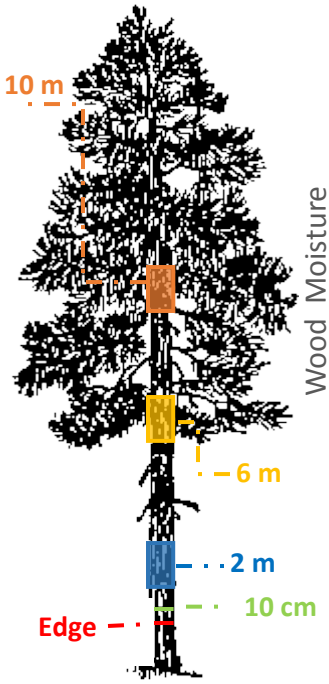
Report - Bundles & Beetles Project

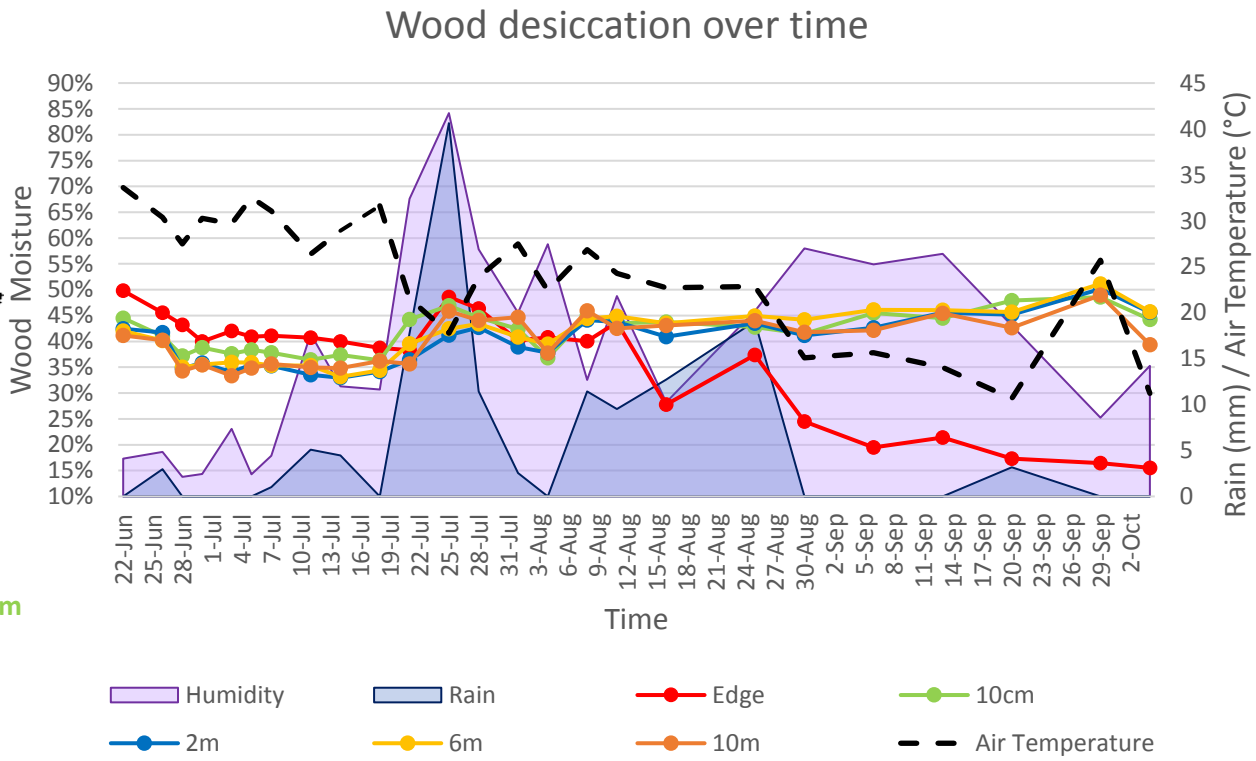
Collaborating institutions: Northern Arizona University, United States Forest Service (USFS), Four Forest Restoration Initiative (4FRI), Campbell Global, The Nature Conservancy (TNC), Flagstaff Watershed Protection Project (FWPP)

➢ Section 1- Wood desiccation

Site: Observatory Mesa, Section 8 – Flagstaff, AZ

- **A total of five bundles were selected and three trees per bundle were monitored.**





On the graph above, each one of the tree locations that we are monitoring is represented by one specific color as follows: **Edge (red)**, **10 cm (green)**, **2 m (blue)**, **6 m (yellow)**, and **10 m (orange)**. In addition to each tree location, the graph shows three other parameters: Humidity (%), Rain (mm), and Air Temperature (°C).

Several inferences can be drawn from this graph:

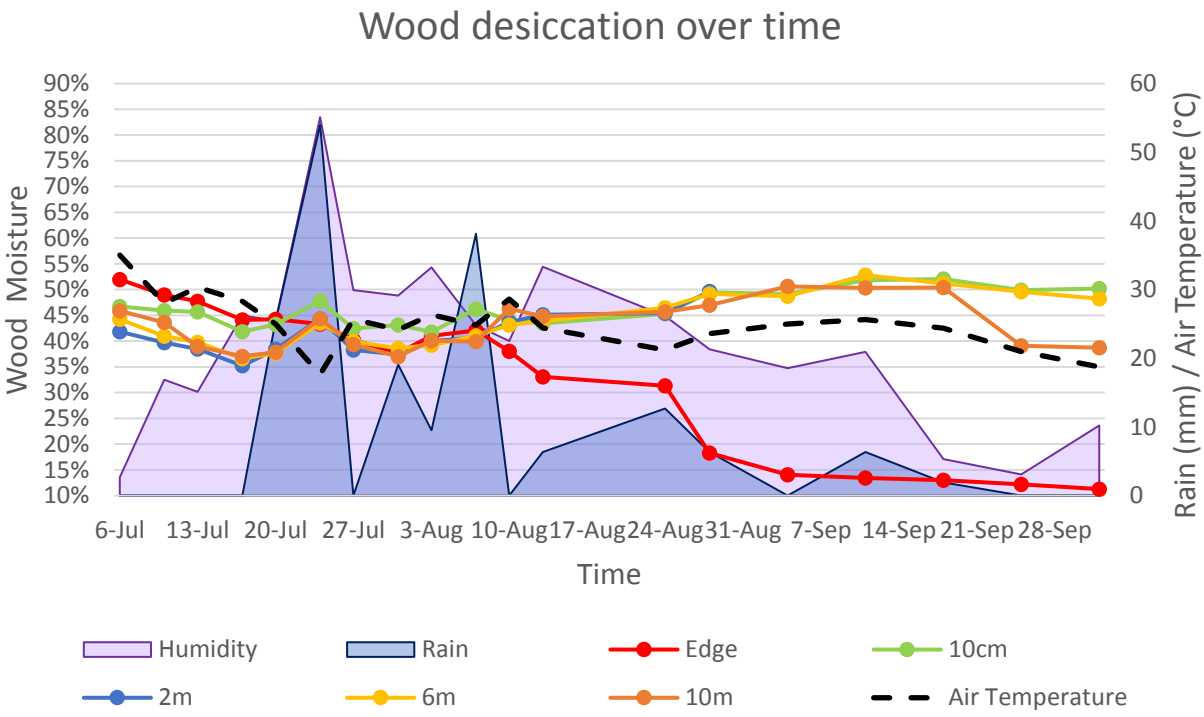
1- Our initial measurements indicated that the wood moisture content was somewhere between 40% - 50%.
2- All of the tree regions (except for the edge) reached their lowest moisture content right before the monsoons started with a moisture content of 33% - 38%. After these tree locations were rained over, their moisture content increased to about 40% - 50% (back to where they were before monsoons started) and it maintained at about that same level since (except for the Edge, which kept continuously drying).
3- The edge's drying rate pattern is different from the rest of the tree. For approximately one month, the edge was drying at about the same rate in which the rest of the tree locations were drying but

the edge's moisture content started to drop soon after this moment and it continuously dropped since.

4- It seems like all three main effect variables (rainfall, air temperature, and humidity) and maybe even their interactions have an important impact on the wood desiccation process. Proper statistical analysis will help us determine which of these variables (if not all) and which of their interactions (if not all) actually have a significant effect on the wood desiccation process.

Site: Shiner Timber Sale – Williams, AZ

- **A total of five bundles were selected and three trees per bundle were monitored.**



On the graph above, each one of the tree locations that we are monitoring is represented by one specific color as follows: **Edge (red)**, **10 cm (green)**, **2 m (blue)**, **6 m (yellow)**, and **10 m (orange)**. In addition to each tree location, the graph shows three other parameters: Humidity (%), Rain (mm), and Air Temperature (°C).

Several inferences can be drawn from this graph:

1- Our initial measurements indicated that the wood moisture content was somewhere between 42% - 52%.

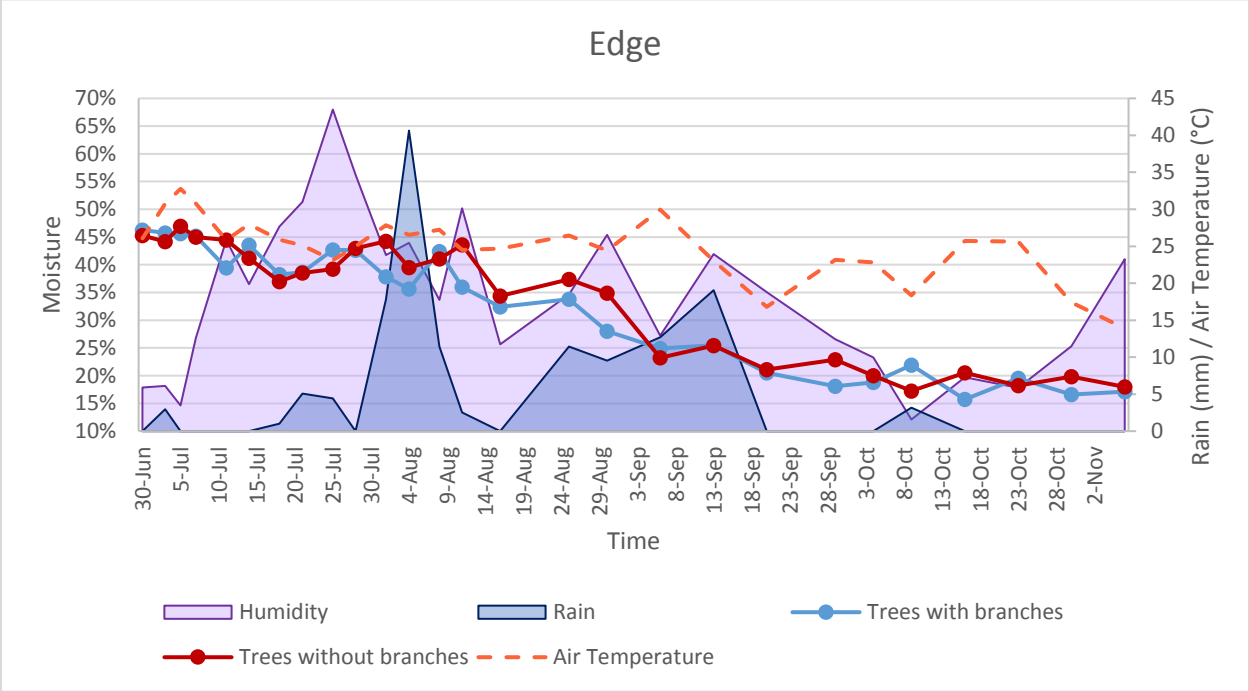
2- All of the tree regions (except for the edge) reached their lowest moisture content right before the monsoons started with a moisture content of 35% - 45%. After these tree locations were rained over, their moisture content increased to about 43% - 47% (close to where they were before monsoons started) and it maintained at about that same level since (except for the Edge, which kept continuously drying).

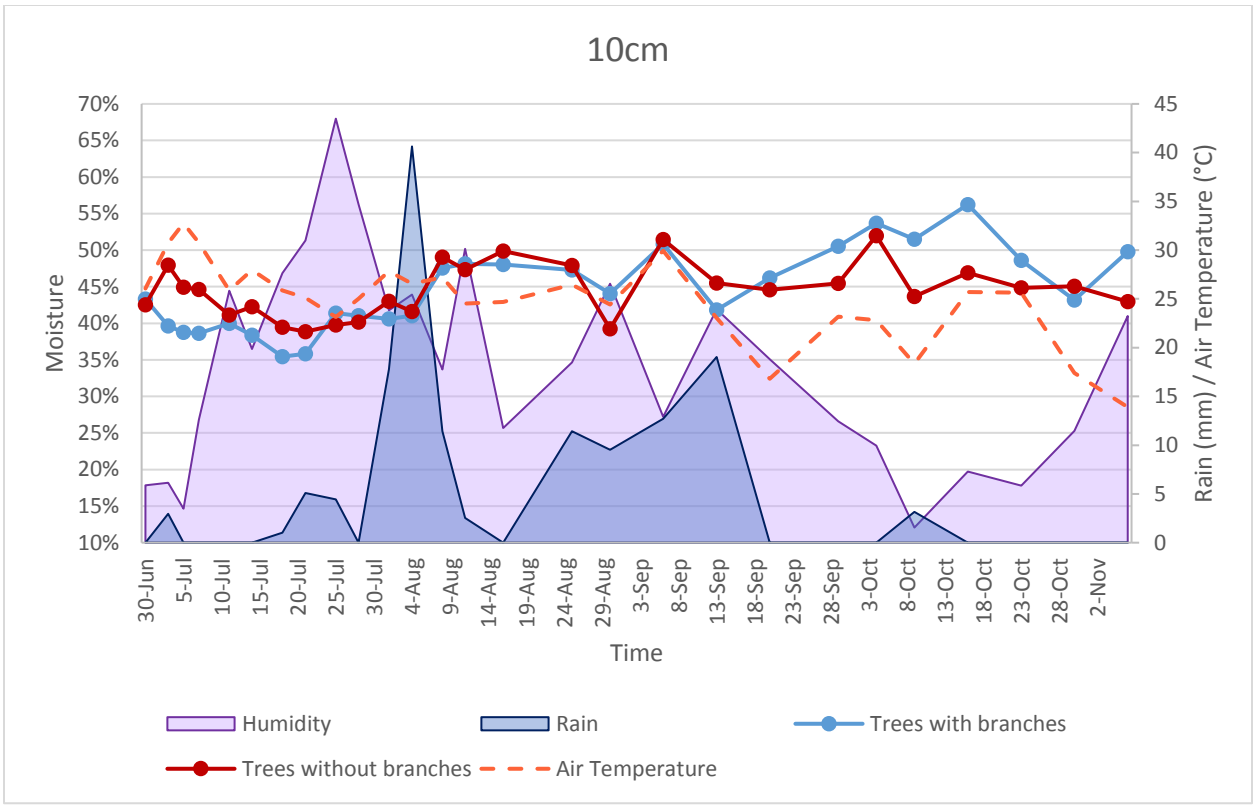
3- The edge's drying rate pattern is different from the rest of the tree. For approximately one month, the edge was drying at about the same rate in which the rest of the tree locations were drying but the edge's moisture content started to drop soon after this moment and it continuously dropped since.

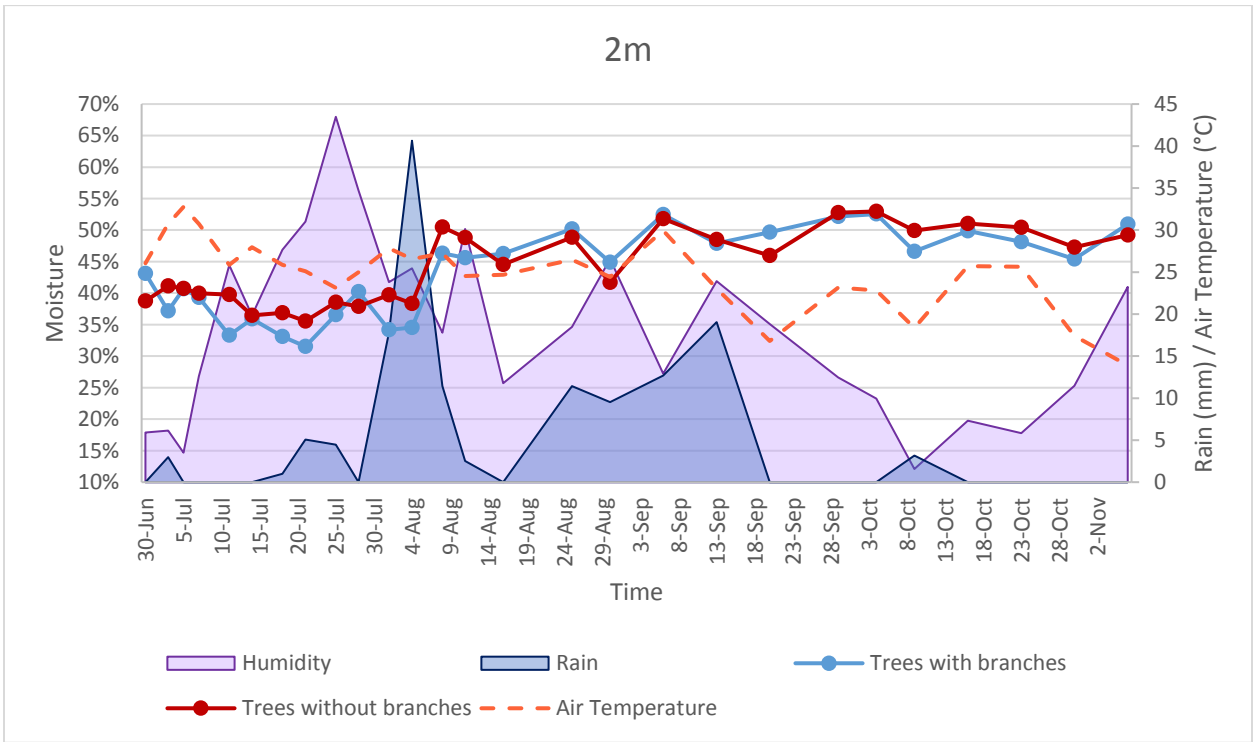
4- Same as in our Observatory Mesa site, it seems like all three main effect variables (rainfall, air temperature, and humidity) and maybe even their interactions have an important impact on the wood desiccation process. Proper statistical analysis will help us determine which of these variables (if not all) and which of their interactions (if not all) actually have a significant effect on the wood desiccation process.

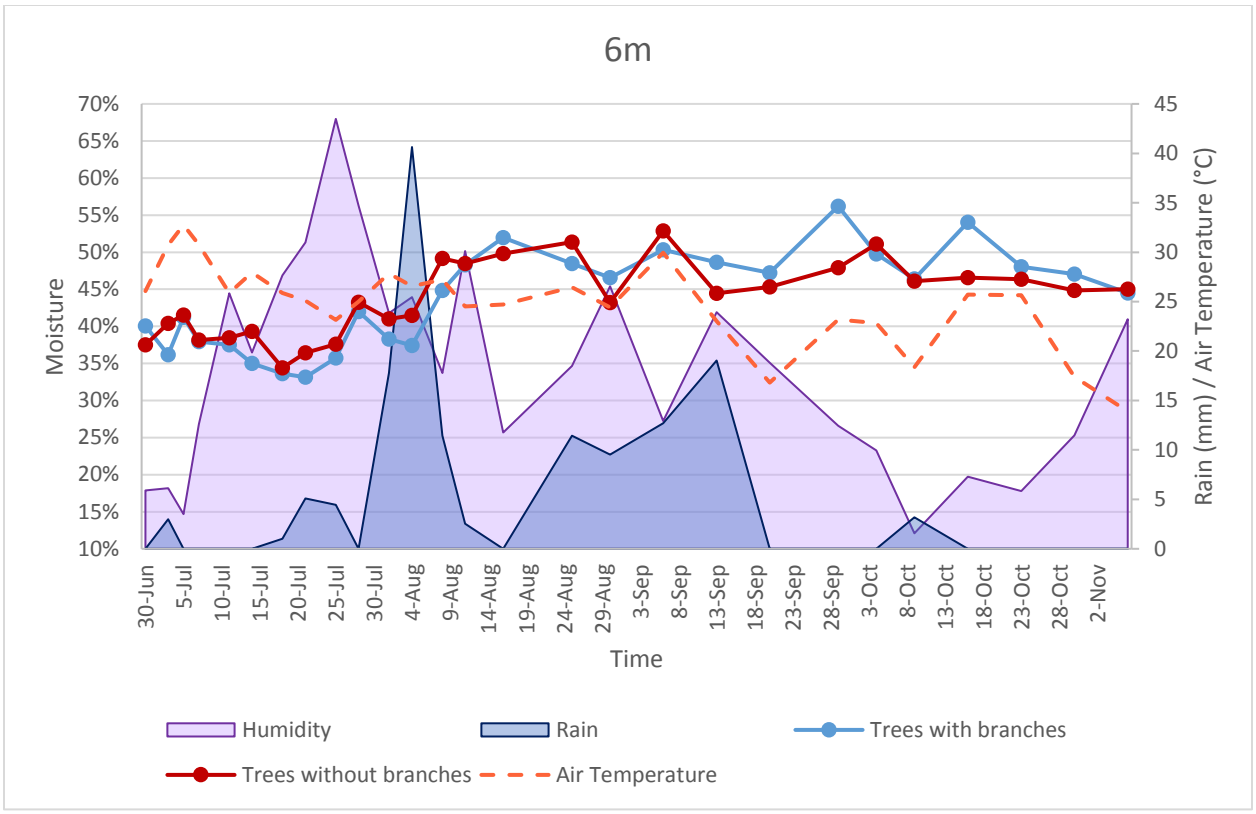
Site: Centennial Forest – Flagstaff, AZ (Paired trees)

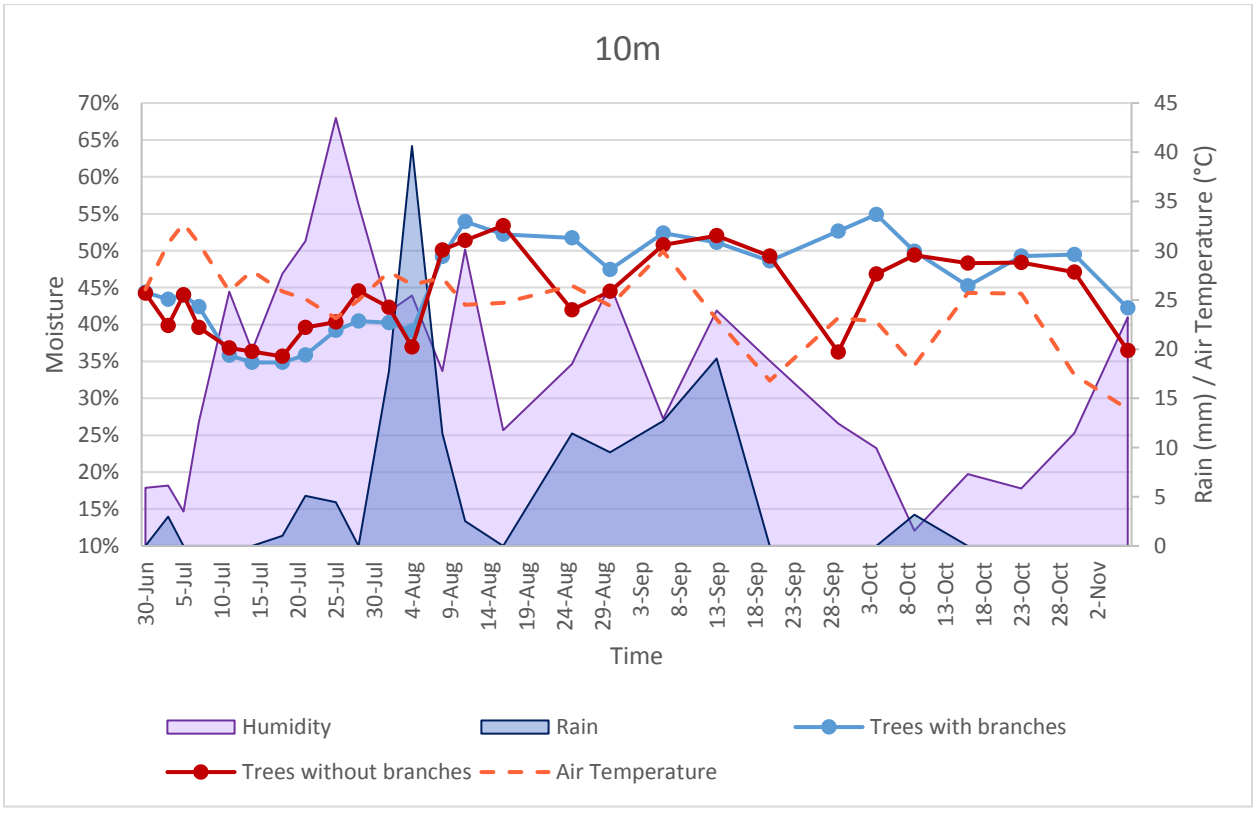
- **A total of five pairs of trees were dropped and all of them were monitored, for a total of 10 trees.**




10cm
Moisture
Rain (mm) / Air Temperature (°C)
Time
70%
65%
60%
55%
50%
45%
40%
35%
30%
25%
20%
15%
10%
45
40
35
30
25
20
15
10
5
0
30-Jun
5-Jul
10-Jul
15-Jul
20-Jul
25-Jul
30-Jul
4-Aug
9-Aug
14-Aug
19-Aug
24-Aug
29-Aug
3-Sep
8-Sep
13-Sep
18-Sep
23-Sep
28-Sep
3-Oct
8-Oct
13-Oct
18-Oct
23-Oct
28-Oct
2-Nov
Humidity
Rain
Trees with branches
Trees without branches
Air Temperature


2m
Moisture
Rain (mm) / Air Temperature (°C)
Time
70%
65%
60%
55%
50%
45%
40%
35%
30%
25%
20%
15%
10%
45
40
35
30
25
20
15
10
5
0
30-Jun
5-Jul
10-Jul
15-Jul
20-Jul
25-Jul
30-Jul
4-Aug
9-Aug
14-Aug
19-Aug
24-Aug
29-Aug
3-Sep
8-Sep
13-Sep
18-Sep
23-Sep
28-Sep
3-Oct
8-Oct
13-Oct
18-Oct
23-Oct
28-Oct
2-Nov
Humidity
Rain
Trees with branches
Trees without branches
Air Temperature


6m
Moisture
70%
65%
60%
55%
50%
45%
40%
35%
30%
25%
20%
15%
10%
Rain (mm) / Air Temperature (°C)
45
40
35
30
25
20
15
10
5
0
30-Jun
5-Jul
10-Jul
15-Jul
20-Jul
25-Jul
30-Jul
4-Aug
9-Aug
14-Aug
19-Aug
24-Aug
29-Aug
3-Sep
8-Sep
13-Sep
18-Sep
23-Sep
28-Sep
3-Oct
8-Oct
13-Oct
18-Oct
23-Oct
28-Oct
2-Nov
Time
Humidity
Rain
Trees with branches
Trees without branches
Air Temperature


10m
Moisture
70%
65%
60%
55%
50%
45%
40%
35%
30%
25%
20%
15%
10%
Rain (mm) / Air Temperature (°C)
45
40
35
30
25
20
15
10
5
0
30-Jun
5-Jul
10-Jul
15-Jul
20-Jul
25-Jul
30-Jul
4-Aug
9-Aug
14-Aug
19-Aug
24-Aug
29-Aug
3-Sep
8-Sep
13-Sep
18-Sep
23-Sep
28-Sep
3-Oct
8-Oct
13-Oct
18-Oct
23-Oct
28-Oct
2-Nov
Time
Humidity
Rain
Trees with branches
Trees without branches
Air Temperature

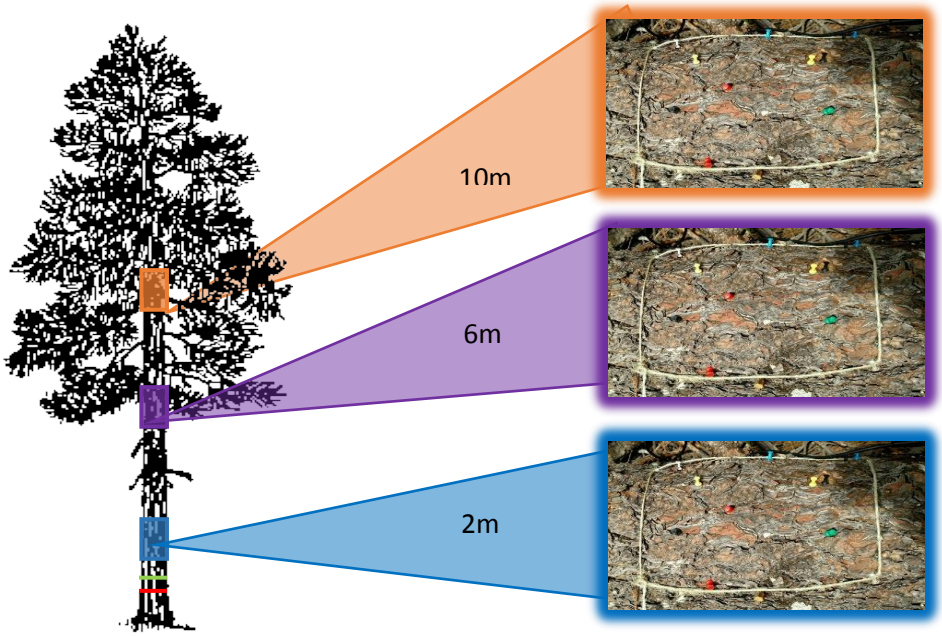
Each one of the five graphs above represents one specific tree location (Edge, 10 cm, 2 m, 6 m, and 10 m). Each one of these graphs contains information regarding the wood desiccation process for both trees with branches and trees without branches; along with their main effects (rainfall, air temperature, and humidity).

Several inferences can be drawn from these graphs:

1- Our initial measurements indicated that the wood moisture content was somewhere between 40% - 45%.
2- All of the tree regions (except for the edge) reached their lowest moisture content right before the monsoons started with a moisture content of 33% - 37%. After these tree locations were rained over, their moisture content increased to about 50% - 54% (even higher than our initial measurements) and it maintained at about that same level since (except for the Edge, which kept continuously drying).
3- The edge's drying rate pattern is different from the rest of the tree. For approximately one month, the edge was drying at about the same rate in which the rest of the tree locations were drying but the edge's moisture content started to drop soon after this moment and it continuously dropped since.
4- Same as in our other two sites, it seems like all three main effect variables (rainfall, air temperature, and humidity) and maybe even their interactions have an important impact on the wood desiccation process. Proper statistical analysis will help us determine which of these variables (if not all) and which of their interactions (if not all) actually have a significant effect on the wood desiccation process.
5- There does not seem to be a distinct difference in the wood desiccation process between trees with branches and trees without branches.

➢ Section 2- Beetle attacks

- **A total of five bundles were selected and three trees per bundle were monitored, for a total of 15 trees.**



Each monitored tree had three 8 ½" x 11" -survey plots at different locations: 2 m, 6 m, and 10m; as shown on this diagram.

Site: Observatory Mesa, Section 8 – Flagstaff, AZ

Bark Beetles			
Tree location	**Total number of attacks**	**Number of survey plots**	**Average number of attacks**
2m	32	15	**2.1**
6m	98	14	**7.0**
10m	74	9	**8.2**

Wood Borers			
Tree location	**Total number of attacks**	**Number of survey plots**	**Average number of attacks**
2m	27	15	**1.8**
6m	26	14	**1.9**
10m	11	9	**1.2**

Ambrosia Beetles			
Tree location	**Total number of attacks**	**Number of survey plots**	**Average number of attacks**
2m	8	15	**0.5**
6m	14	14	**1.0**
10m	3	9	**0.3**

1. Bark beetle attacks are more common in the higher (branched) locations of the tree: 10 m, 6 m; with an average of 8.2 and 7.0 attacks per survey plot, respectively.
2. Wood borers seems to prefer the lower (unbranched) locations of the tree: 6 m, 2 m; with an average of 1.9 and 1.8 attacks per survey plot, respectively.
3. Ambrosia beetles tend to attack the middle section of the tree more often: 6 m, with an average of 1 attack per survey plot.

Site: Shiner Timber Sale –Williams, AZ

- **A total of five bundles were selected and three trees per bundle were monitored, for a total of 15 trees.**

Bark Beetles			
Tree location	**Total number of attacks**	**Number of survey plots**	**Average number of attacks**
2m	15	15	**1.3**
6m	87	15	**5.9**
10m	55	6	**9.7**

Wood Borers			
Tree location	**Total number of attacks**	**Number of survey plots**	**Average number of attacks**
2m	2	15	**0.1**
6m	1	15	**0.1**
10m	0	6	**0**

Ambrosia Beetles			
Tree location	**Total number of attacks**	**Number of survey plots**	**Average number of attacks**
2m	0	15	**0**
6m	0	15	**0**
10m	0	6	**0**

1. Bark beetle attacks are more common in the higher (branched) locations of the tree: 10 m, 6 m; with an average of 9.7 and 5.9 attacks per survey plot, respectively.
2. Wood borers seems to prefer the lower (unbranched) locations of the tree: 6 m, 2 m; with an average of 0.1 attacks per survey plot.
3. We did not get any Ambrosia beetle attacks in this site.

Site: Centennial Forest –Flagstaff, AZ (Paired trees)

- **A total of five pairs of trees were dropped and all of them were monitored, for a total of 10 trees.**

Bark beetles					
Tree location	**Total number of attacks – Trees with branches**	**Total number of attacks – Trees without branches**	**Number of survey plots**	**Average number of attacks – Trees with branches**	**Average number of attacks – Trees without branches**
2m	38	53	5	7.6	10.6
6m	93	69	5	18.6	13.8
10m	102	60	4	25.5	15.0

On average, bark beetles seem to prefer the branched areas of the tree (10 m) but attacks were more prominent in trees with branches with 25.5 attacks per survey plot vs. 15.0 attacks per survey plot in trees without branches.

Wood borers					
Tree location	**Total number of attacks – Trees with branches**	**Total number of attacks – Trees without branches**	**Number of survey plots**	**Average number of attacks – Trees with branches**	**Average number of attacks – Trees without branches**
2m	3	1	5	0.6	0.2
6m	7	2	5	1.4	0.4
10m	11	2	4	2.8	0.5

On average, wood borers seem to prefer the branched areas of the tree (10 m) but attacks were more prominent in trees with branches with 2.8 attacks per survey plot vs. 0.5 attacks per survey plot in without branches trees.

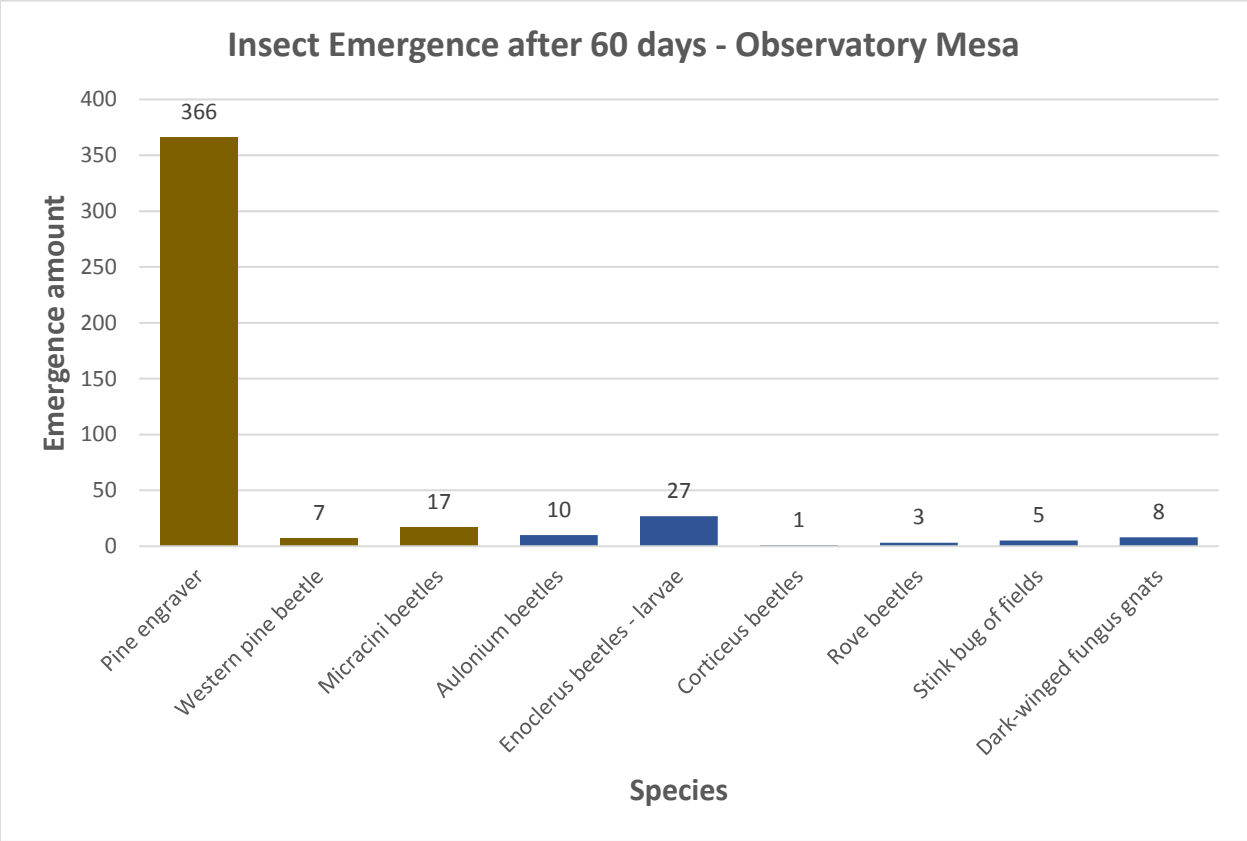
Ambrosia beetles					
Tree location	**Total number of attacks – Trees with branches**	**Total number of attacks – Trees without branches**	**Number of survey plots**	**Average number of attacks – Trees with branches**	**Average number of attacks – Trees without branches**
2m	5	1	5	1.0	0.2
6m	1	1	5	0.2	0.2
10m	5	0	4	1.25	0

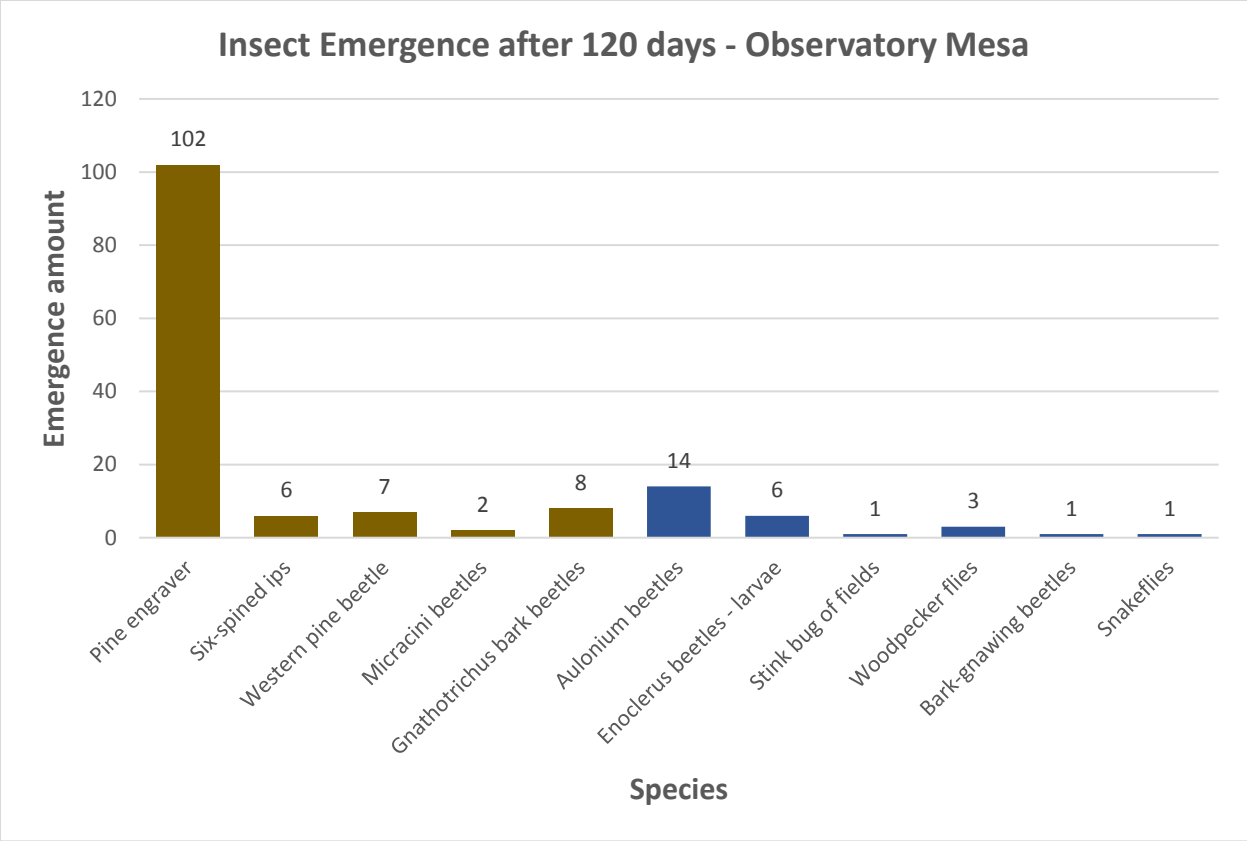
There is no evident distinct pattern of attacks for ambrosia beetles. In branched trees, attacks are higher both closer to the base of the tree (2 m) as well as high up at branch level (10 m). In trees without branches, it seems like these beetles prefer the lower and middle region (2 m and 6 m).

➢ Section 3 – Insect Emergence chambers

- **After 60 days of moisture recordings, we cut a total of 15 one-foot chunks (bolts), three from each tree location on every bundle. The bolts were then brought to the laboratory and placed inside of emergence chambers. A weekly count of the species and their respective amount was performed for eight weeks. The same was done after 120 days of moisture recordings. This protocol was applied to both our Observatory Mesa and Shiner Timber Sale sites.**

Site: Observatory Mesa, Section 8 – Flagstaff, AZ



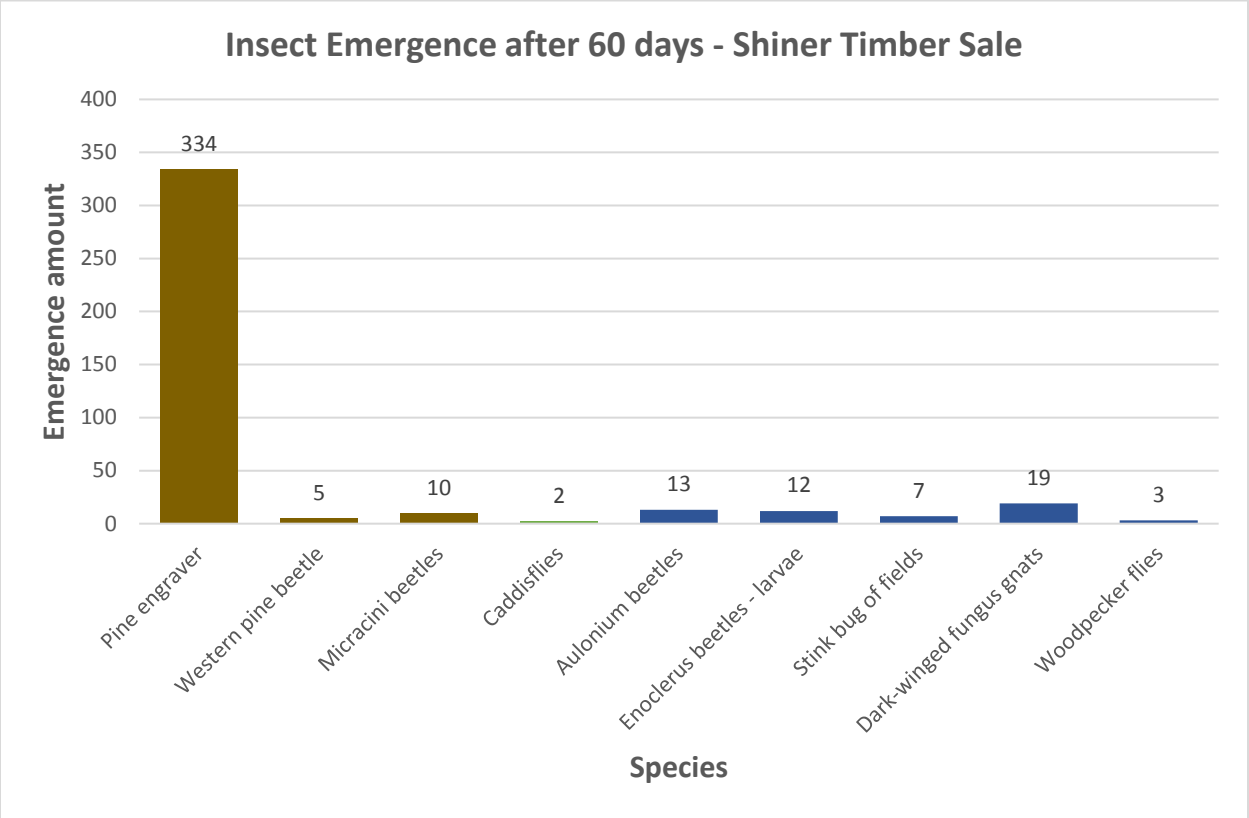


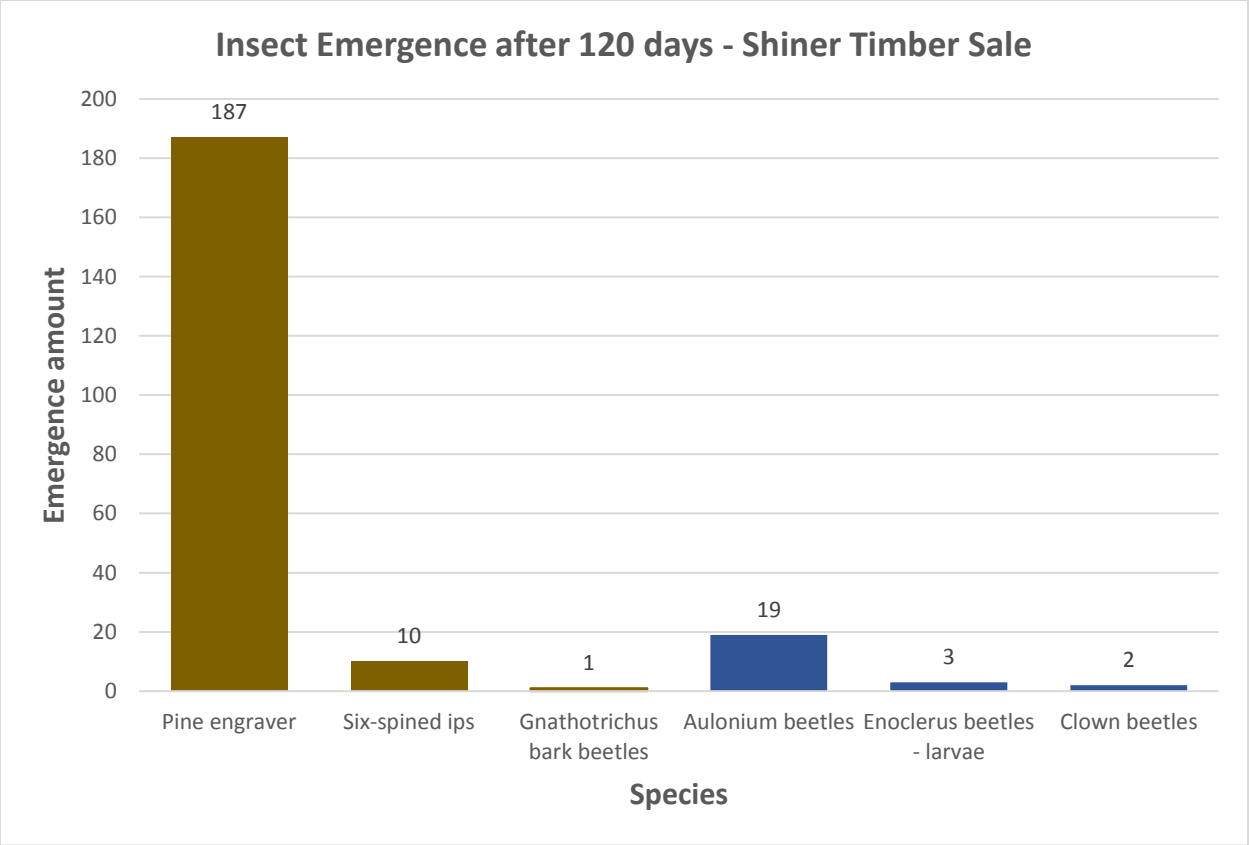
On the graphs above, **bark beetles** are represented in **brown** and their **natural enemies/predators** are represented in **blue**.

Several inferences can be drawn from these graphs:

1- There were more insects coming out of the bolts after 60 days than after 120 days (444 vs. 151, respectively – Almost 4 times as much).
2- In terms of biodiversity, there was a higher number of insect species after 120 days than after 60 days (11 vs. 9, respectively). Although there was a higher number of bark beetle natural enemies/predators after 60 days than after 120 days (54 vs. 26, respectively – Almost twice as much).
3- Though the biodiversity of bark beetles was higher after 120 days, the raw number of bark beetle emergence was higher after 60 days (390 vs. 125), which suggests that the bundles are more prone to bark beetle attacks during the first 60 days after they have been stacked.

Site: Shiner Timber Sale – Williams, AZ





On the graphs above, **bark beetles** are represented in **brown** and their **natural enemies/predators** are represented in **blue**.

Several inferences can be drawn from these graphs:

1- There were more insects coming out of the bolts after 60 days than after 120 days (405 vs. 222, respectively – Almost twice as much).
2- In terms of biodiversity, contrarily to our findings in Observatory Mesa, there was a higher number of insect species after 60 days than after 120 days (9 vs. 6, respectively). There was also a higher number of bark beetle natural enemies/predators after 60 days than after 120 days (54 vs. 25, respectively).
3- Biodiversity of bark beetles was higher after 60 days and so was the raw number of bark beetle emergence (349 vs. 197), which suggests that the bundles are more prone to bark beetle attacks during the first 60 days after they have been stacked.