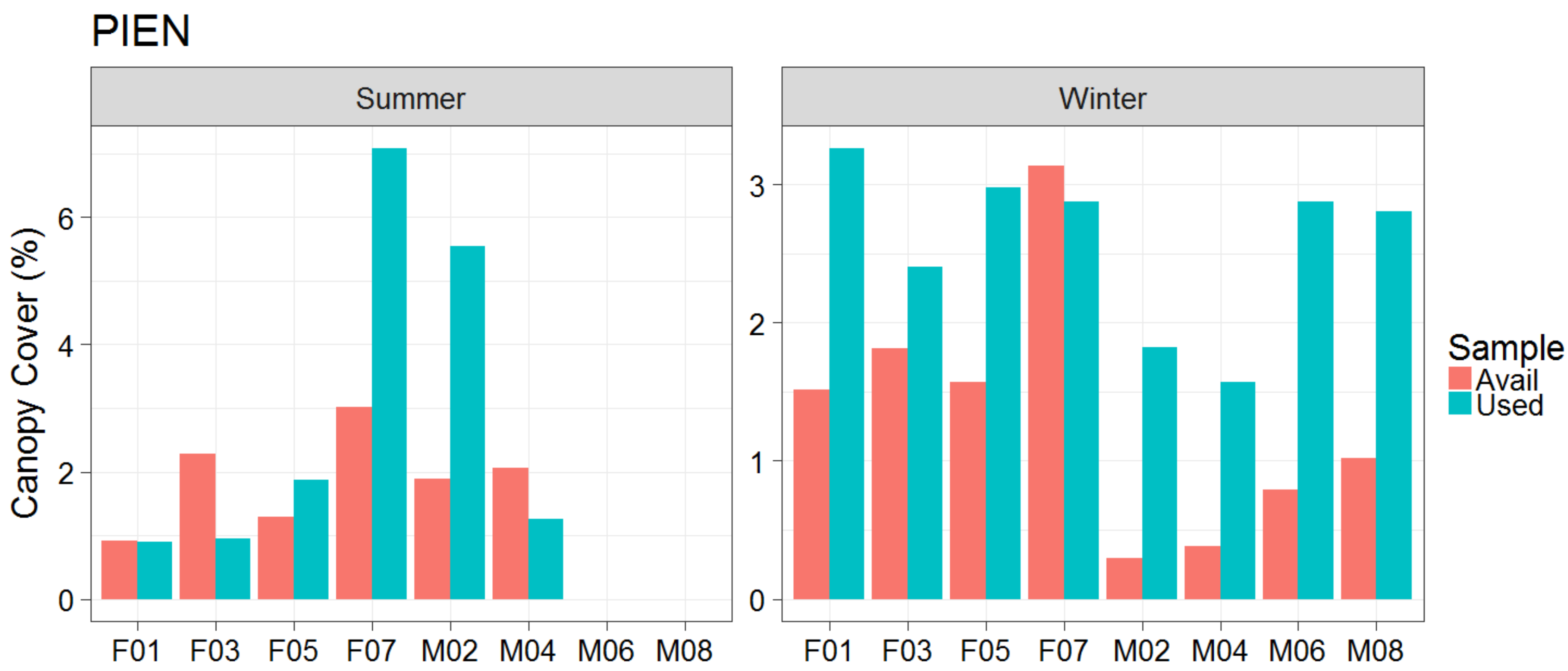


Figure 17. Mean canopy cover at the top layer for live POTR trees at used and available locations for each lynx by summer and winter.

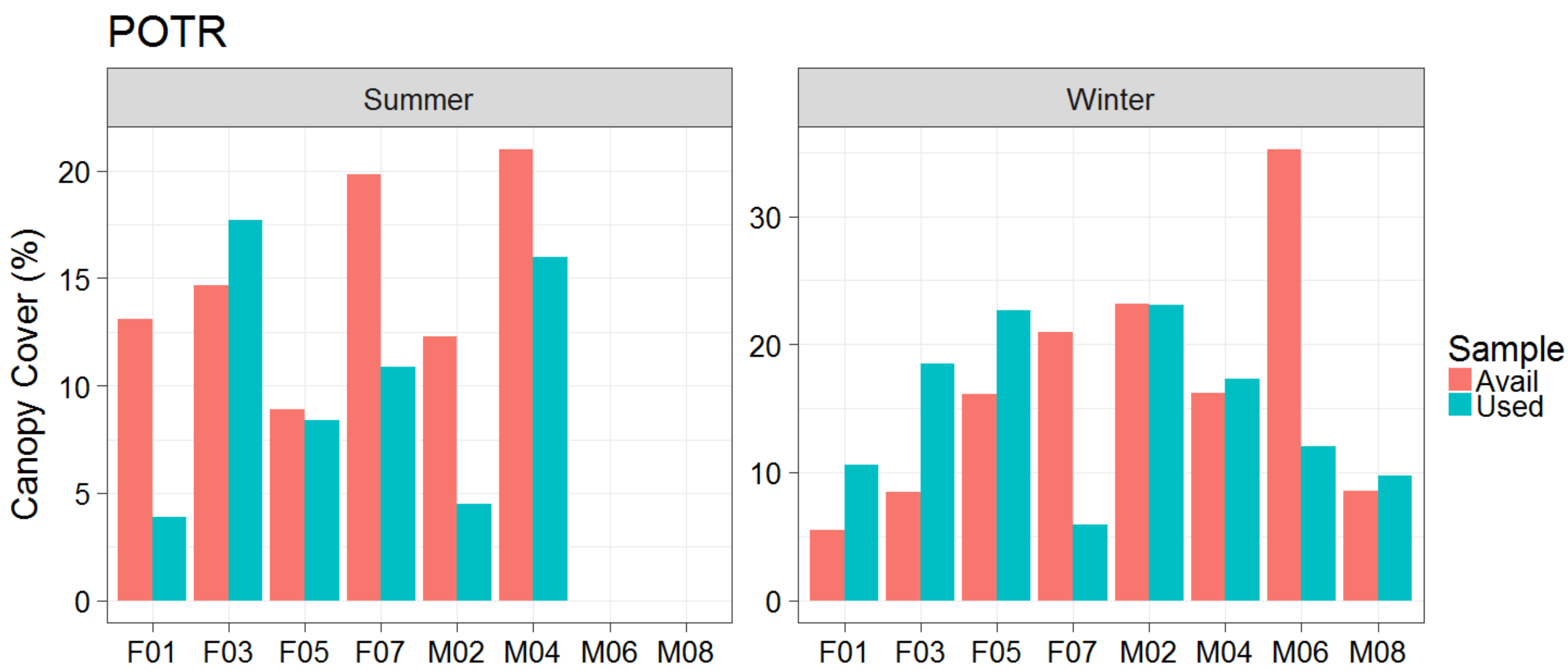
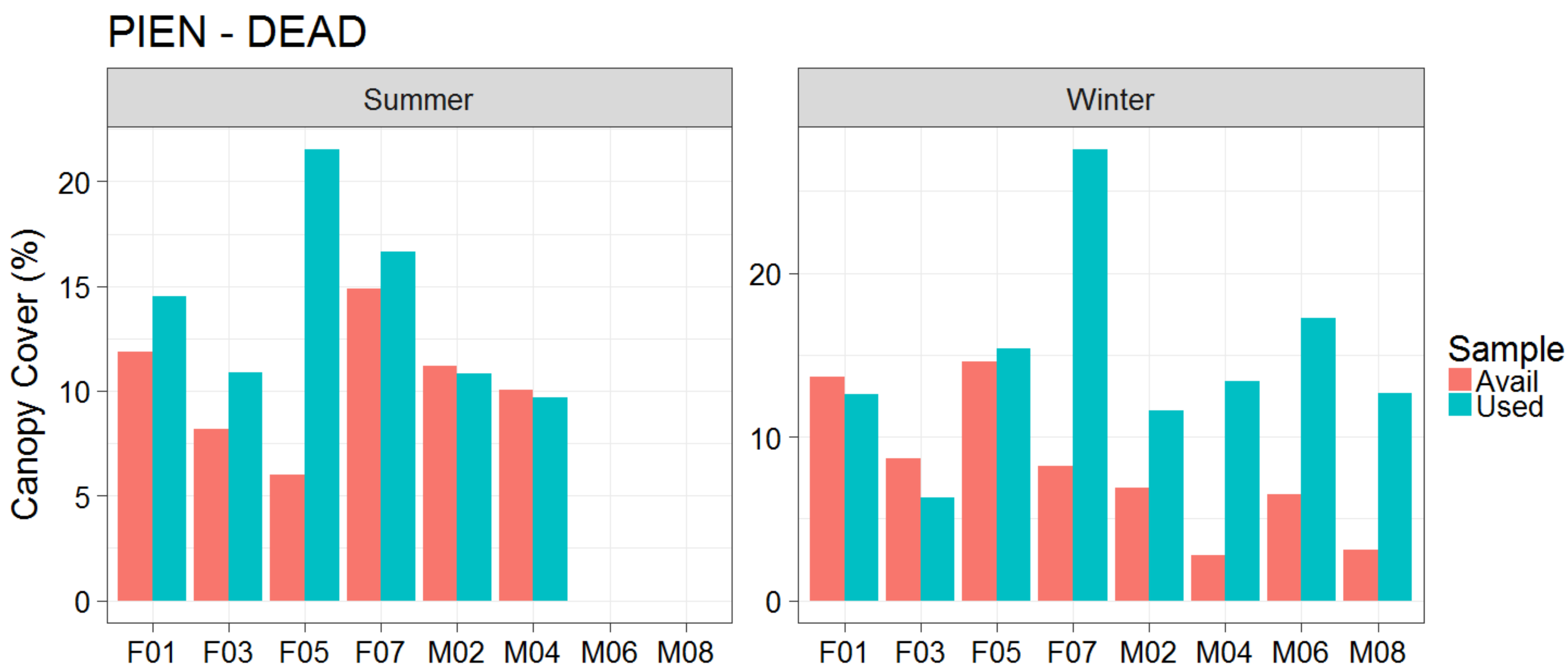


Figure 18. Mean canopy cover at the top layer for dead PIEN trees at used and available locations for each lynx by summer and winter.



Tree Density of Large (≥3 inch DBH) Trees

Figure 19. Mean tree density for live trees at used and available locations for each lynx by summer and winter.

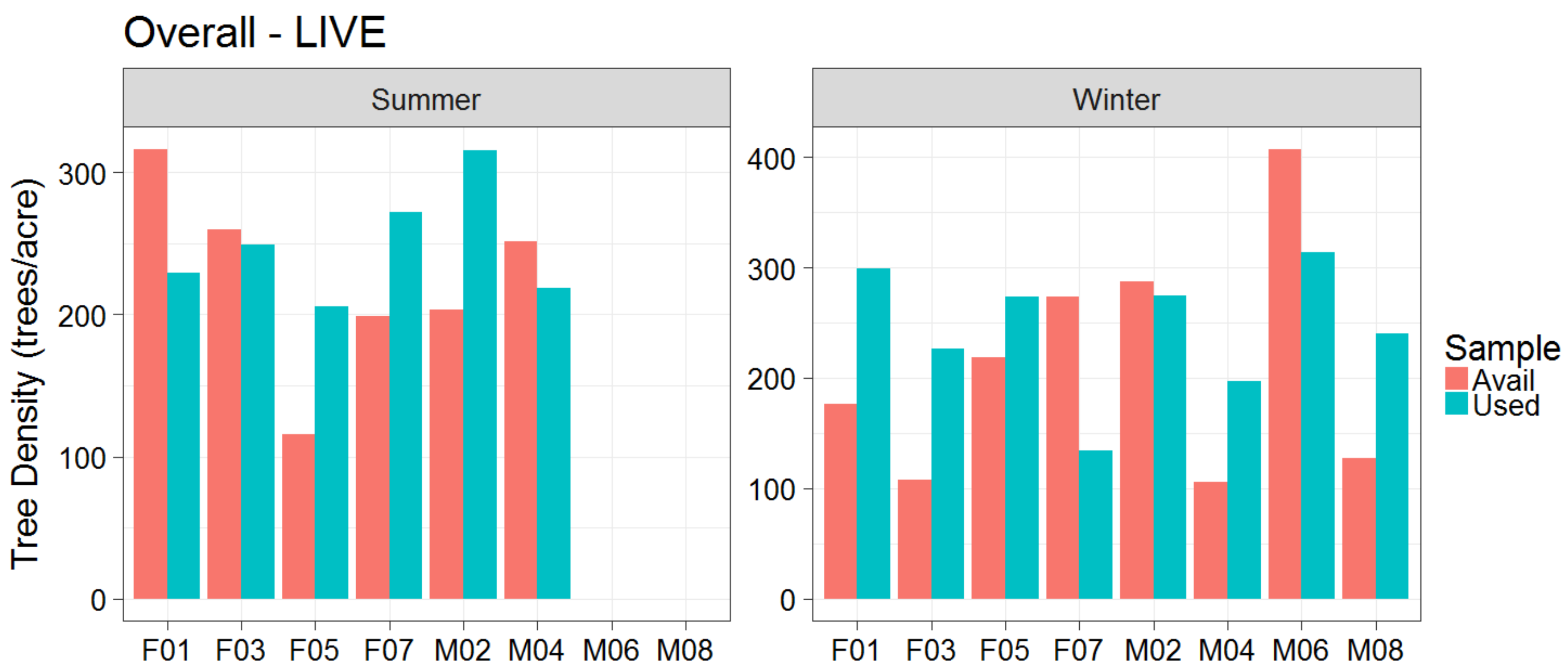


Figure 20. Mean tree density for dead trees at used and available locations for each lynx by summer and winter.

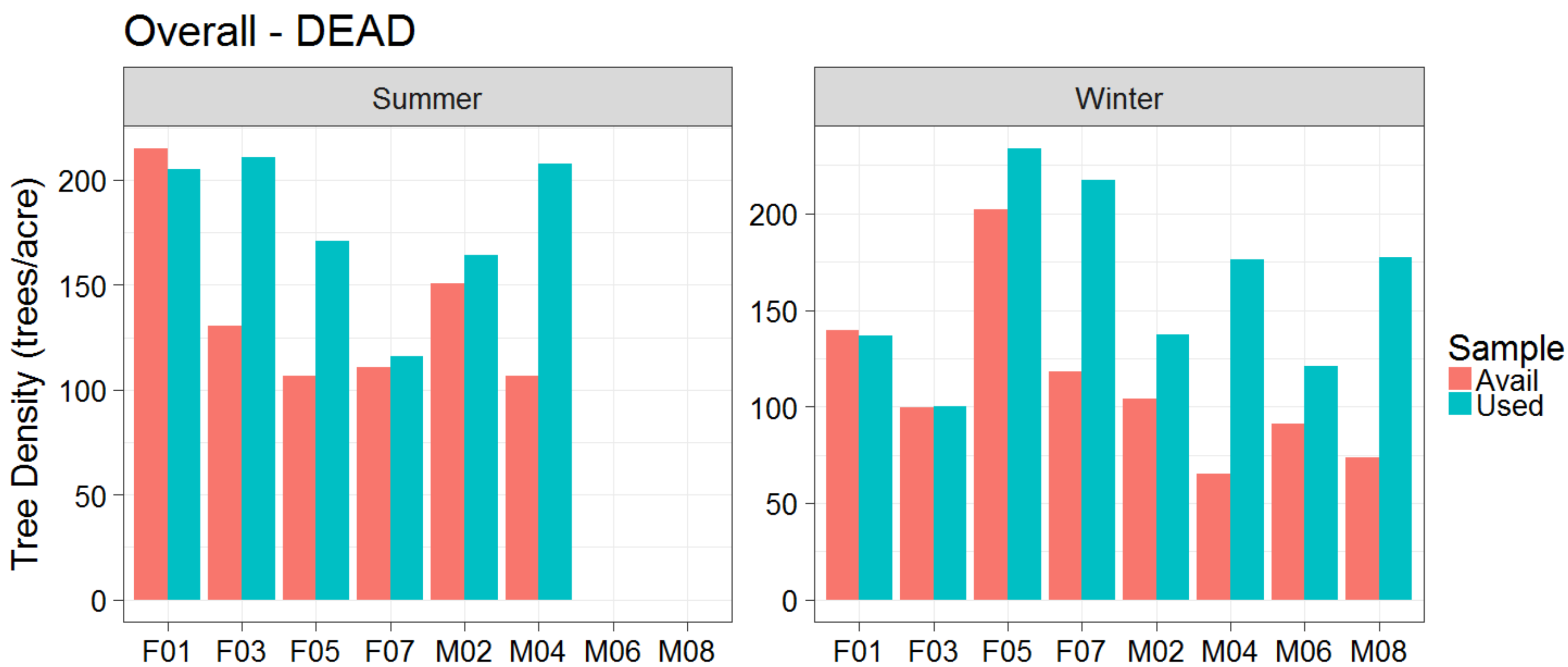
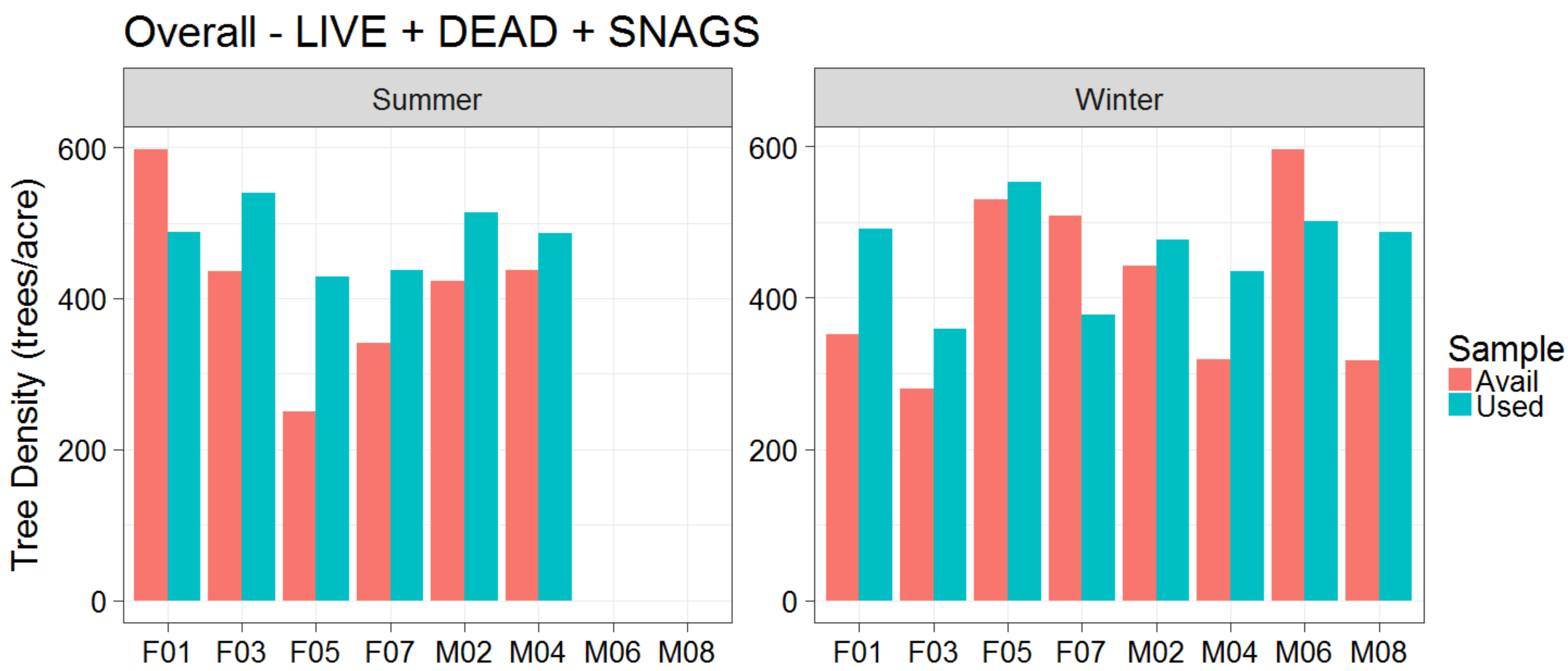


Figure 21. Mean tree density for snags at used and available locations for each lynx by summer and winter.

Figure 22. Mean tree density for all trees combined (live + dead + snags) at used and available locations for each lynx by summer and winter.



Live Trees

Figure 23. Mean tree density for live trees 3-5 inches DBH at used and available locations for each lynx by summer and winter.

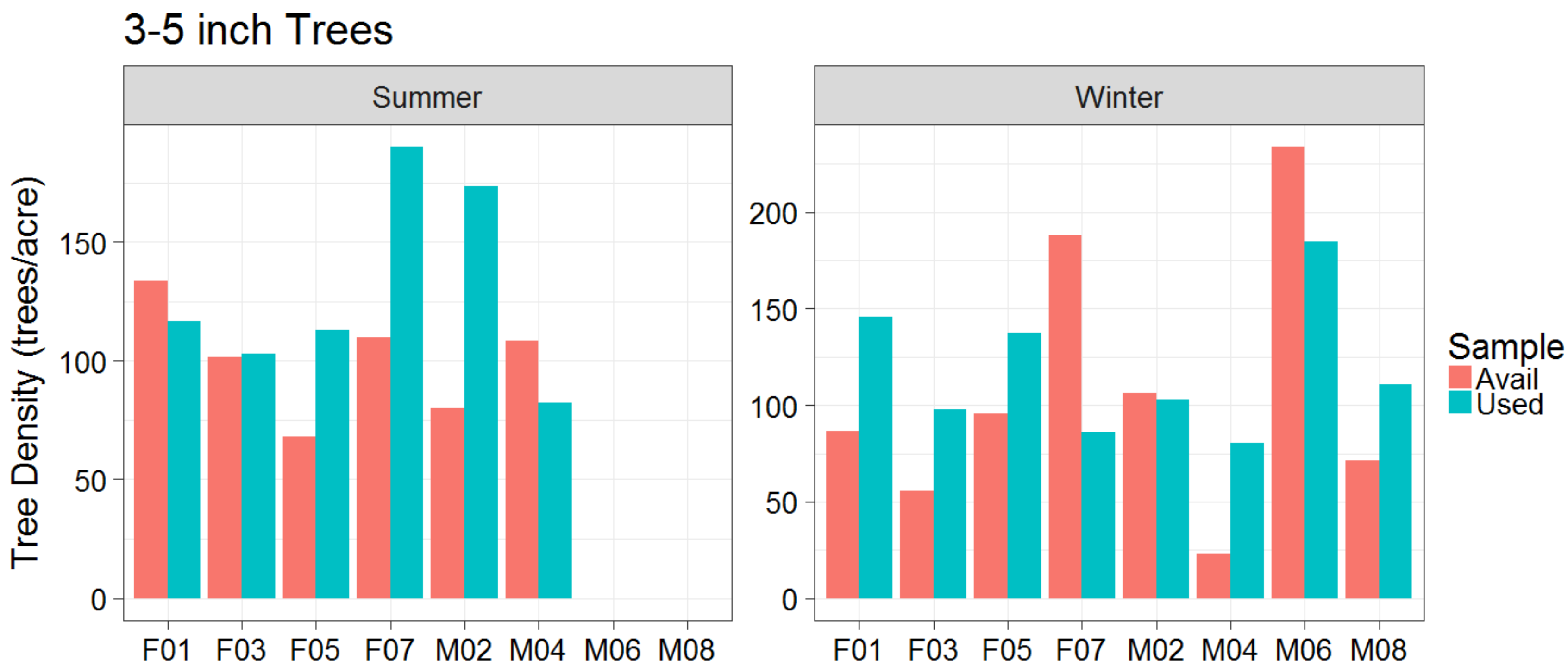


Figure 24. Mean tree density for live trees 5-9 inches DBH at used and available locations for each lynx by summer and winter.

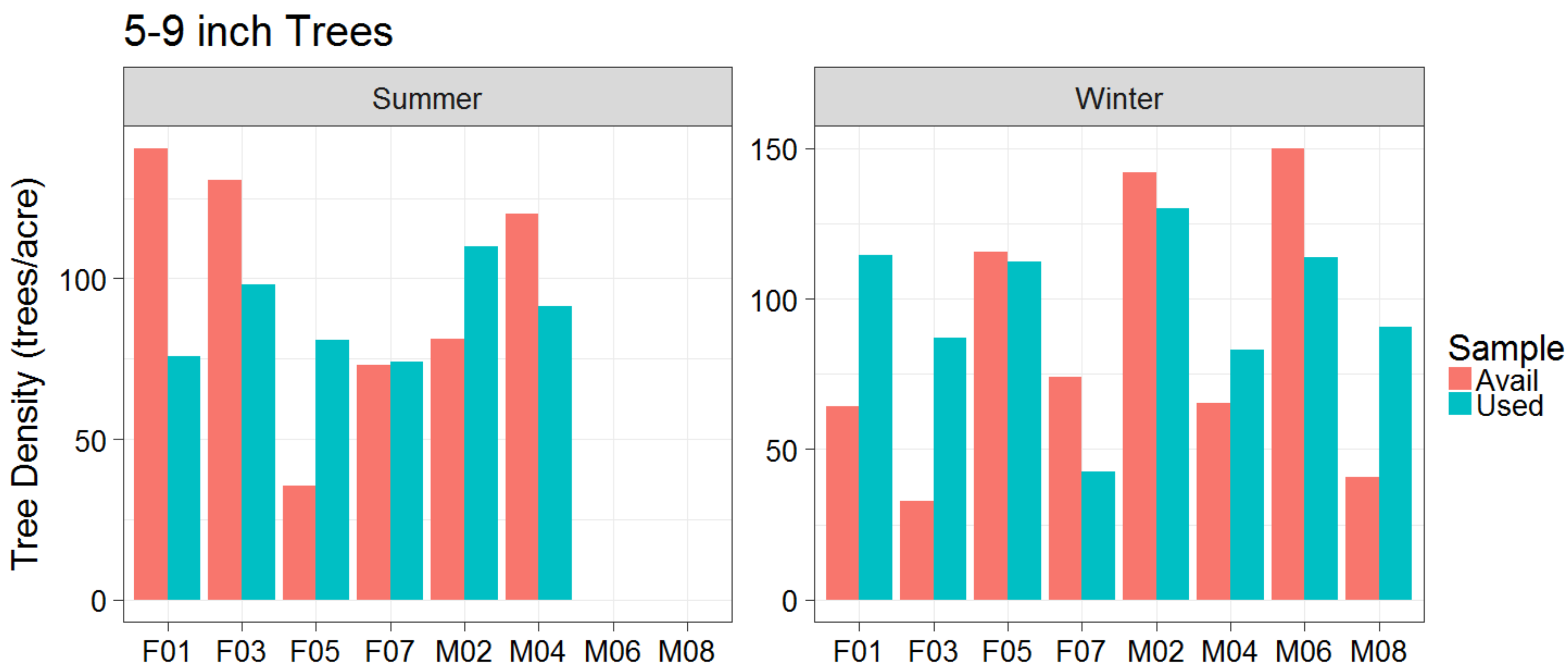


Figure 25. Mean tree density for live trees 9-16 inches DBH at used and available locations for each lynx by summer and winter.

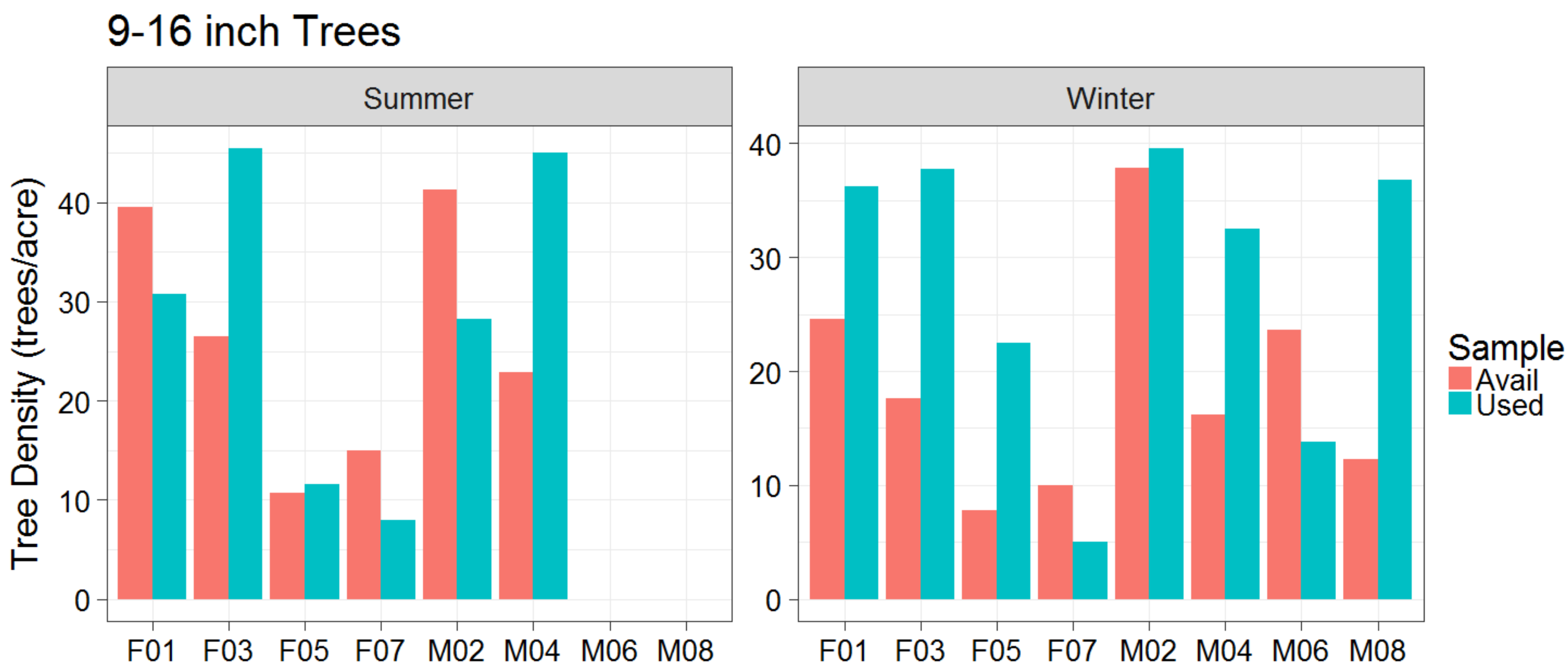
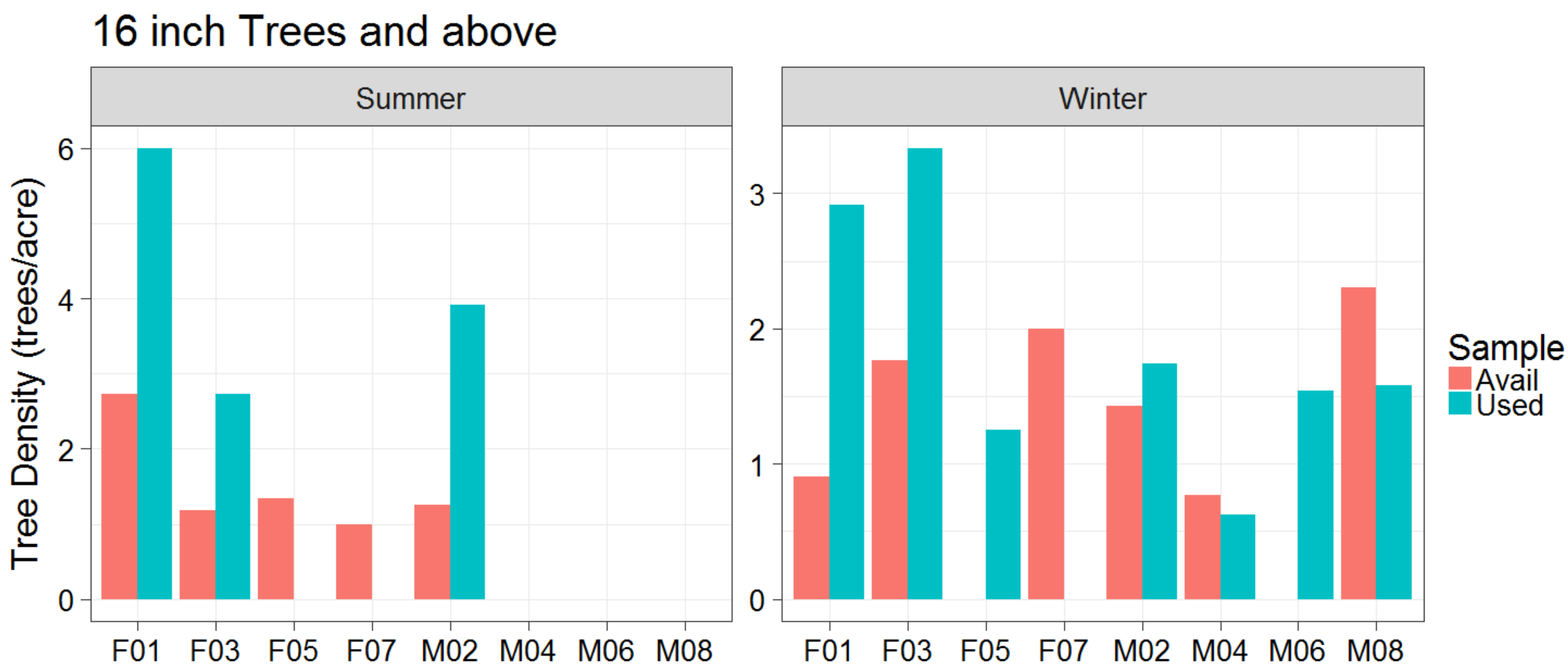


Figure 26. Mean tree density for live trees ≥16 inches DBH at used and available locations for each lynx by summer and winter.



Dead Trees

Figure 27. Mean tree density for dead trees 3-5 inches DBH at used and available locations for each lynx by summer and winter.

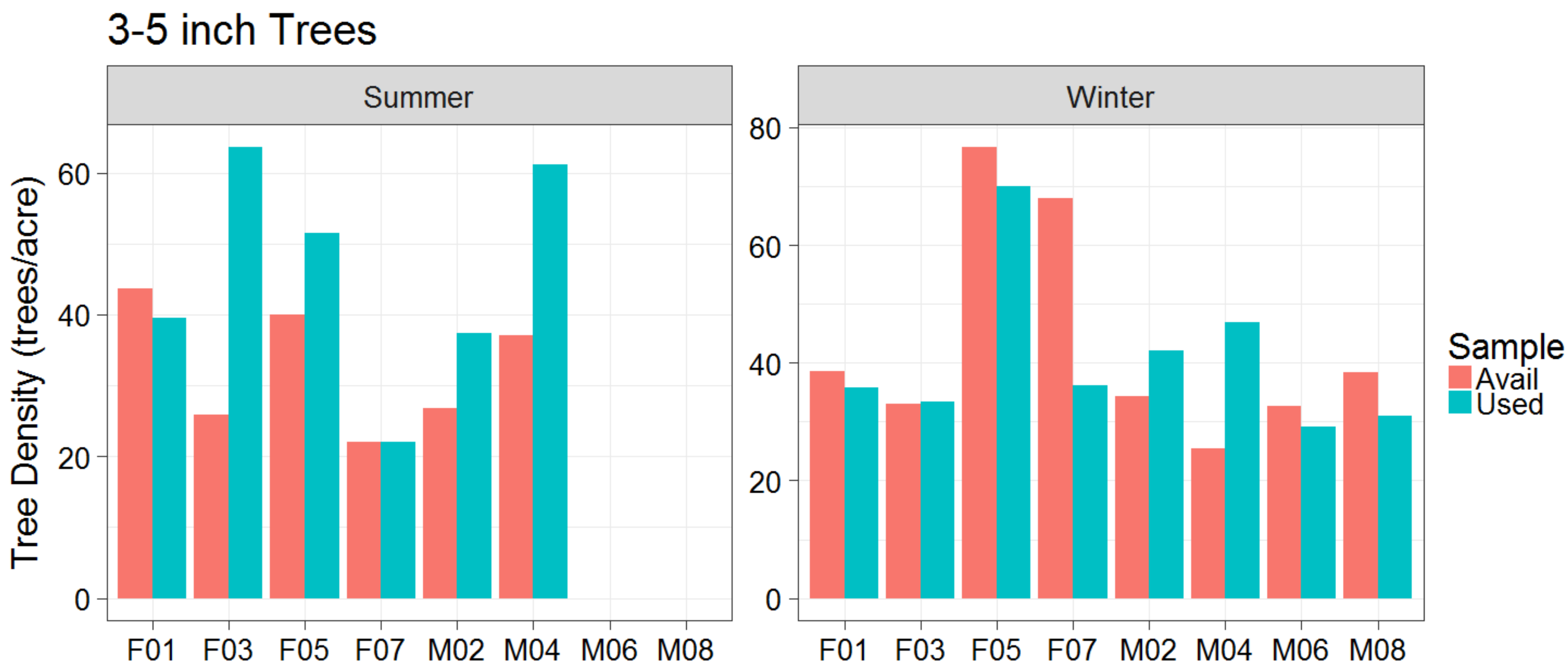


Figure 28. Mean tree density for dead trees 5-9 inches DBH at used and available locations for each lynx by summer and winter.

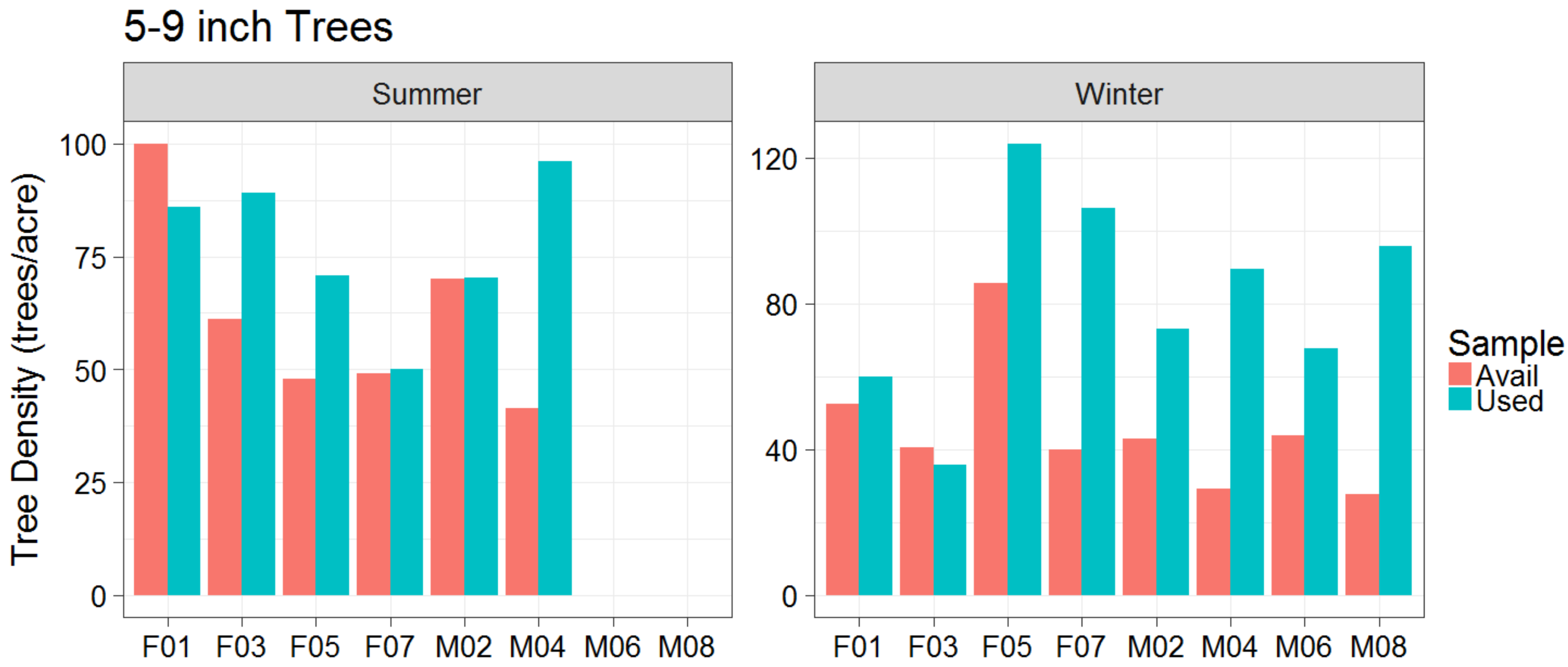


Figure 29. Mean tree density for dead trees 9-16 inches DBH at used and available locations for each lynx by summer and winter.

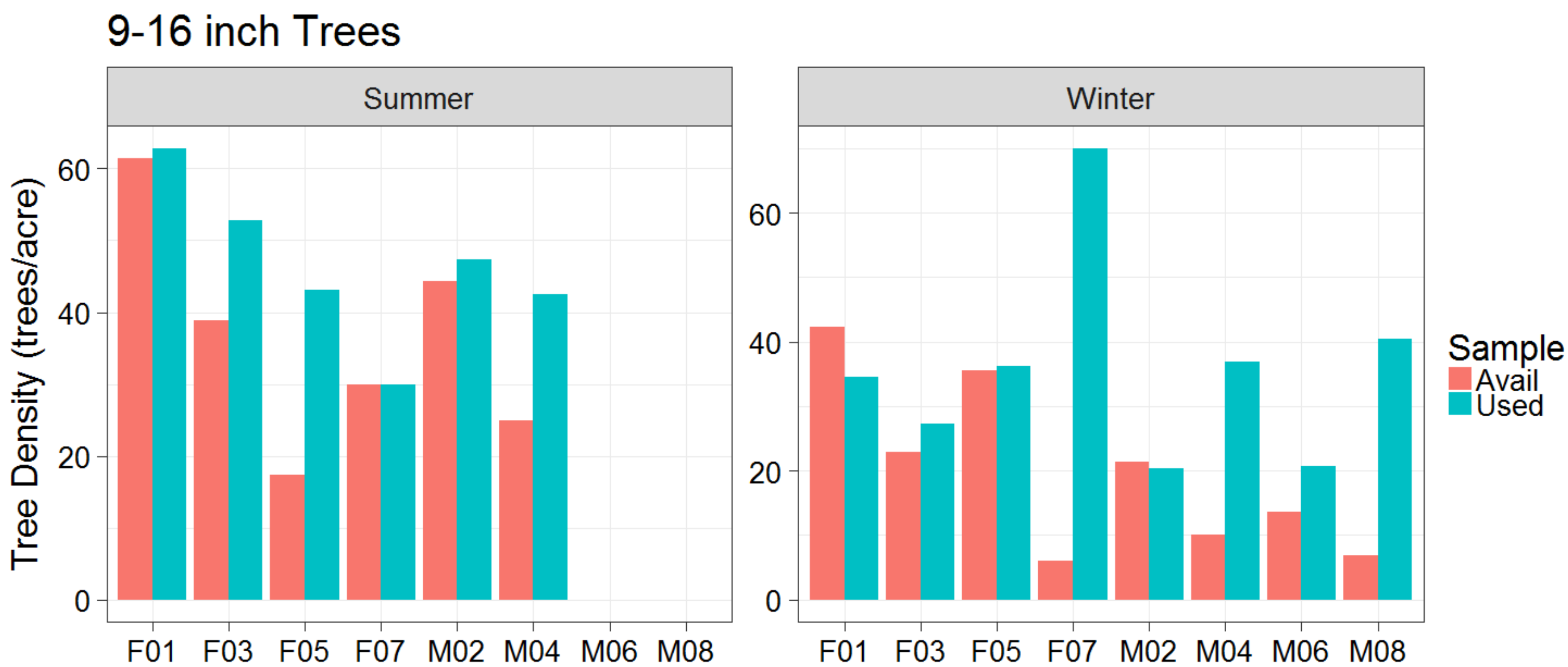
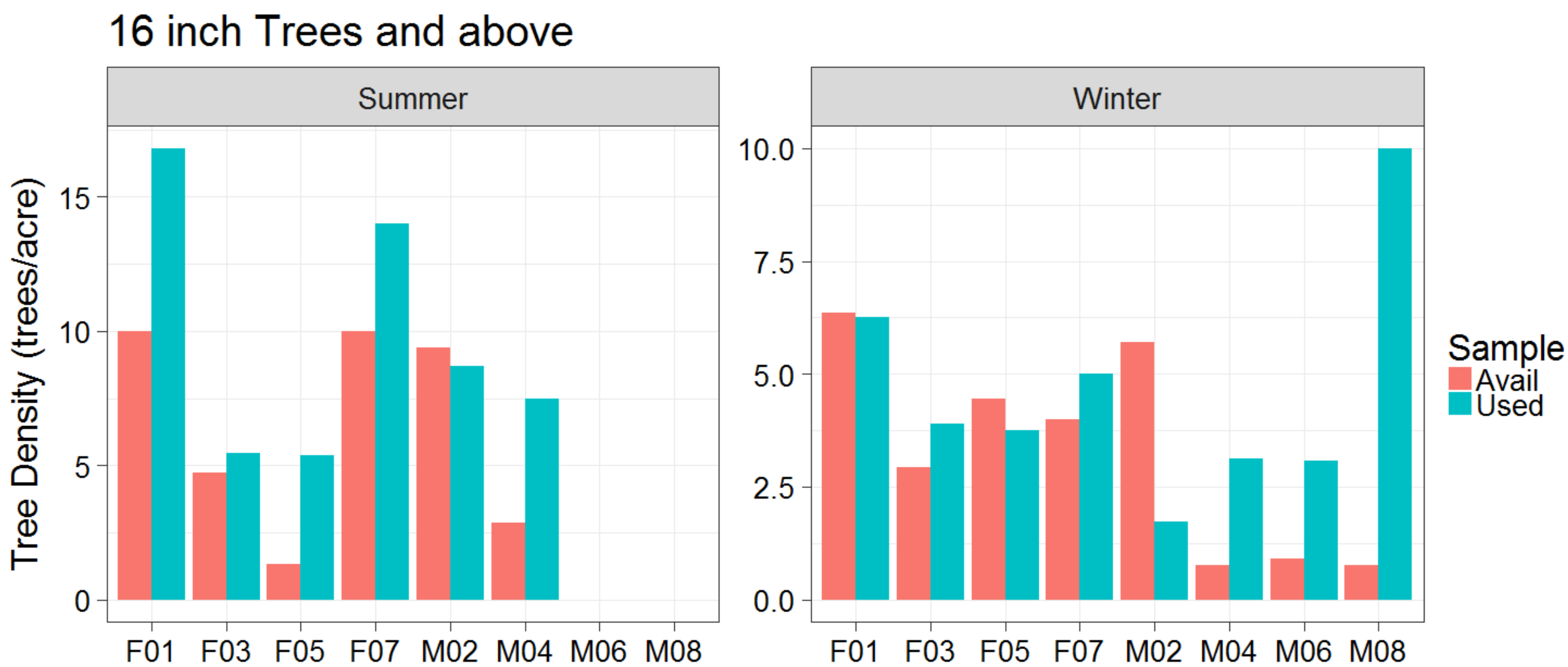


Figure 30. Mean tree density for dead trees ≥16 inches DBH at used and available locations for each lynx by summer and winter.



Species Specific Density

Figure 31. Mean tree density for live ABLA at used and available locations for each lynx by summer and winter.

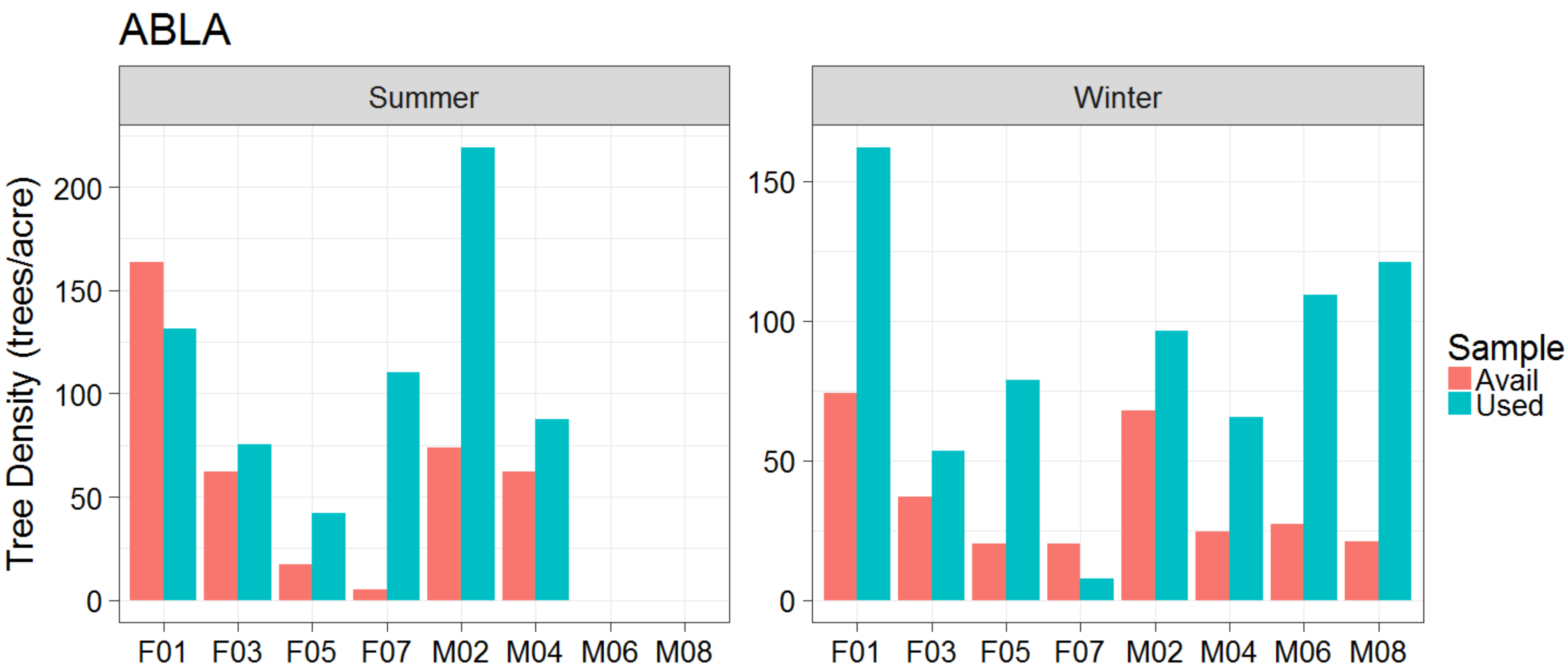


Figure 32. Mean tree density for live PIPU at used and available locations for each lynx by summer and winter.

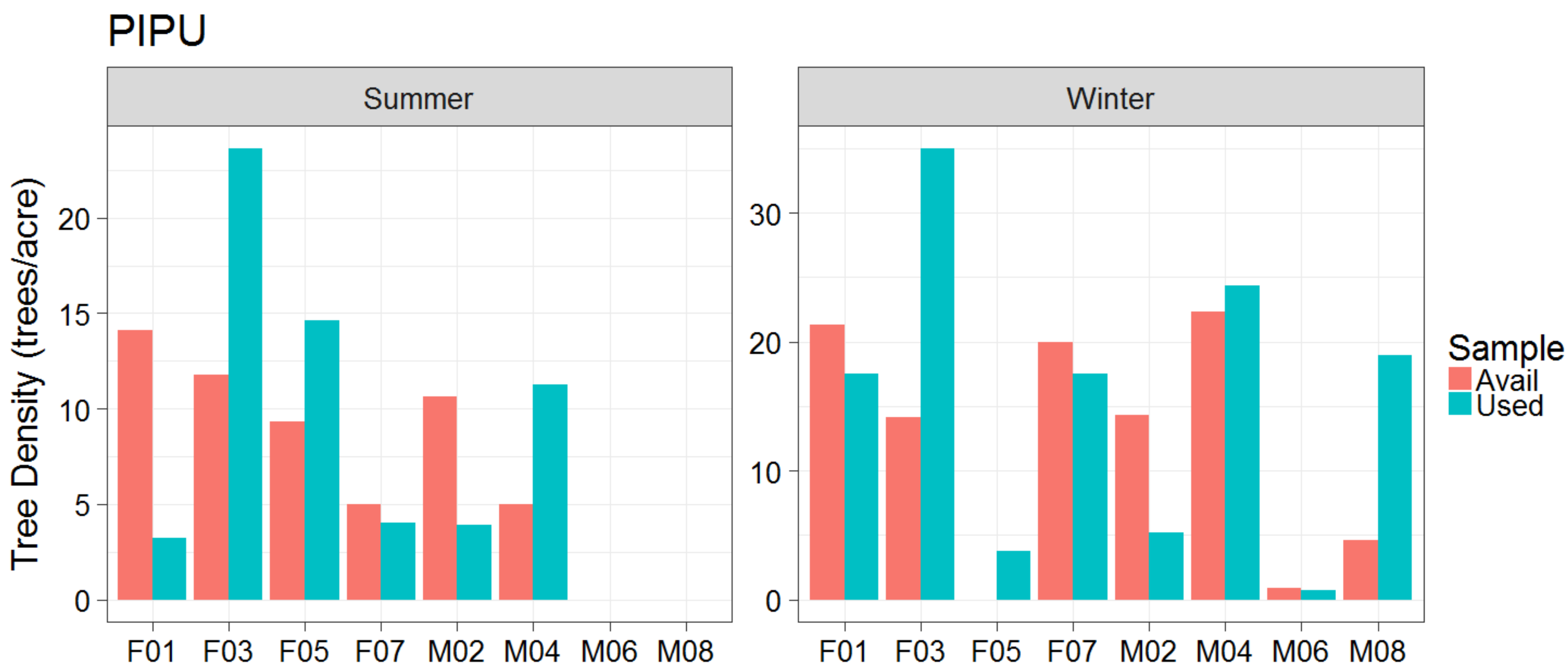


Figure 33. Mean tree density for live PIEN at used and available locations for each lynx by summer and winter.

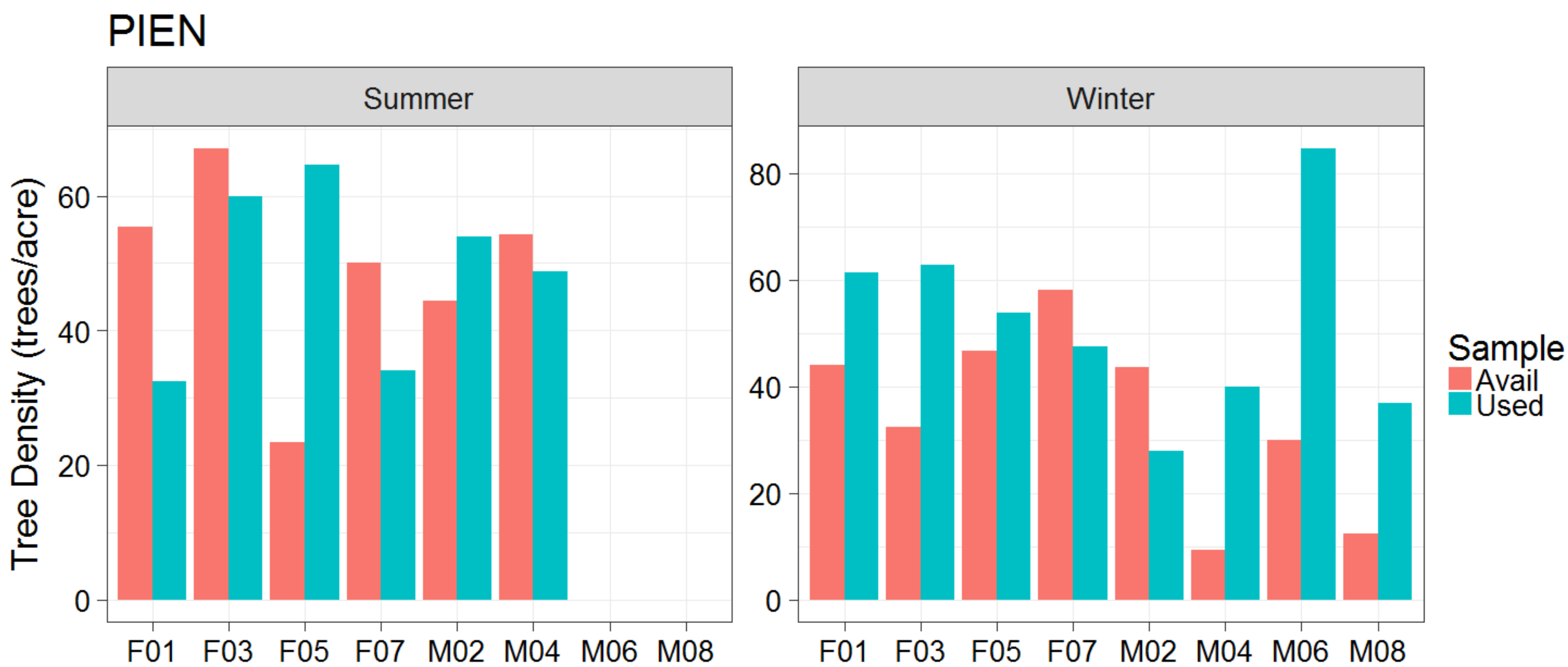


Figure 34. Mean tree density for live POTR at used and available locations for each lynx by summer and winter.

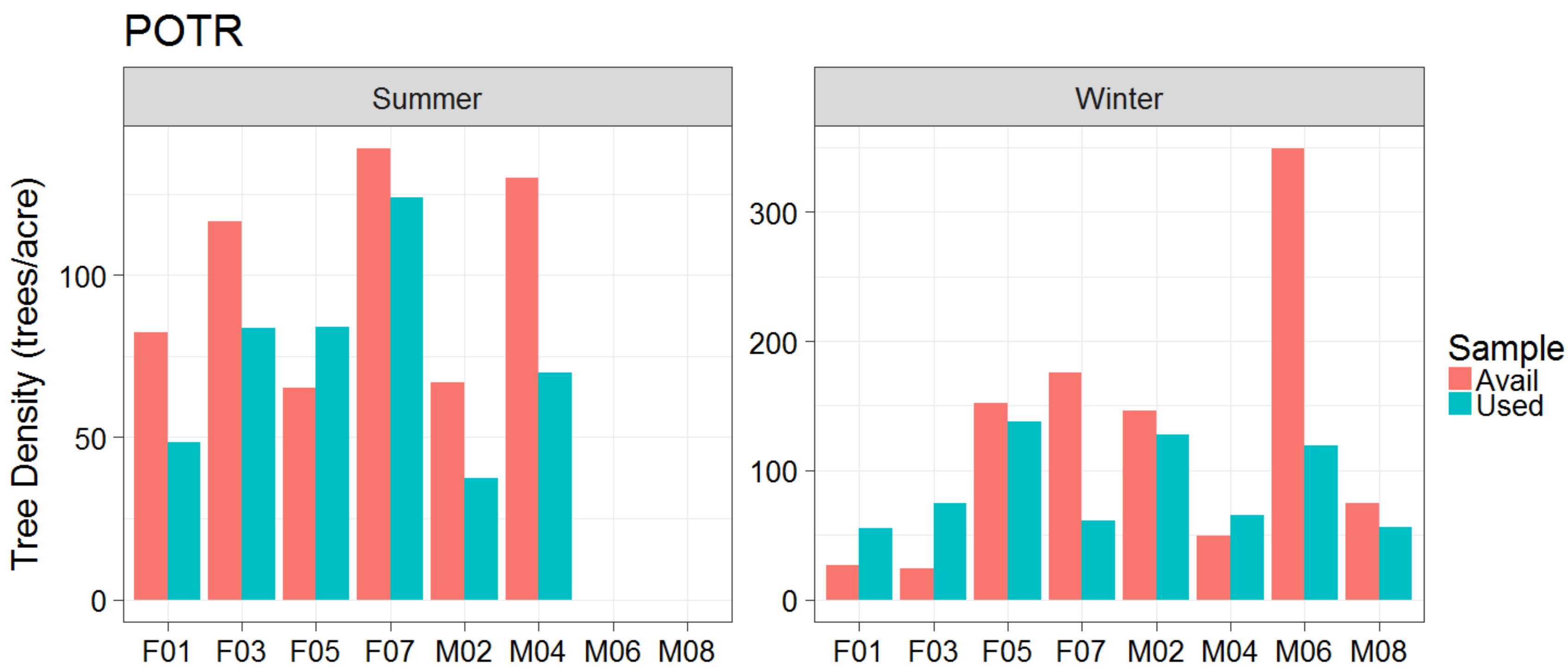


Figure 35. Mean tree density for dead PIEN at used and available locations for each lynx by summer and winter.