Barriers to Recruitment of Cottonwoods on the Northern Range of Yellowstone National Park

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1.0 Introduction:

Research on riparian ecosystems over the past three decades has provided a better understanding of the vital role these ecosystems play in water storage, sediment retention, nutrient and contaminant removal, and as habitat for wildlife (NRC 1995, 2002b). The utilization of riparian ecosystems by wildlife has been shown to be disproportionate to its contribution in the landscape (Thomas 1979, Anderson et al. 1983, Yong W. 2002). This heavy use by some wildlife species may be detrimental to riparian habitats in some regions, for example in some national parks (NRC 2002).

Research to date has largely focused on elk herbivory as the limitation to cottonwood recruitment. Dendrochronological (Keigley 1997)and structural (Keigley 1998) analysis has been performed on several cottonwood stands in Yellowstone's northern range. This was followed by an analysis of predation risk and cottonwood height (Ripple and Beschta 2003). Beschta (Beschta 2003) utilized tree cores collected previously (Keigley 1997) to establish a relationship for tree age at breast height and diameter at breast height. He compared the ages to records of wolf occurrence in Yellowstone as well as discharge of the Lamar and Yellowstone Rivers. Beschta (Beschta 2005) explored sexual vs. asexual reproduction using visual metrics and expanded the data set of tree age at breast height by coring two stands located outside of Yellowstone. He concluded that intense herbivory by elk over the period of wolf extirpation was most likely the cause of reduced cottonwood recruitment in Yellowstone. Recent research suggests that elk herbivory is indirectly related to the decline of willow and aspen, and that hydrologic changes due to local beaver extirpation have directly effected willow and aspen decline (Brown et al. 2006, Wolf 2007).

The limitations of research completed to date include: (1) conclusions based on tree ages at breast height, unknown plant ages with unknown error among trees, (2) little analysis of recruitment processes, and (3) little consideration of possible barriers to recruitment other than elk herbivory. The research by Keigley and Beschta consider breast height increment cores to represent tree age when an estimate of the time to reach breast height is included. However, floodplain species like cottonwoods require the tree to be harvested and the germination point found to accurately determine age (Everitt 1968, Scott et al. 1996, Cooper et al. 2003) and even to determine the approximate time trees need to reach breast height in the study area. In addition to stem burial issues, heavy browsing of woody species may prevent plants from increasing in diameter and height and there may be little correlation between size and age in smaller size classes of heavily browsed plants.

Research on sexual vs. asexual reproduction was based on visual parameters, and research using genetic analysis indicates that substrate and distance from a larger tree may not accurately reflect the method of reproduction (Roberts 1999). However, these measures were utilized by Beschta (Beschta 2005). There have been no local hydrologic analyses at any site to address the influence of climate variables on seedling establishment. Over the period of wolf extirpation there have been few flood events large enough to allow sexual reproduction (Baker 1990, Beschta 2003) and cottonwood stands have been found that established following larger floods in the 1970's (Keigley 1997).

2.0 Methods:

2.1.0 Study Site:

This study was performed on the Northern Range of Yellowstone National Park. Within the Northern Range portions of the Gardiner River, Lamar River and Soda Butte Creek were selected as study reaches (Fig. 1)

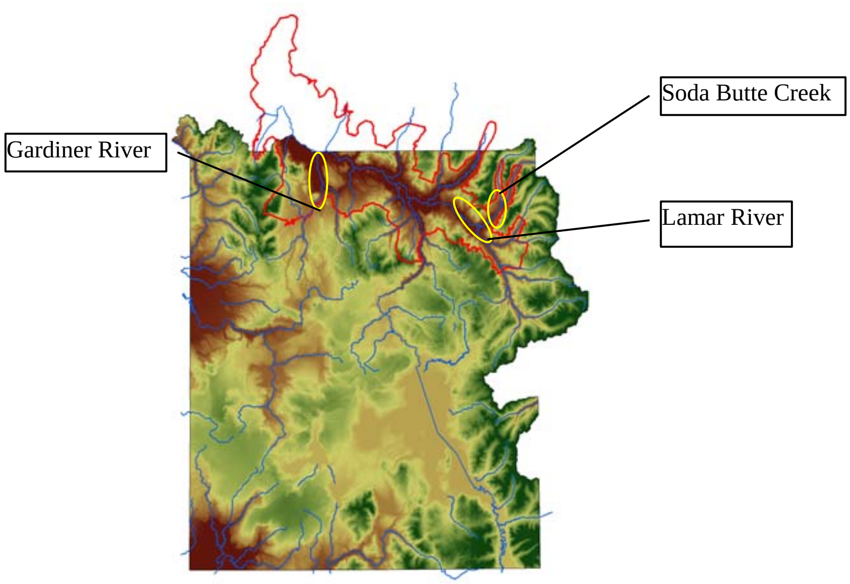

Figure 1: Location of Study sites in the Northern Range of YNP.

2.2.0 Mapping:

2.2.1 Catkin Bearing Trees:

Each catkin bearing tree 10 cm in diameter and larger was mapped along the Gardiner, Soda Butte, and Lamar Rivers using a hand held Trimble® GPS unit. Mapping occurred from late May 2007 through early July 2007. Each tree was placed into one of four size classes based on bole diameter at the ground surface using a Biltmore stick. Two measurements were taken for each tree and averaged to determine the final size class. In addition size classes, individuals were divided into species and sex. Species was determined based upon leaf and bole morphology, bole diameter, and overall plant structure. Sex was determined by the presence or absence of female catkins.

2.2.2 Suppressed Trees and Seedlings:

Suppressed trees and seedlings stands were mapped as polygons due to the number of individuals present. Each stand was classified as PT (*Populus trichocarpa*), PA (*Populus angustifolia*), HY (hybrid), and MXD (mixed) stands. Stands were delineated based upon landform and similar densities as visually assessed in the field.

2.3.0 Densities:

Densities were determined for 50% of the polygons mapped. Polygons were selected using the random selection tool in ARCGIS®. Within each polygon five points were generated using the random point generation tool in ARCGIS®. During field sampling the number sample point selected in each polygon was determined at the site based upon variability of densities with in the polygon. A variable plot size was used based upon apparent densities. If the density appeared to be less than one plant per m^2 larger plots were used and varied in size from four to 100 m^2. When densities were estimated to be greater than one plant per m^2 a plot of one m^2 was used. The number of plots per polygon varied based upon the apparent variability within the polygon estimated visually and the overall size of the polygon.

Calculation for the estimate of the total population was weighted based upon the area sampled relative to the total area in each reach. This was done to avoid an over estimate caused by an increase in the average density from stands with unusually high densities but low areal extent.

2.4.0 Tree Harvest:

Maximum size of trees selected for harvest was set at a ground basal diameter of less than 30 cm and a height of less than 6.1 m. Trees were selected to distribute harvest throughout the research area and give an even distribution of size classes among the trees sampled. When a tree was selected for harvest the ground surface was marked and the plant was excavated using hand tools. The tree was excavated to a depth sufficient to ensure the point of germination was collected. The plant height and diameter were measured in when the plant was of sufficient size cross-sections were collected at 30, 80, 150, 200, 300, and 400 cm.

2.5.0 Asexual Reproduction Sample Collection and Analysis:

A group of 26 catkin bearing trees along Soda Butte Creek were selected for sampling of genetic material to determine the relationship between individuals. The Soda Butte Creek area was selected because during tree harvest the greatest concentration of asexual reproduction occurred in this area. A sub-sample of the trees that occur along the creek was sampled based upon the proximity of individuals to one another. Leaves were collected from each individual and placed into desiccant until stored in a -80ºC freezer. DNA was extracted from each sample and ISSR analysis was performed. Resulting gels were then scored for presence or absence of a band and these scores were compared to determine if samples were genetically similar.

In addition to the collection of genetic material in catkin bearing trees during excavation of smaller trees for aging, mode of reproduction was noted and analyzed separately.

3.0 Results:

3.1.0 Demographics of Catkin Bearing Trees:

A total of 1,102 catkin bearing trees were mapped in the study area. A total of 402, 589, and 111 trees were mapped in the Gardiner, Lamar, and Soda Butte reaches respectively. Across all three reaches there were more males than females. Immature plants comprised a small proportion of the population in the Gardiner and Lamar reaches with an absence of immature plants from the Soda Butte reach (Table 1).

	Gardiner	Lamar	Soda Butte	Total
Male	58.5	52.5	56.8	55.1
Female	36.8	45.3	43.2	42.0
Immature	4.7	2.2	0.0	2.9

Table 1: Percent male, female, and immature trees in the population by reach.

The distribution of species is highly variable between reaches. In both the Gardiner and Lamar reaches hybrids composed the greatest portion of the population, however, in the Soda Butte reach nearly all catkin bearing trees are *Populus angustifolia* (Table 2). *Populus trichocarpa* is absent from the Gardiner and Soda Butte reaches and is only present in the upper most section of the Lamar (Table 2).

	Gardiner	Lamar	Soda Butte	Total
Poan	46.3	22.9	97.3	38.9
Potr	0.0	4.1	0.0	2.2
Hybrid	53.7	73.0	2.7	58.9

Table 2: Percent of each species in the population by reach.

The distribution of diameter classes between the study reaches exhibited similar trends between the Lamar, Soda Butte, and overall distribution with the fewest trees in the smallest and largest diameter classes; however, the Gardiner reach maintained the largest proportion of trees in the smallest two size classes (Table 3).

	Gardiner	Lamar	Soda Butte	Total
10-30 (cm)	25.1	5.3	14.4	13.4
30-50 (cm)	46.8	24.4	55.9	35.8
50-70 (cm)	20.4	34.0	25.2	28.1
70-100 (cm)	4.2	21.7	3.6	13.5
100+ (cm)	3.5	14.6	0.9	9.2

Table 3: Percent of each diameter class in the population by reach.

3.1.1 Genetic Analysis of Reproductive Mode in Catkin Bearing Trees:

Analysis of genetic material shows that 44% of reproduction is asexual within the sampled sub-stand along Soda Butte Creek. Of the 26 individuals sampled DNA extraction was unsuccessful on one individual. Within the successful extractions 14 individuals exhibited identical banding with at least one other individual in the sample. From this sample one individual was subtracted from each match to account for the sexual propagation of a parent plant leaving 8 asexual reproduced individuals (Fig. 2 and Fig. 3).

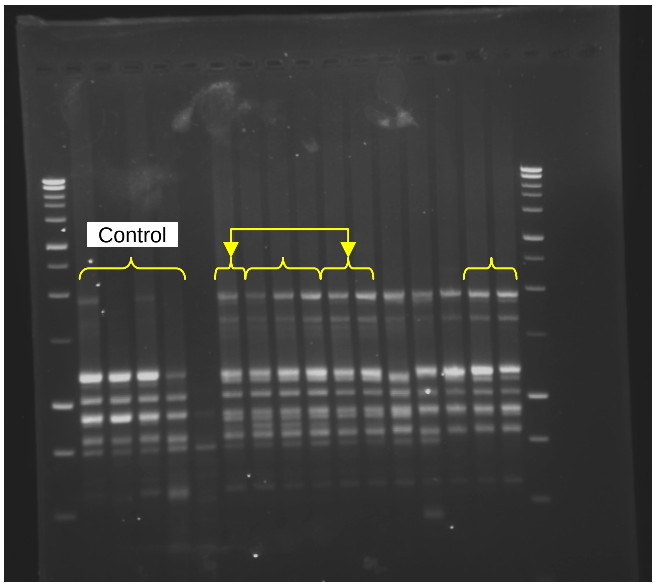

Figure 2: Genetic analysis of control and samples 1 thru 12 from Soda Butte Creek.

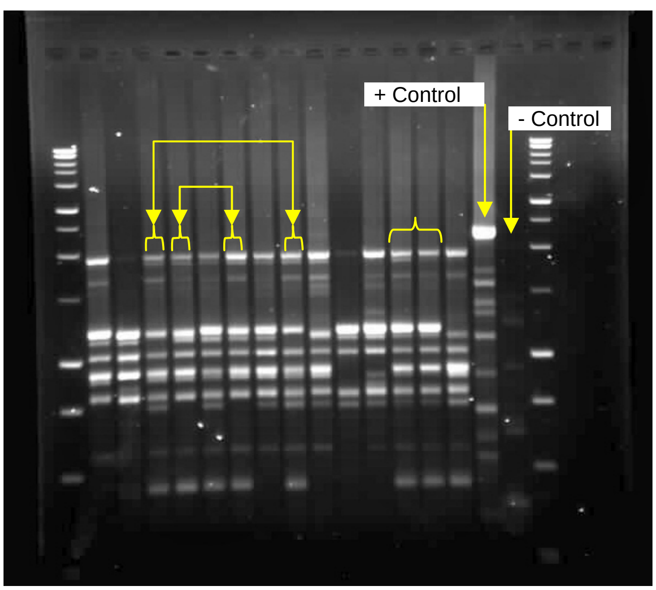

Figure 3: Genetic analysis of samples 13 thru negative control from Soda Butte Creek.

3.2.0 Suppressed Tree and Seedling Stand Mapping and Densities:

A total of 226 suppressed tree and seedling stands were mapped within the 3 reaches. These stands contain approximately 1,811,525 plants across 325,879 m^2 (Table 4). The Lamar reach contained nearly 4 times as many stands as the Soda Butte reach and 8 times the number of stands as the Gardiner reach. The Lamar reach also contained a higher density of plants within the stands than the Gardiner and Soda Butte reaches.

	Gardiner	Lamar	Soda Butte	Total
Number of Stands	20	161	45	226
Total Area (m^2)	15675	230152	80053	325879
Average Density (plants/m^2)	2.7	9.1	2.2	
Estimated Population	42685	1681745	87095	1811525

Table 4: Number of stands, total area, average density and estimated population of new stand by reach and in aggregate for the study area.

3.2.1 Age Distributions and Mode of Reproduction in Suppressed Tree and Seedling Stands:

A total of 93 trees were aged with 51, 33, and 9 samples divided between the Lamar, Gardiner, and Soda Butte reaches respectively. Samples collected from the Gardiner and Lamar reaches were limited to establishment within the 30 years with the majority occurring in the last 15 years (Fig. 4). The Soda Butte creek reach differed significantly with establishment from as long ago as 1938, however, this is a minimum age due to heart rot in the main stem of the plant and the age was acquired from a rhizome near the main stem. The Soda Butte also differs from the other reaches in that it has a continuous record of recruitment for the past 50 years (Fig. 4).

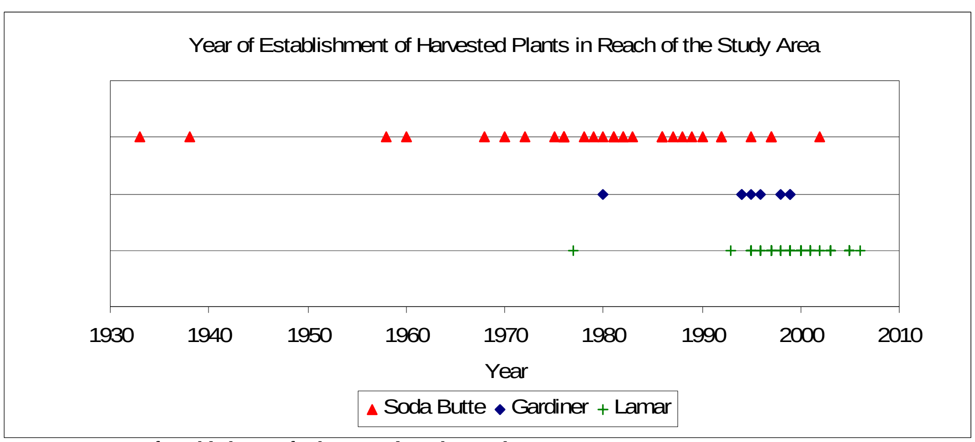

Figure 4: Year of establishment for harvest plants by reach.

Reproductive mode varied significantly between study reaches. The Gardiner and Lamar study reaches exhibited little asexual reproduction with 0 and 1 asexually produced plants found respectively (Table 5). Excavation of plants yielded similar results as genetic analysis with asexual reproduction in 48% of plants identified from excavation data and 44% from genetic analysis.

	Gardiner	Lamar	Soda Butte
Number of samples from reach	9	51	33
Number of asexually produced plants	0	1	16
Percent asexual reproduction	0	2	48

Table 5: Number of plants sampled and associated asexual reproductive rates by reach.

4.0 Discussion:

The results of germination experiments were not reported. The first iteration of this experiment did not succeed due to human error and will be carried out during the 2008 field season. While the germination experiment was unsuccessful, there were several other significant advances in the understanding of cottonwoods on the Northern Range of YNP. The three most significant findings from this research are: (1) discovery of continuous recruitment over the past 50 years along Soda Butte Creek, (2) a recognition of intersectional hybrids as a significant portion of the cottonwood population, and (3) the population estimates for each study reach. Each of these findings is in contrast to previous studies (NRC 2002b, Beschta 2003). It is the intent of this project to continue to develop a better understanding of the factors influencing the recruitment of cottonwoods on the northern range of YNP.

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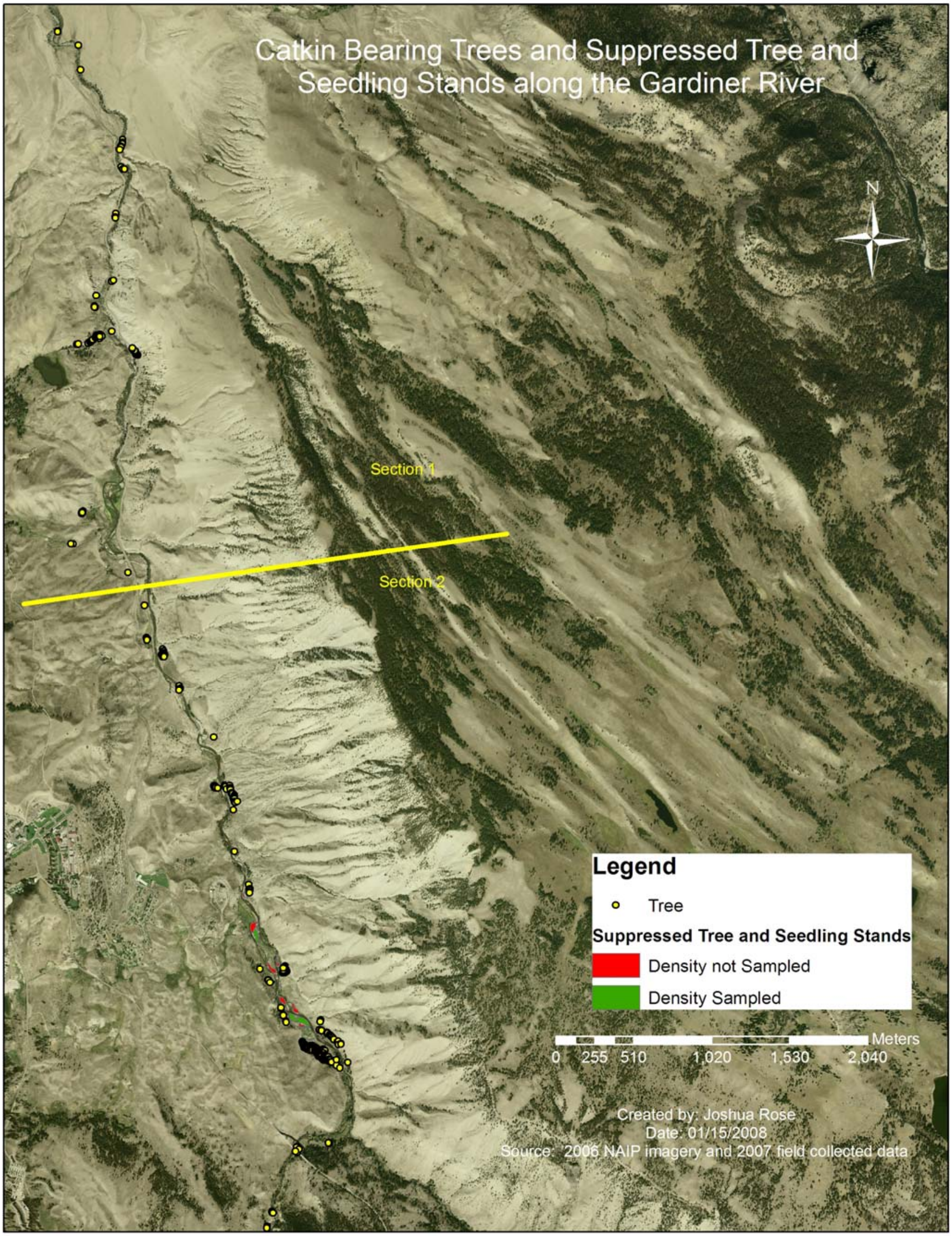
Appendix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Suppressed Tree and Seedling Stands
Density not Sampled
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Meters
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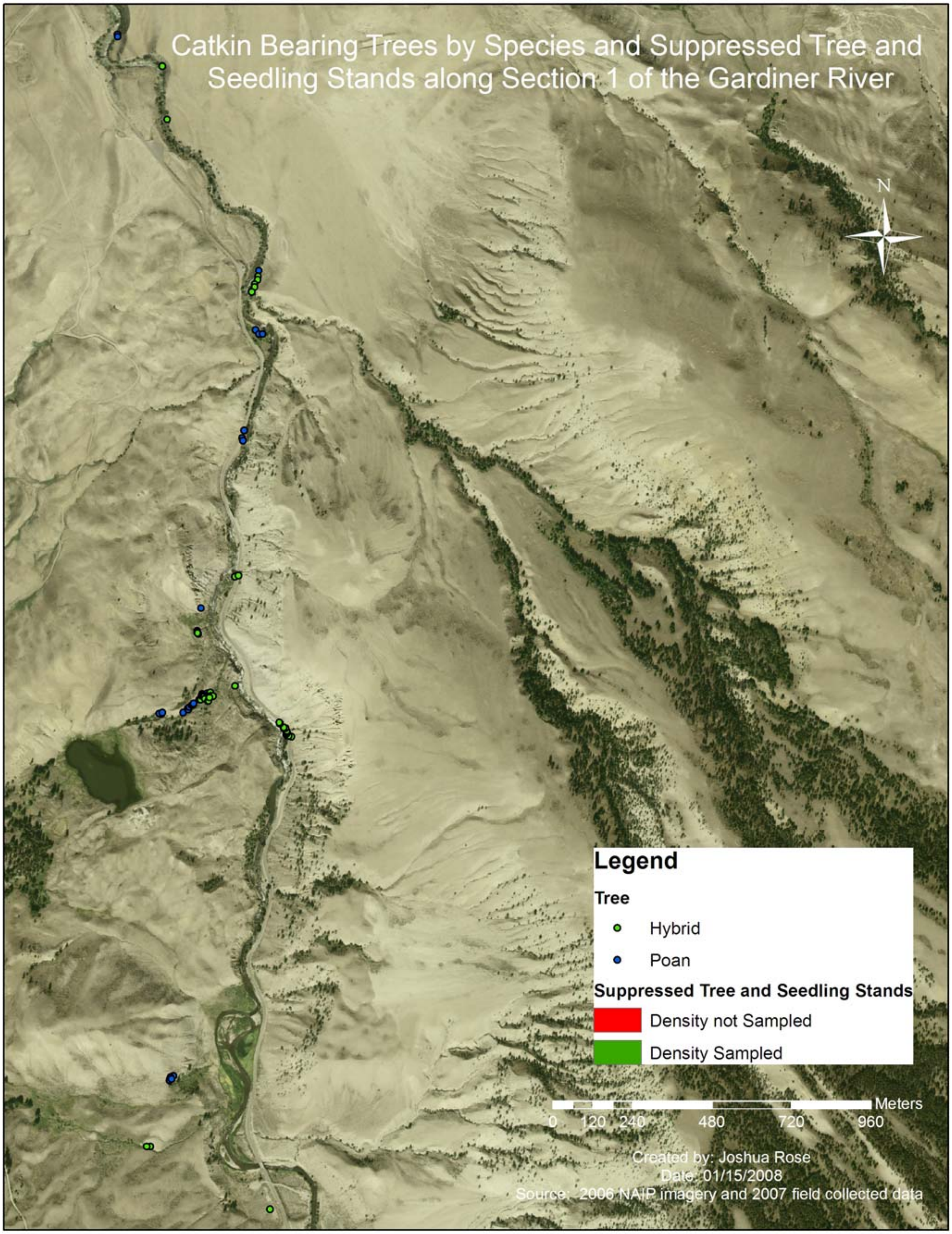
Catkin Bearing Trees by Species and Suppressed Tree and Seedling Stands along Section 1 of the Gardiner River
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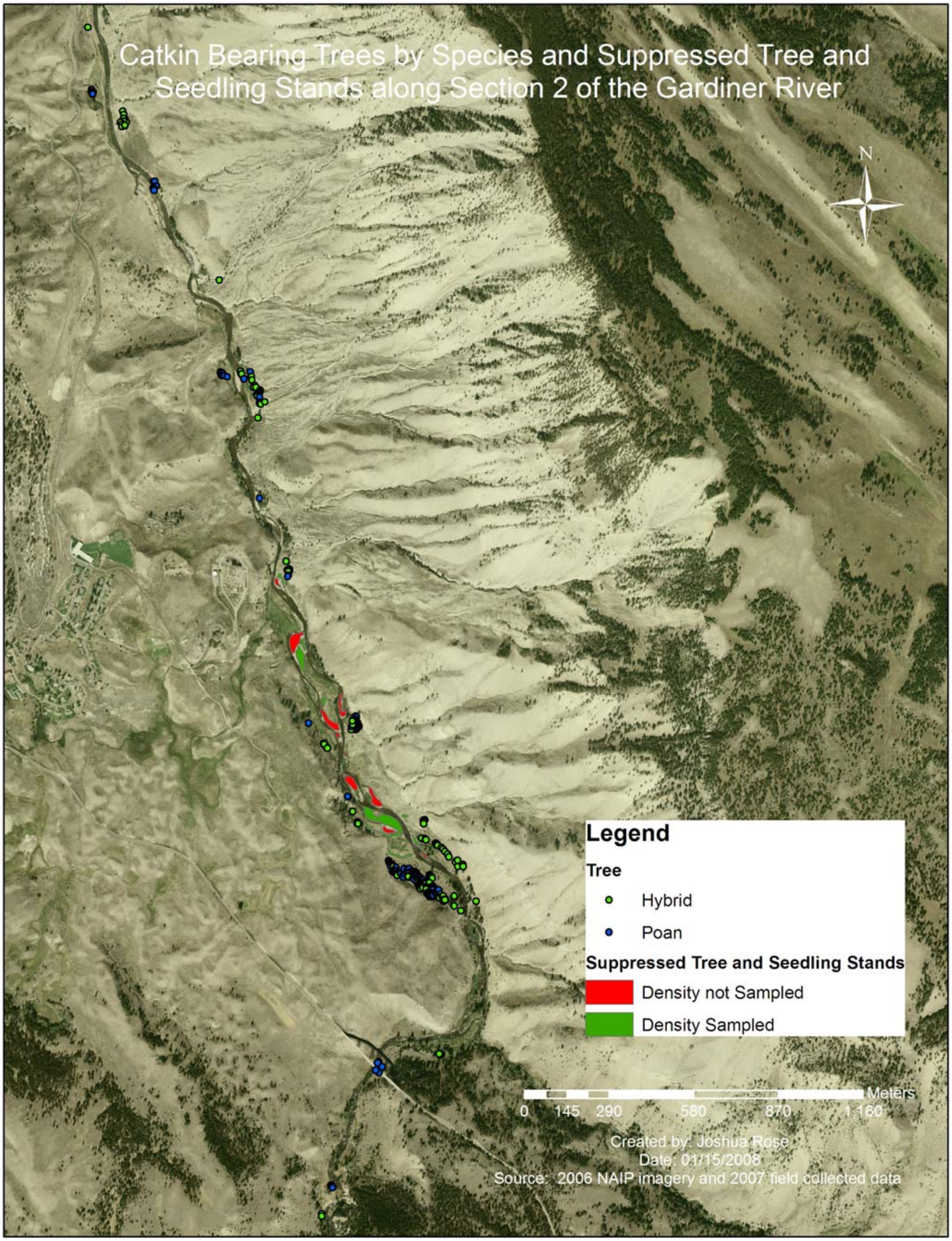

Catkin Bearing Trees by Species and Suppressed Tree and Seedling Stands along Section 2 of the Gardiner River
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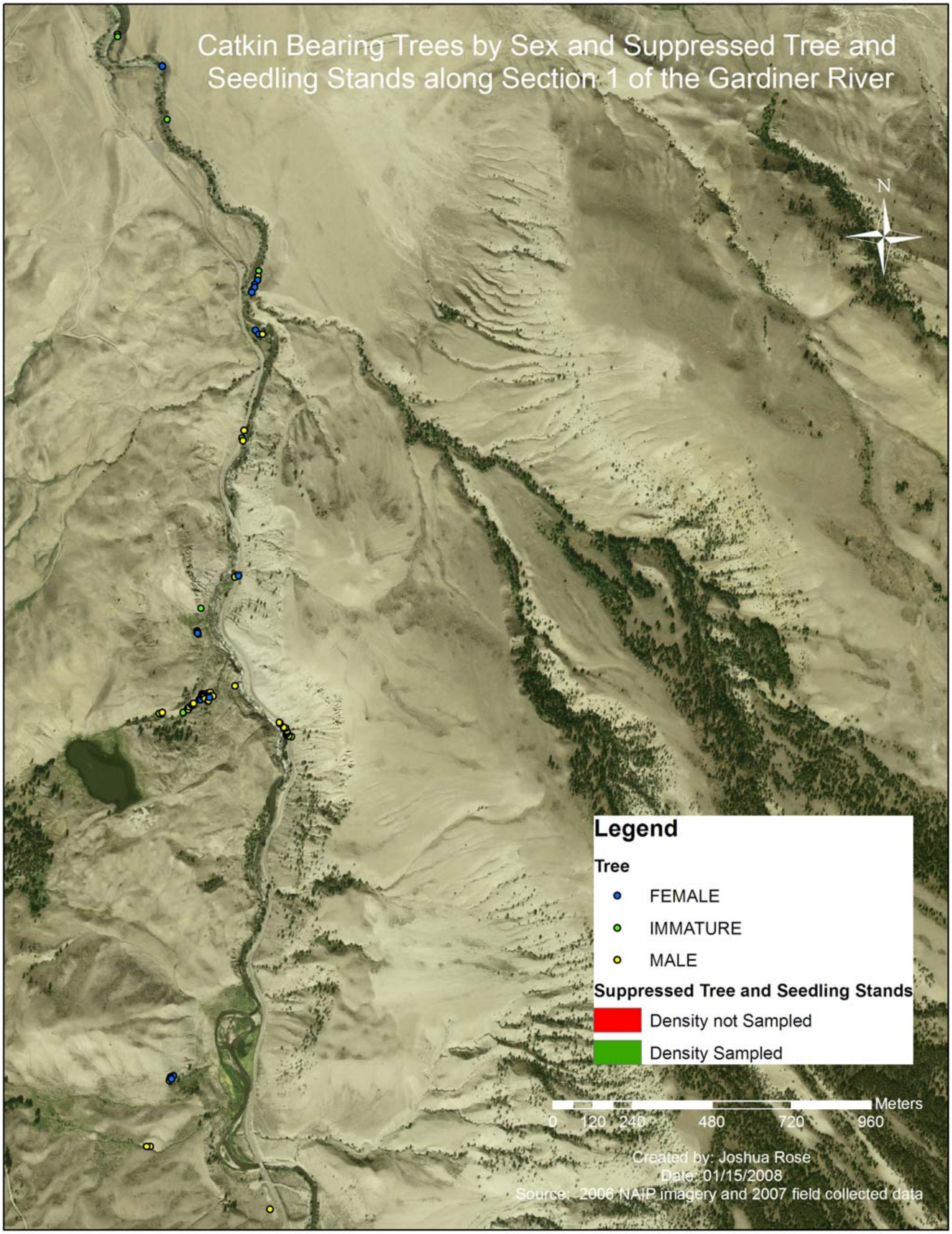

Catkin Bearing Trees by Sex and Suppressed Tree and Seedling Stands along Section 1 of the Gardiner River
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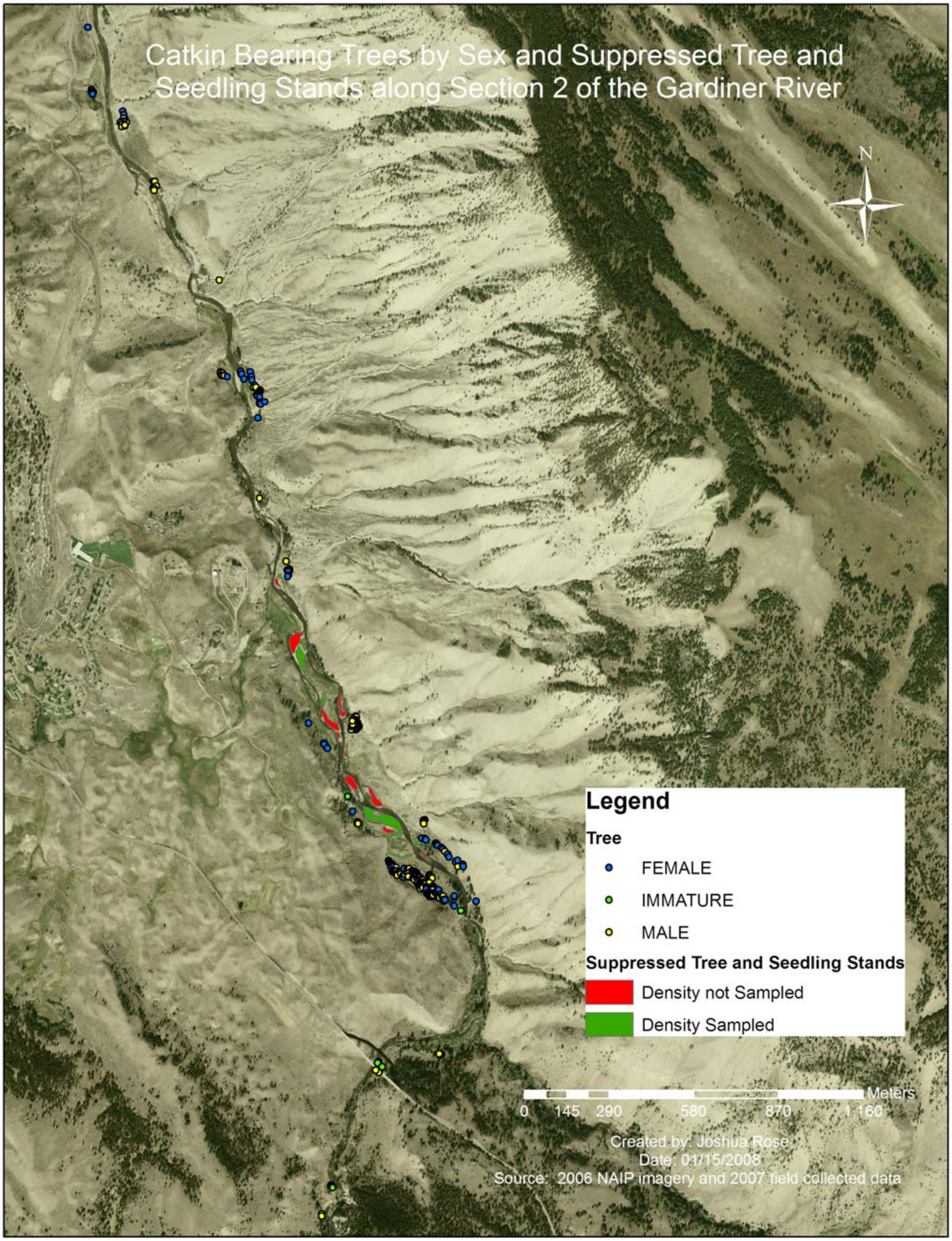
Catkin Bearing Trees by Sex and Suppressed Tree and Seedling Stands along Section 2 of the Gardiner River
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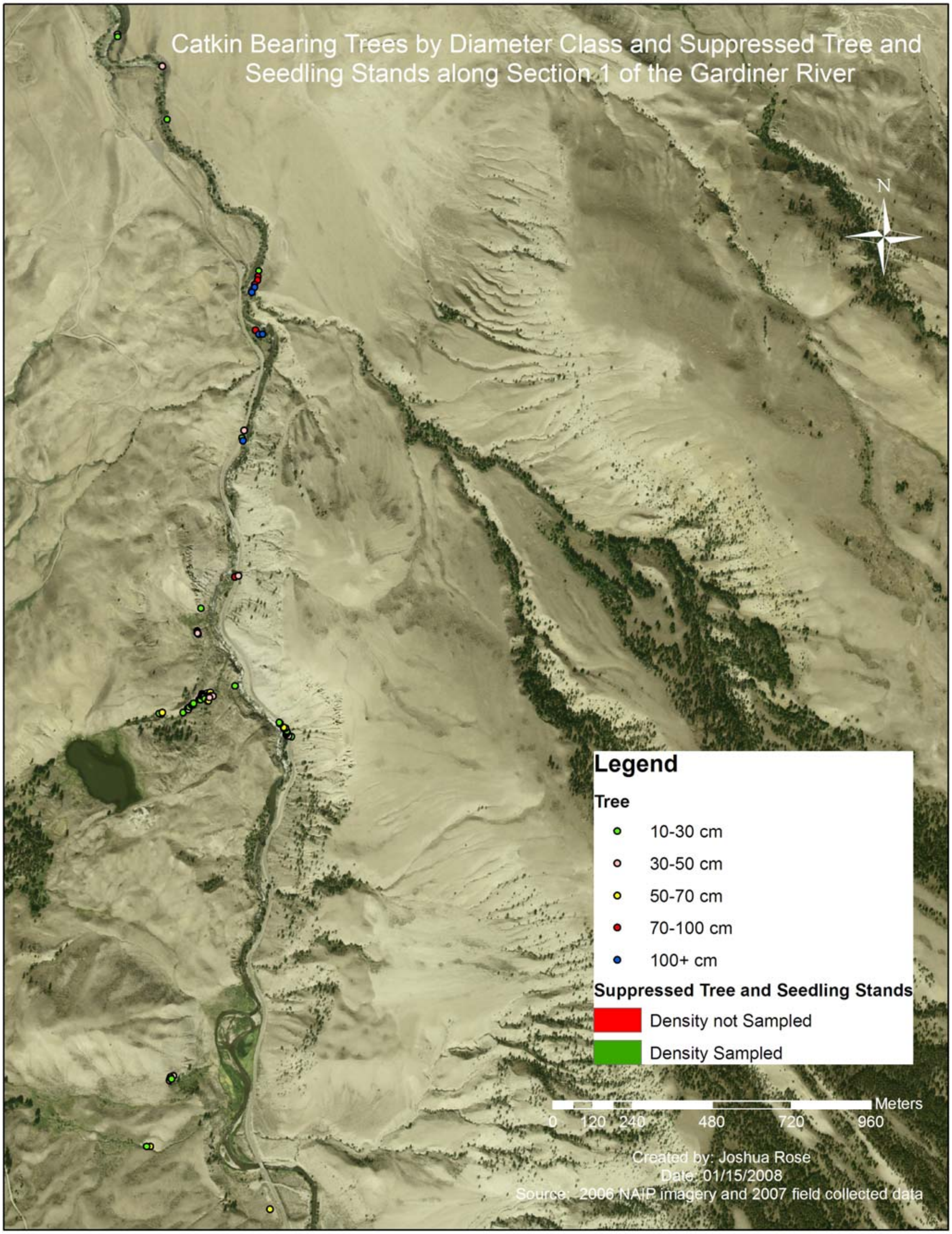
Source: 2006 NAIP imagery and 2007 field collected data


Catkin Bearing Trees by Diameter Class and Suppressed Tree and Seedling Stands along Section 1 of the Gardiner River
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50-70 cm
70-100 cm
100+ cm
Suppressed Tree and Seedling Stands
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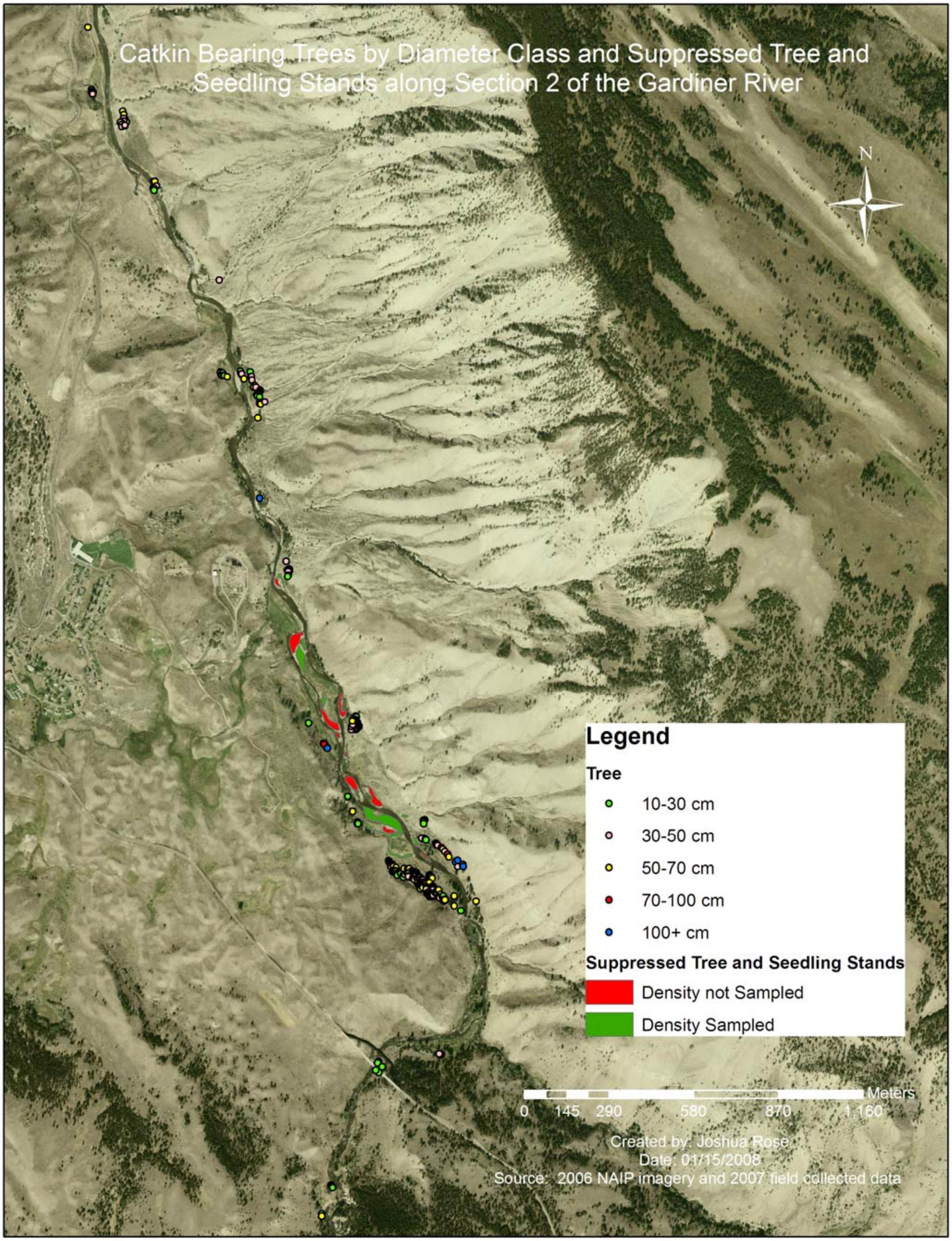
Catkin Bearing Trees by Diameter Class and Suppressed Tree and Seedling Stands along Section 2 of the Gardiner River
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Suppressed Tree and Seedling Stands
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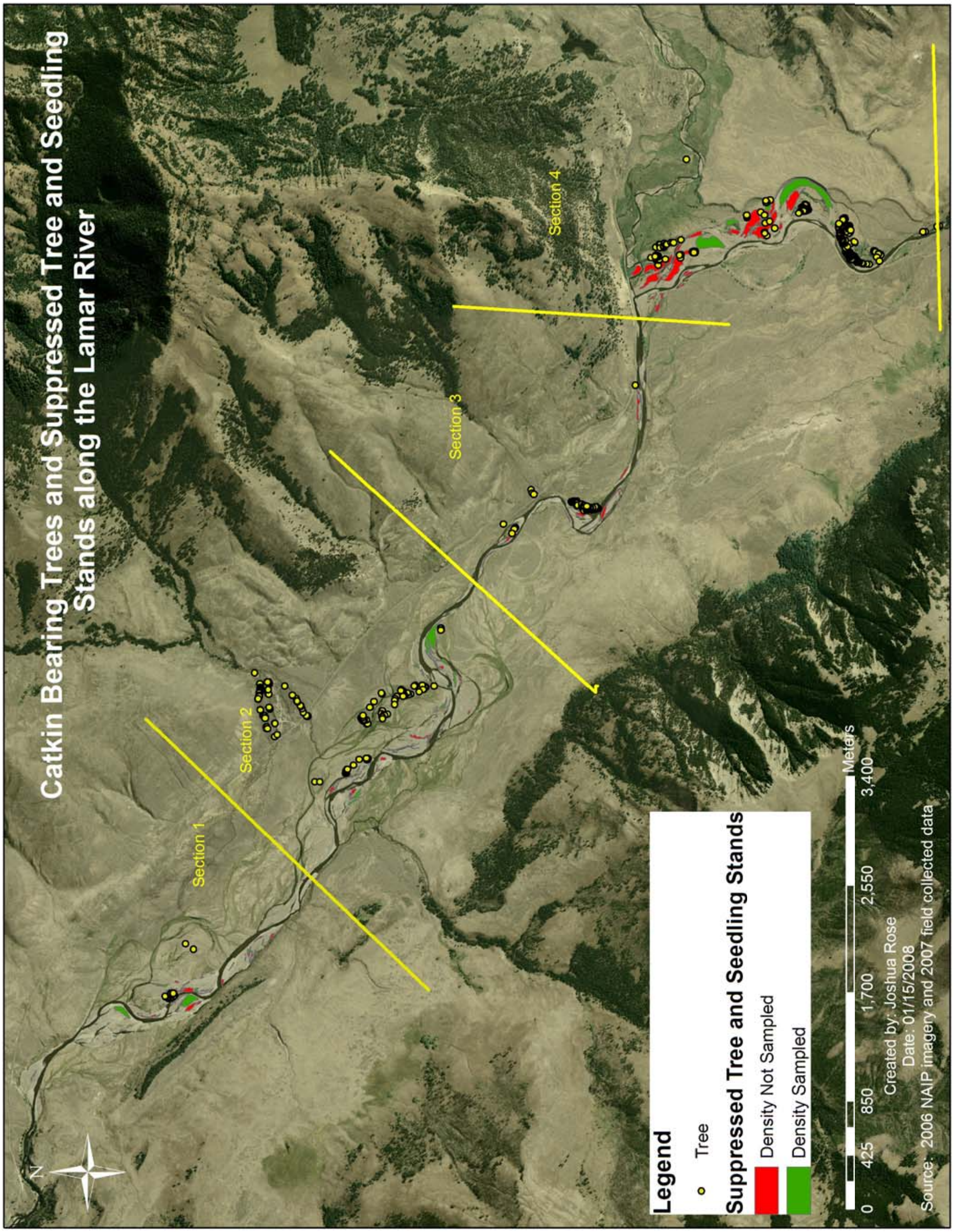
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Suppressed Tree and Seedling Stands
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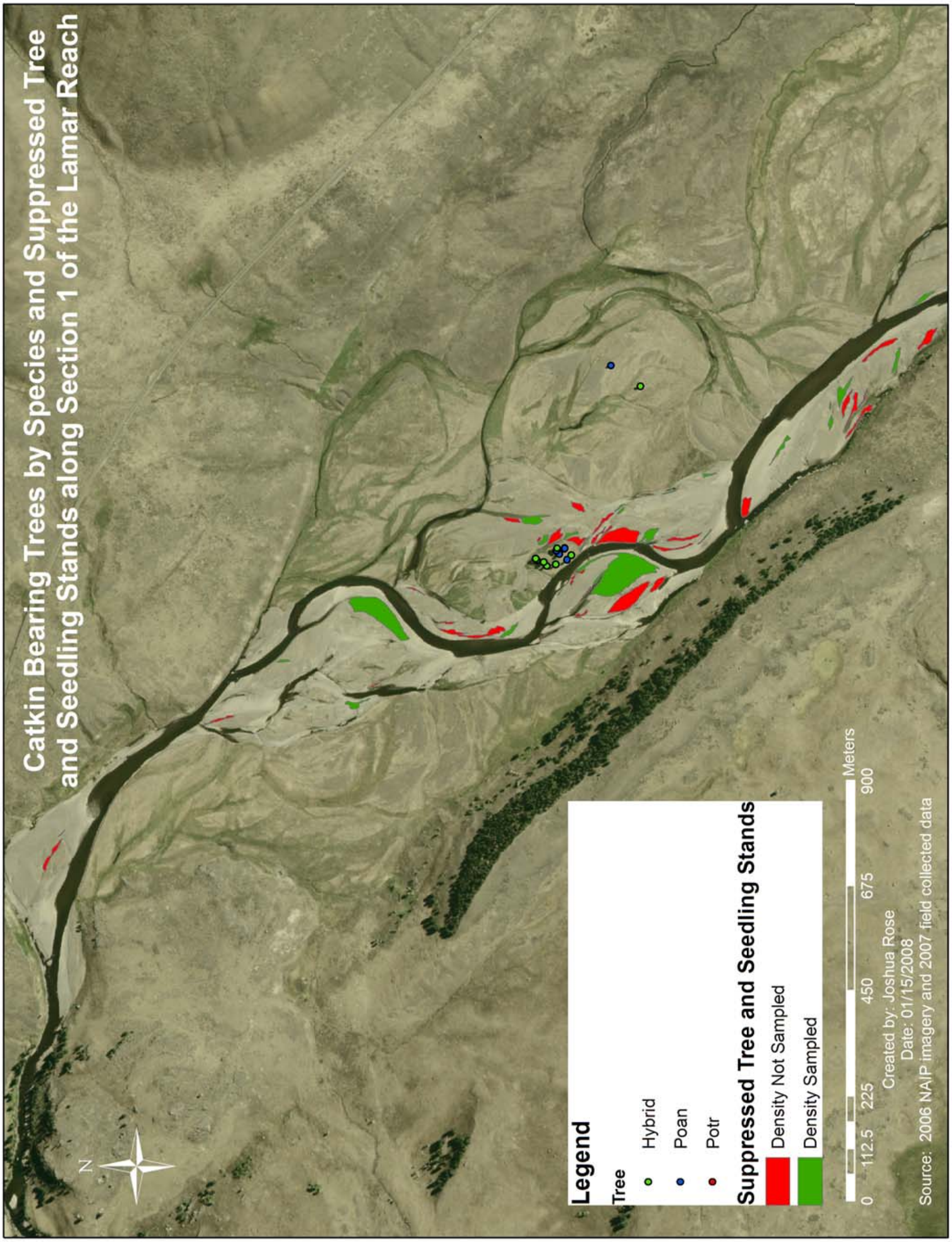
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and Seedling Stands along Section 1 of the Lamar Reach
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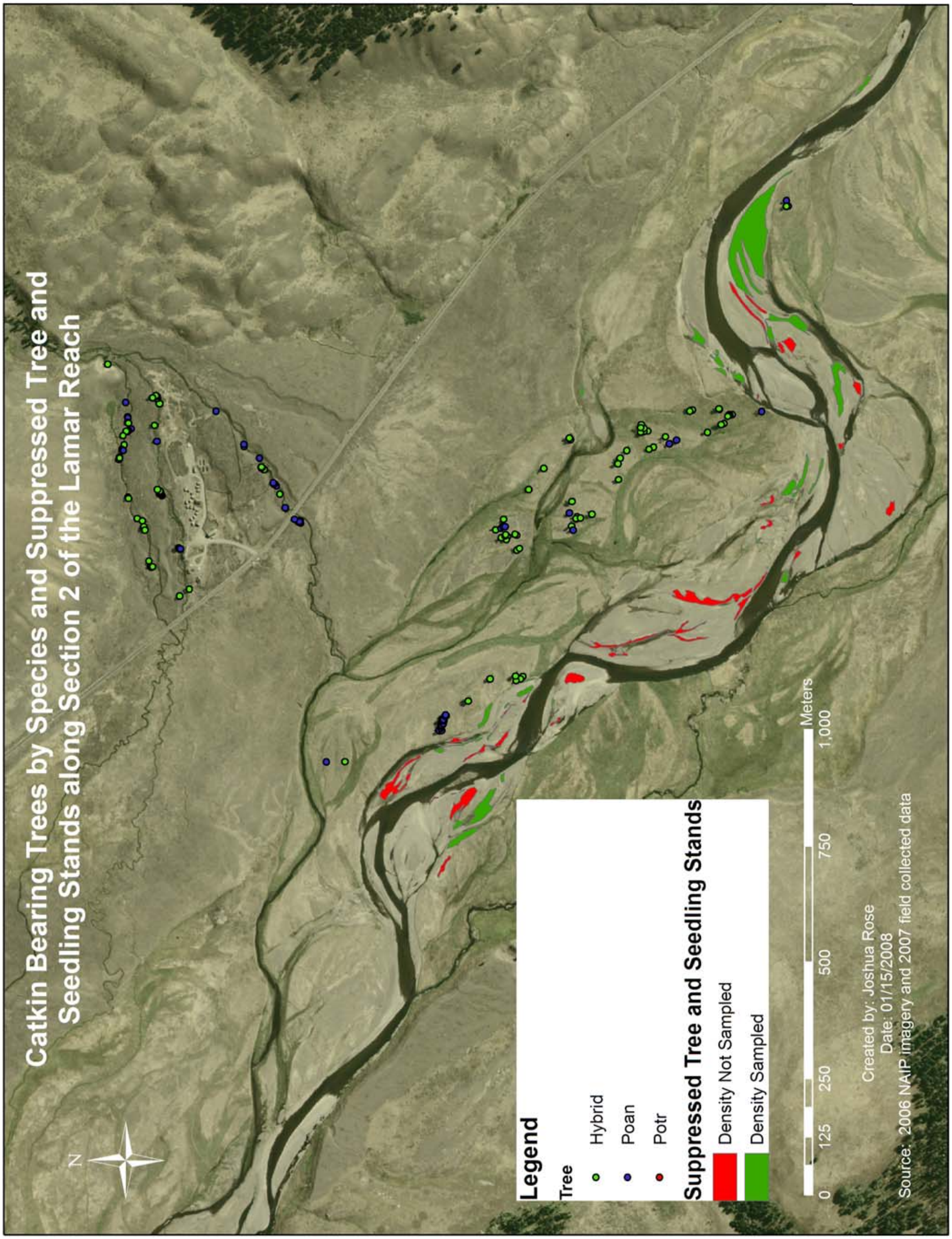
Catkin Bearing Trees by Species and Suppressed Tree and
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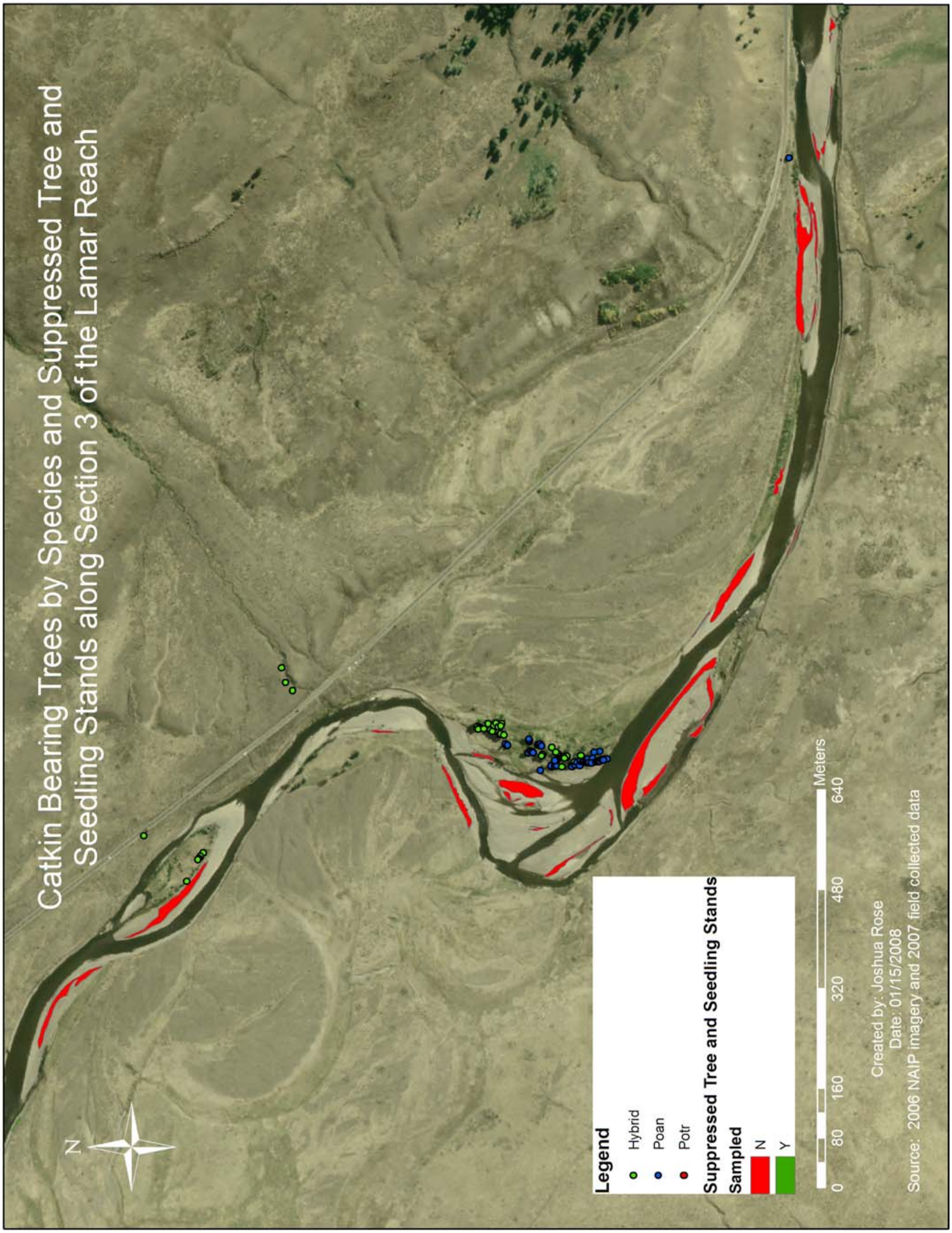
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Seedling Stands along Section 3 of the Lamar Reach
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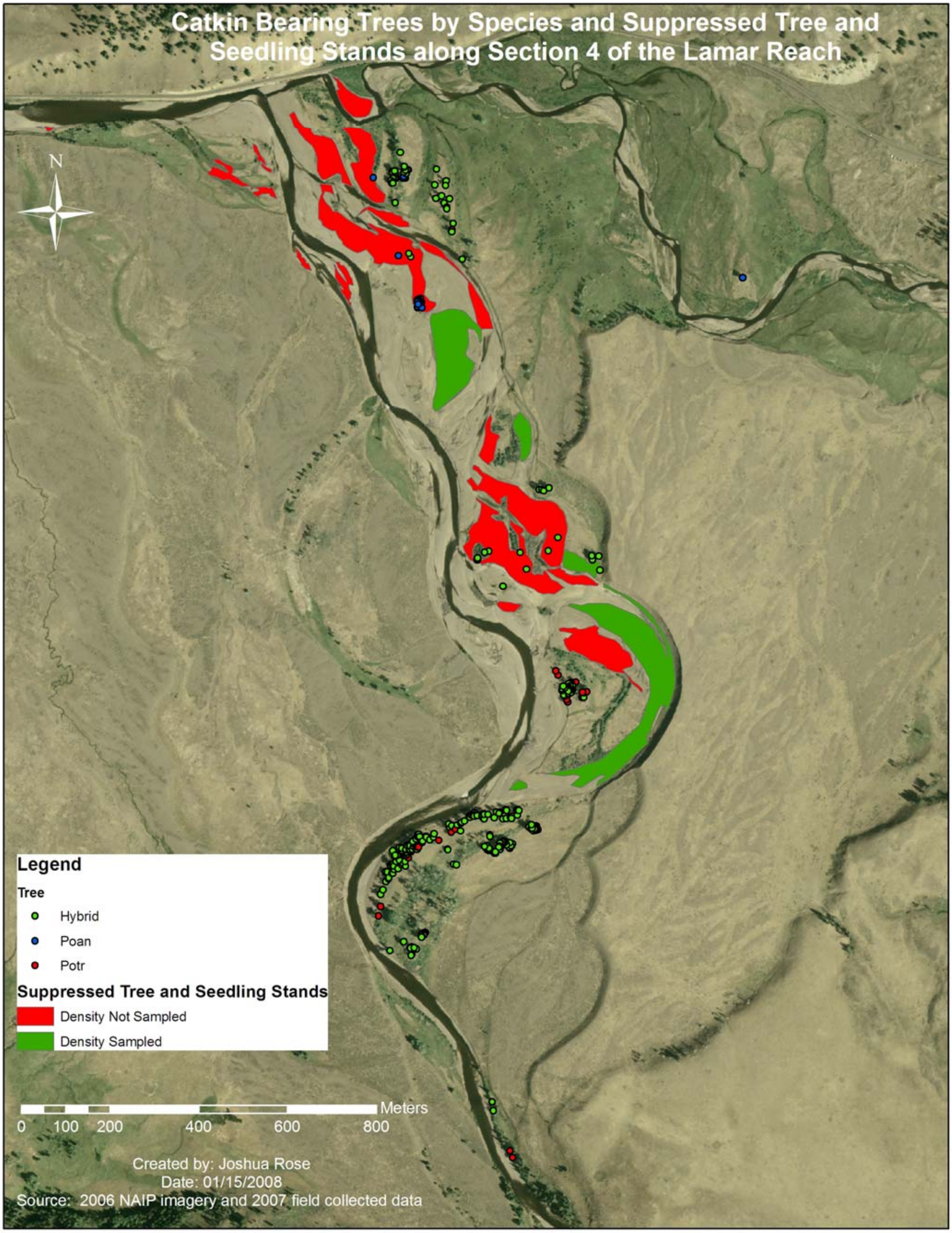
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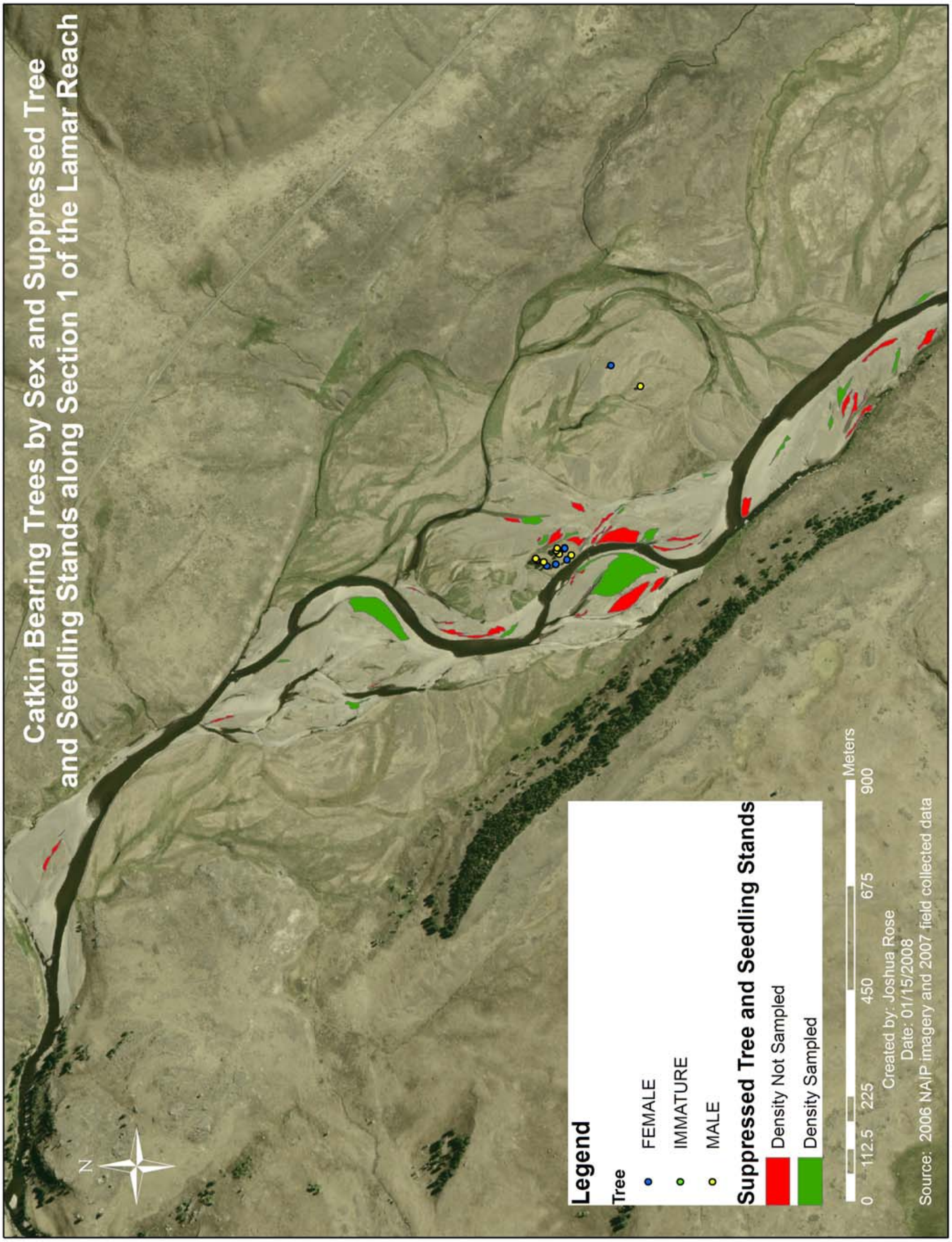
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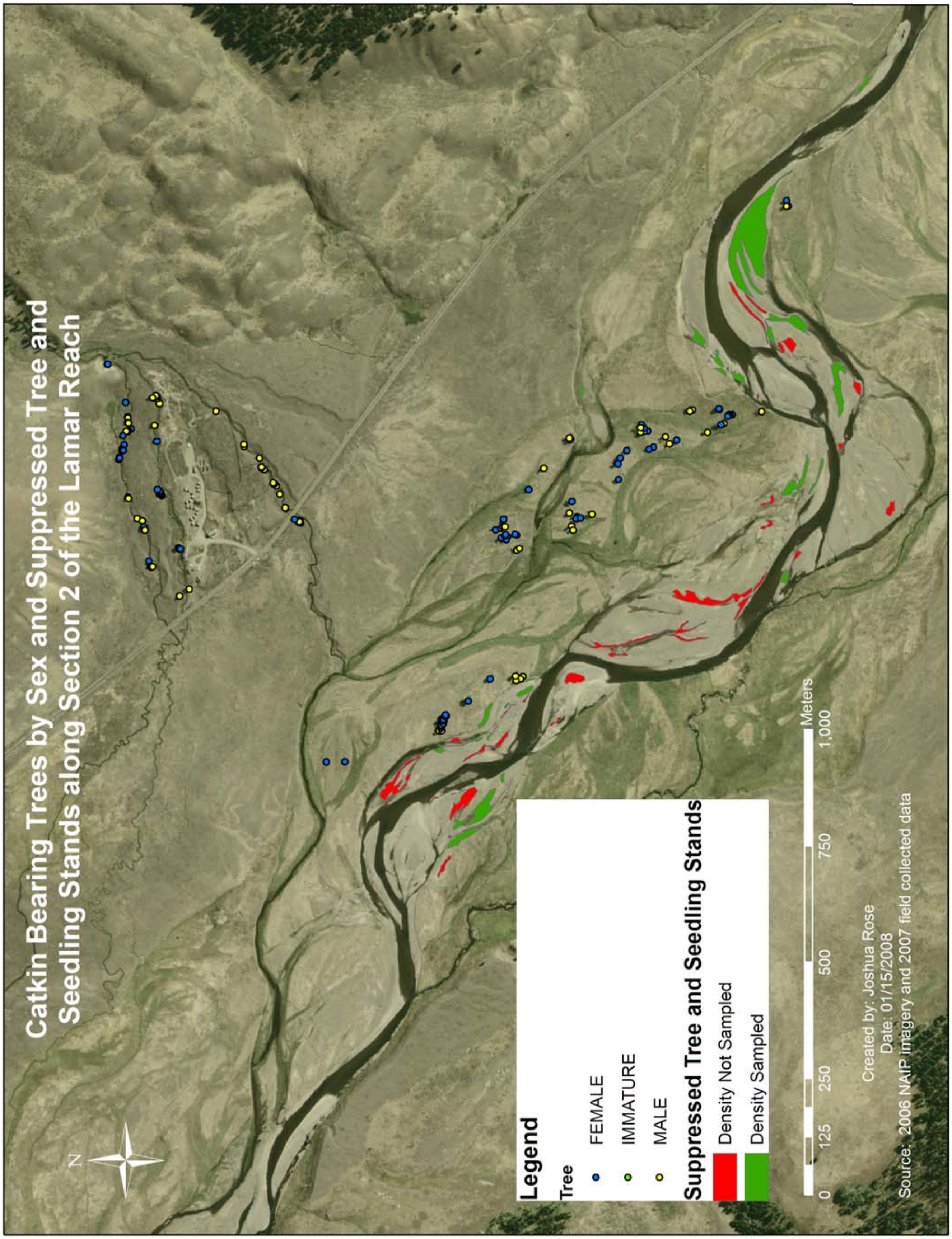

Catkin Bearing Trees by Sex and Suppressed Tree and Seedling Stands along Section 2 of the Lamar Reach
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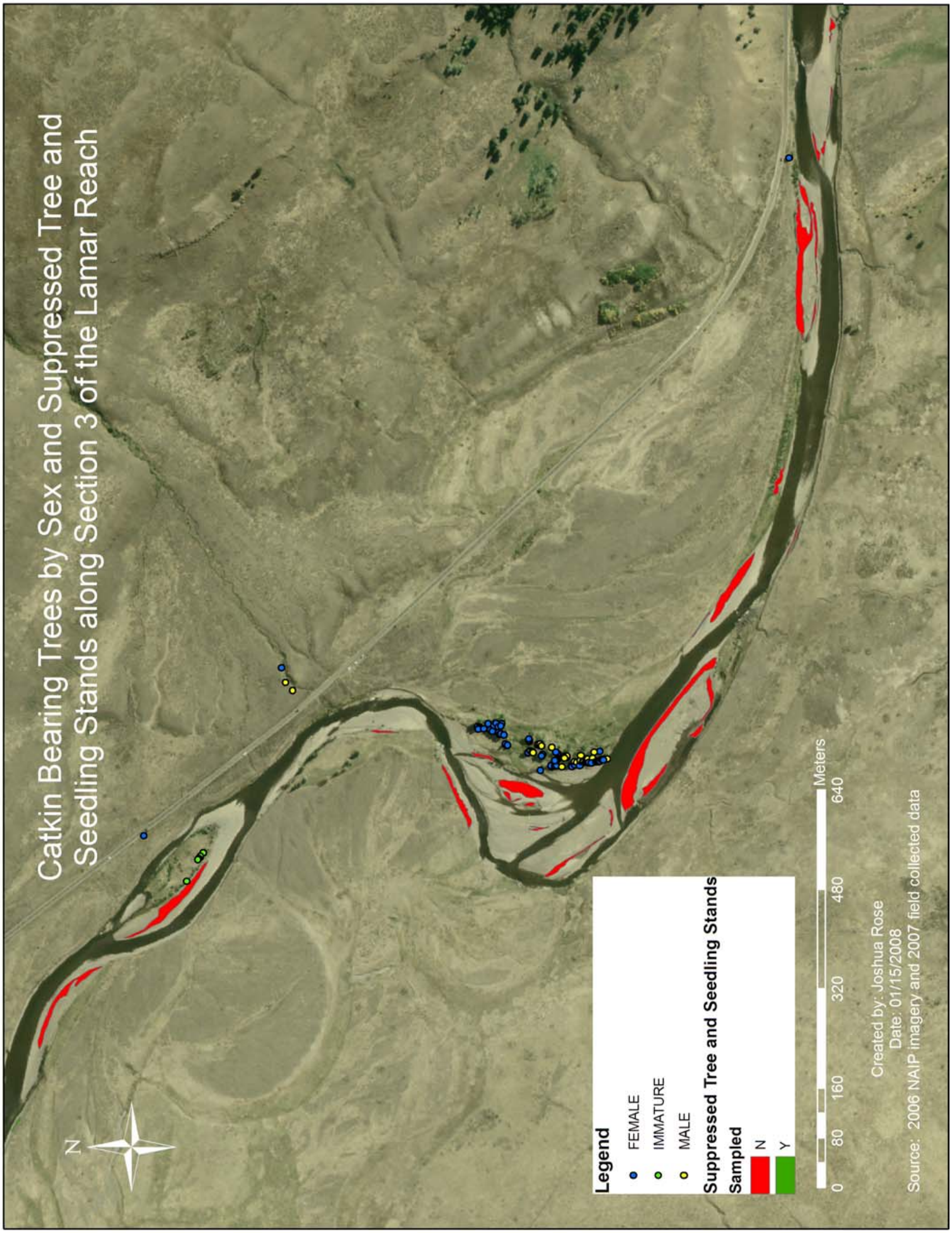
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Seedling Stands along Section 3 of the Lamar Reach
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Suppressed Tree and Seedling Stands
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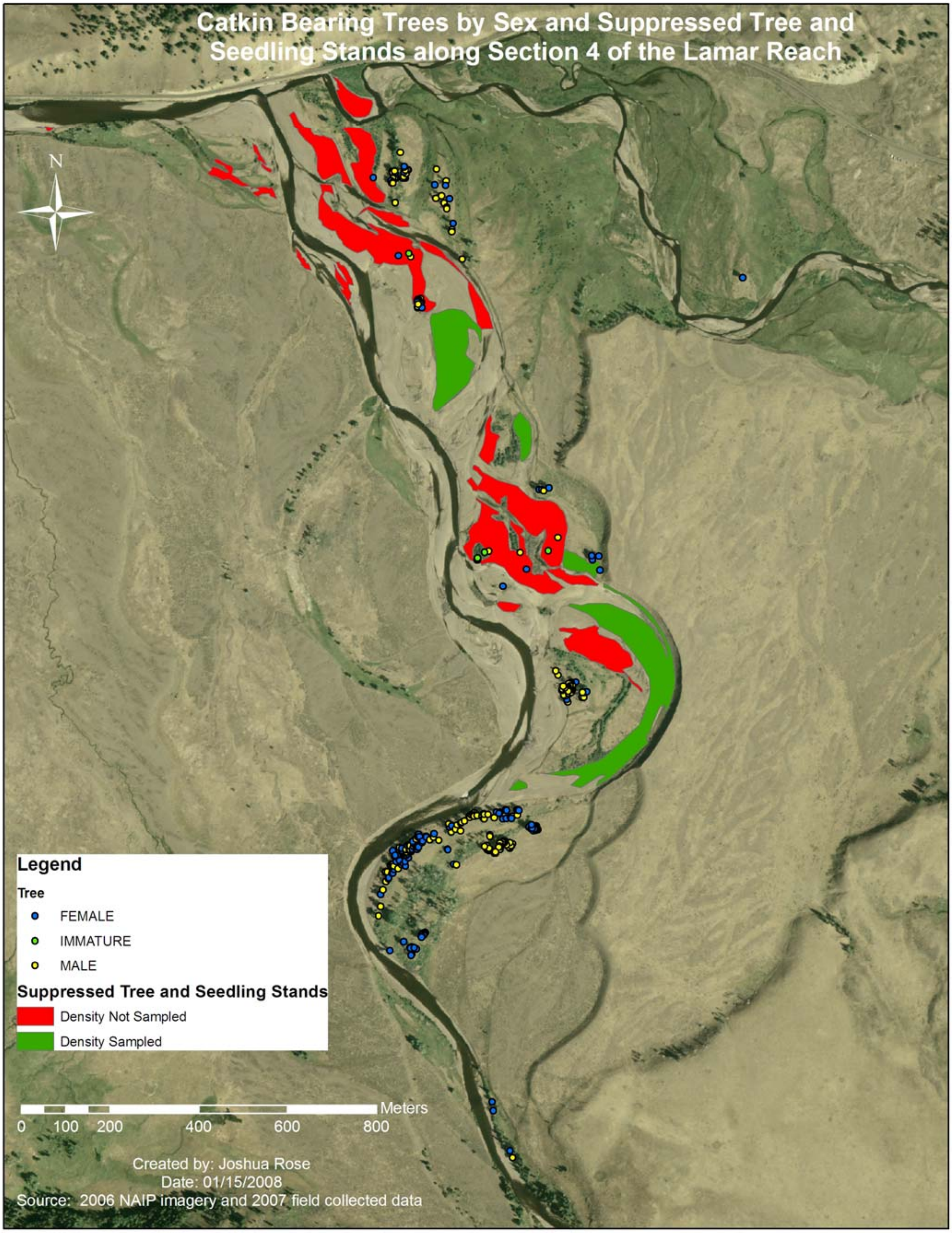
Catkin Bearing Trees by Sex and Suppressed Tree and Seedling Stands along Section 4 of the Lamar Reach
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Suppressed Tree and Seedling Stands
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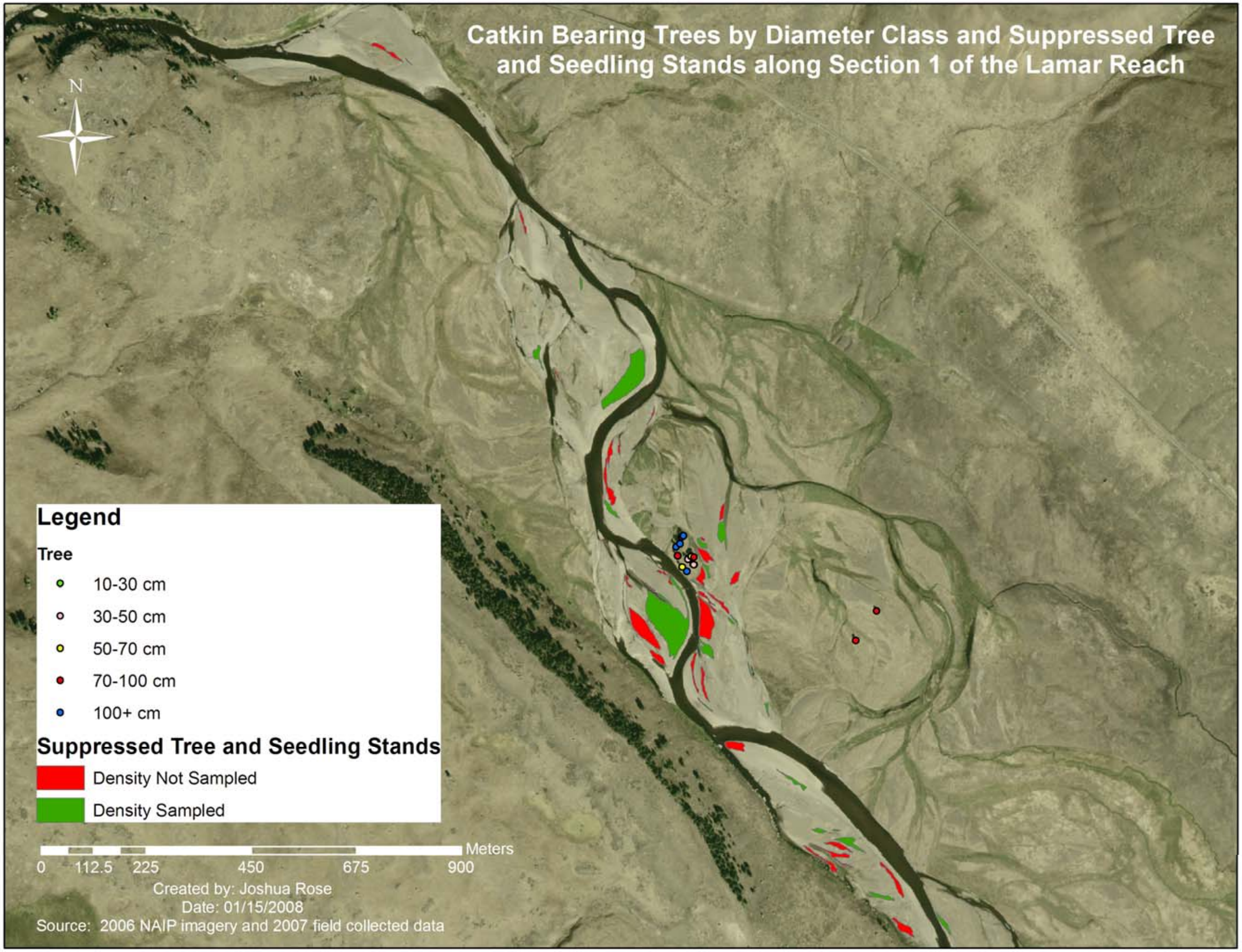
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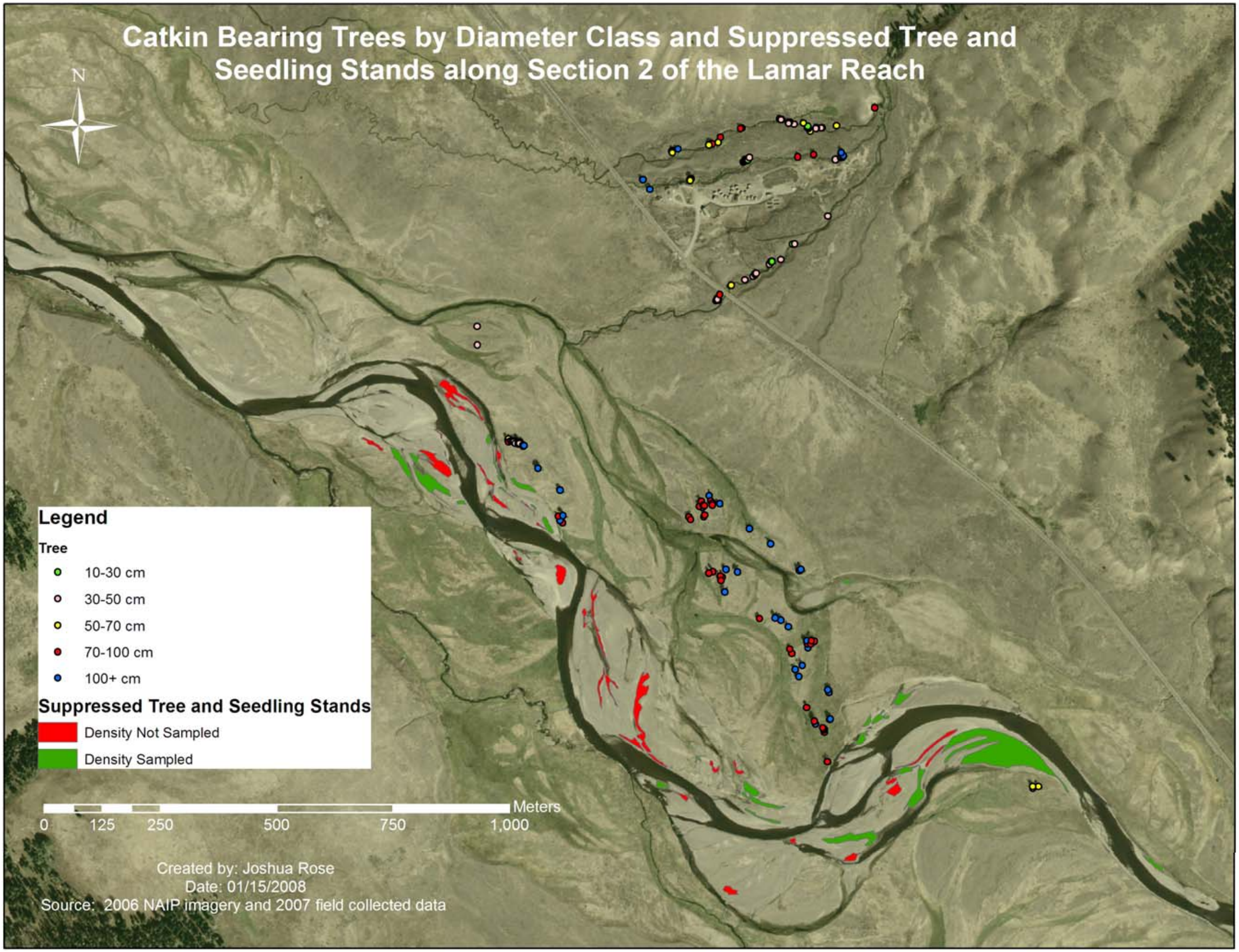
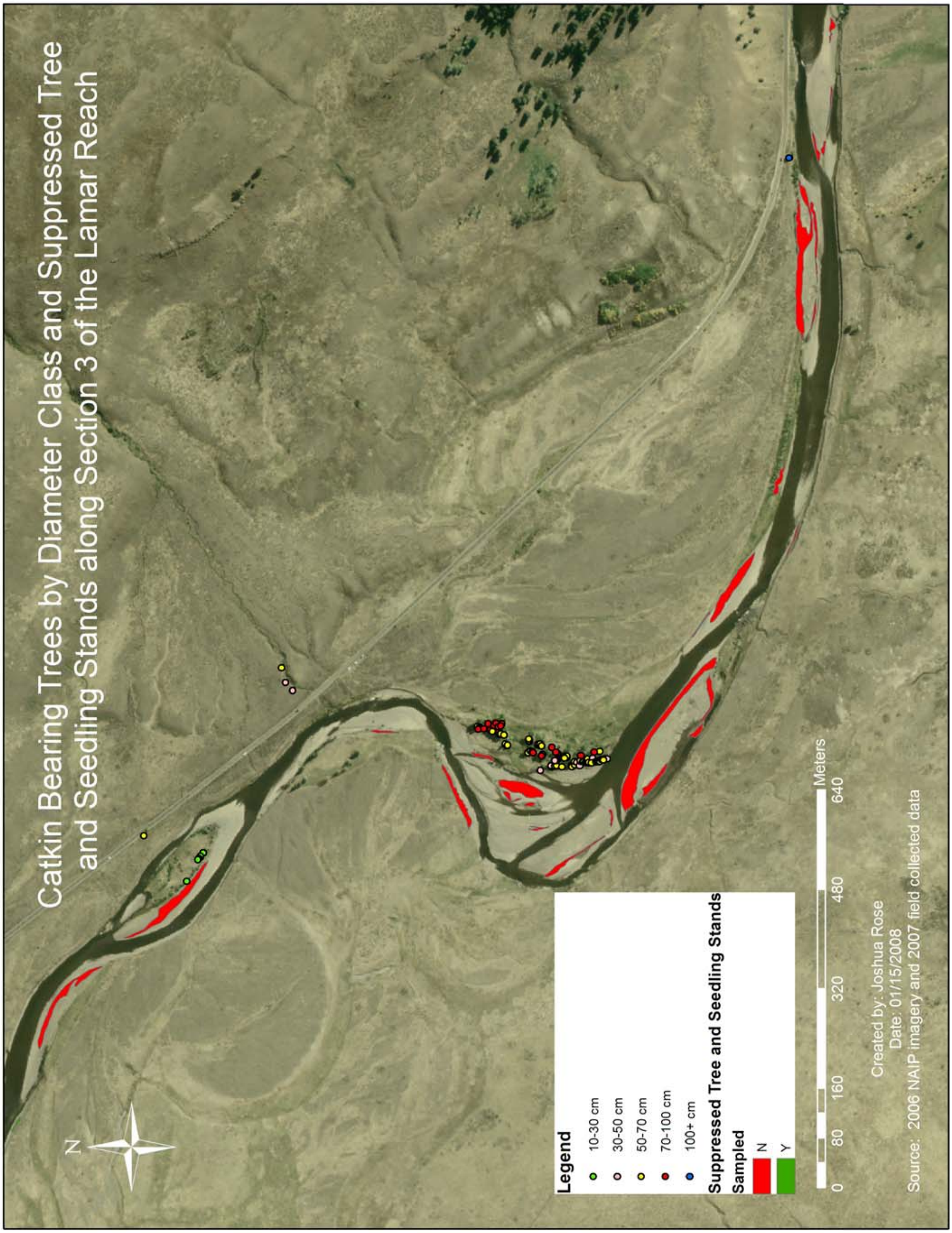
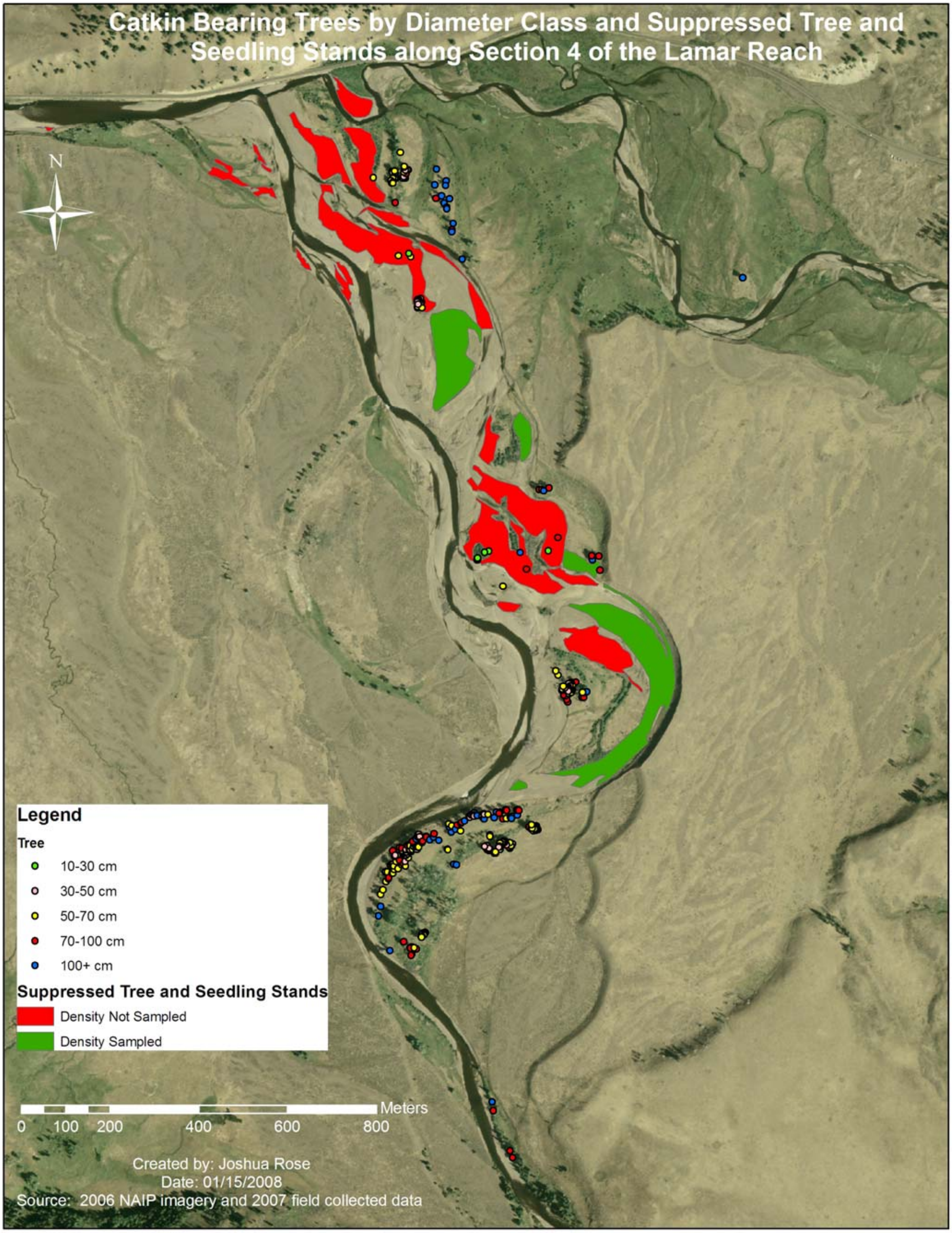
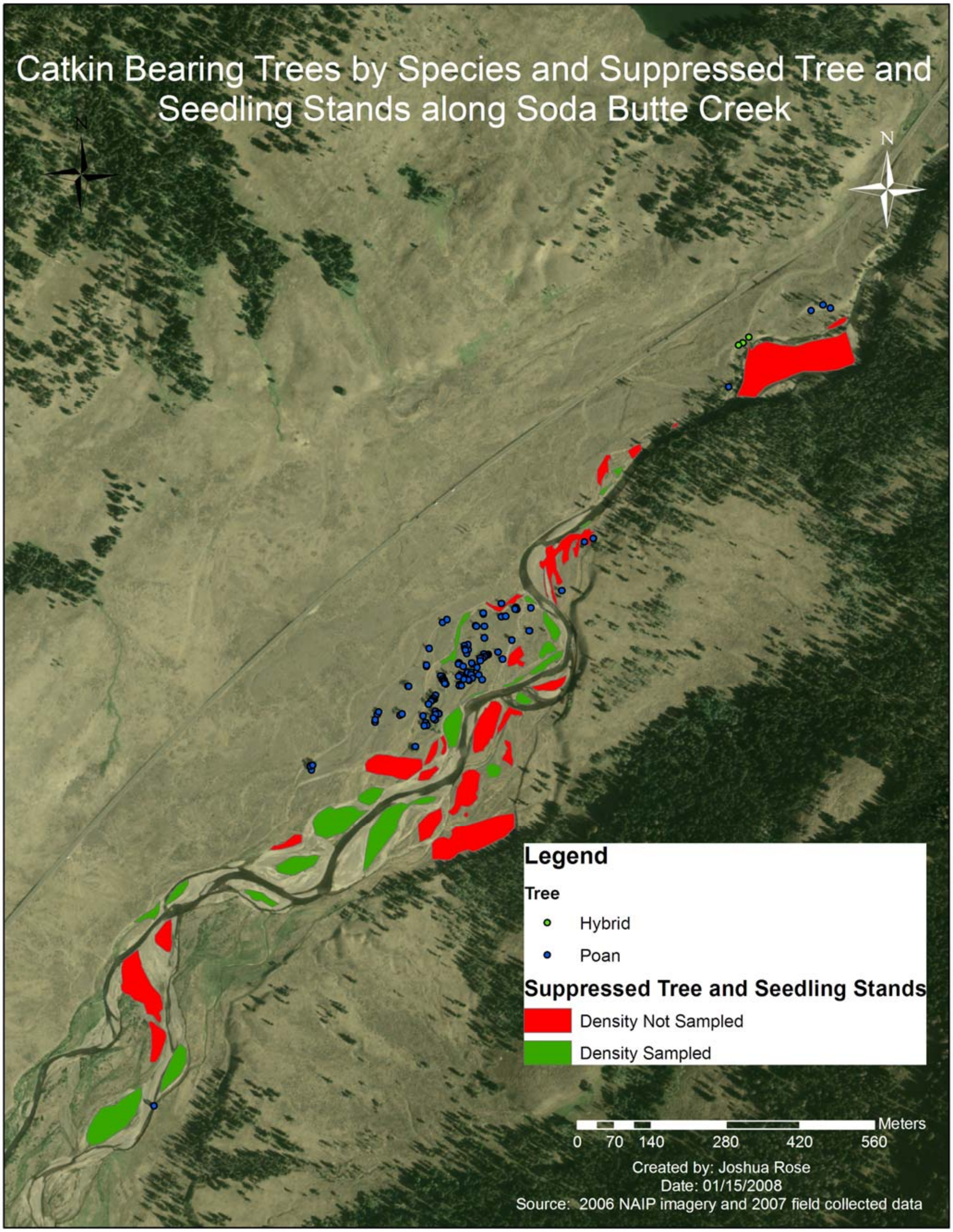
Legend
Tree
10-30 cm
30-50 cm
50-70 cm
70-100 cm
100+ cm
Suppressed Tree and Seedling Stands
Density Not Sampled
Density Sampled
0 112.5 225 450 675 900 Meters
Created by: Joshua Rose
Date: 01/15/2008
Source: 2006 NAIP imagery and 2007 field collected data

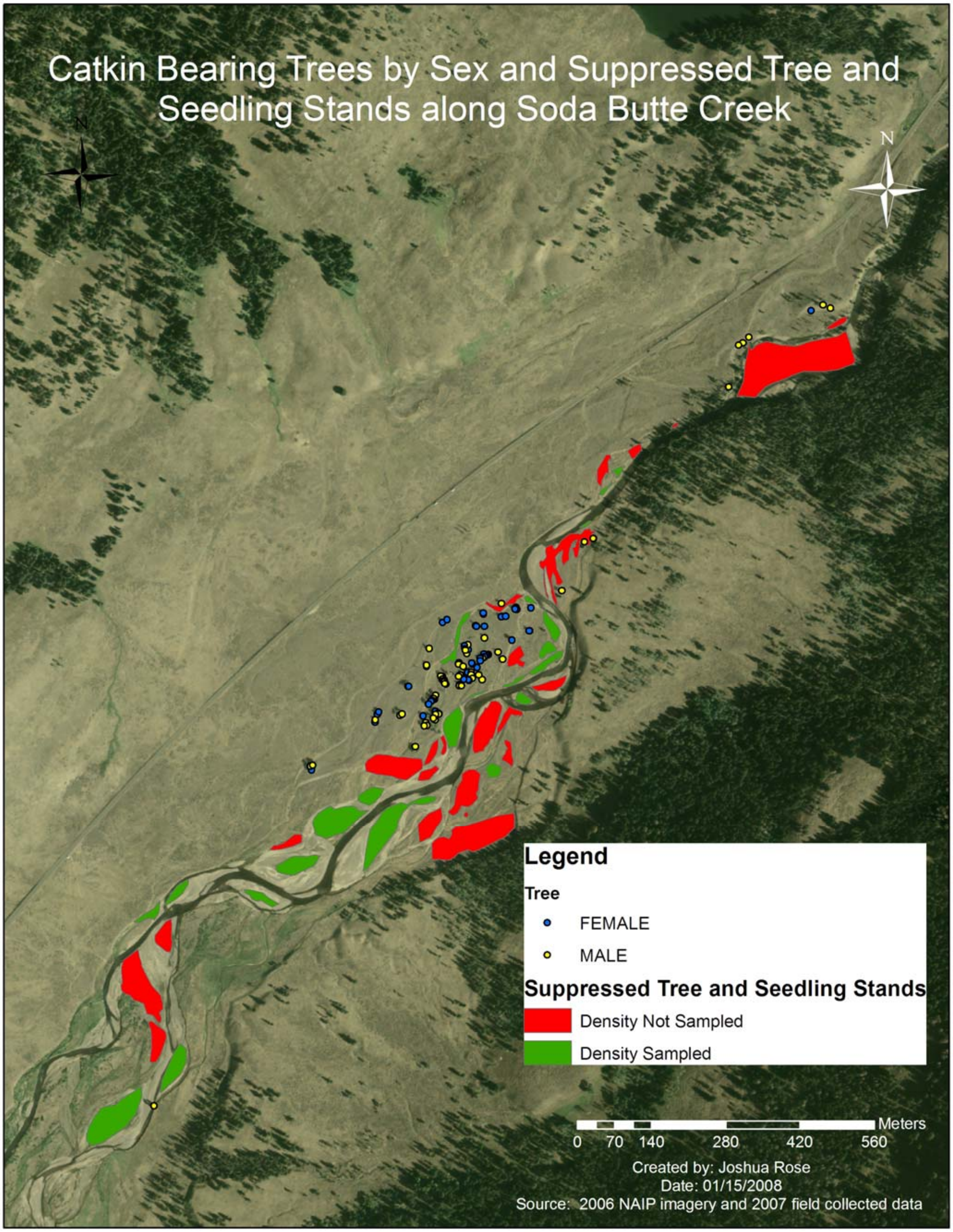

Catkin Bearing Trees by Diameter Class and Suppressed Tree and Seedling Stands along Section 2 of the Lamar Reach
N
Legend
Tree
10-30 cm
30-50 cm
50-70 cm
70-100 cm
100+ cm
Suppressed Tree and Seedling Stands
Density Not Sampled
Density Sampled
0 125 250 500 750 1,000
Meters
Created by: Joshua Rose
Date: 01/15/2008
Source: 2006 NAIP imagery and 2007 field collected data

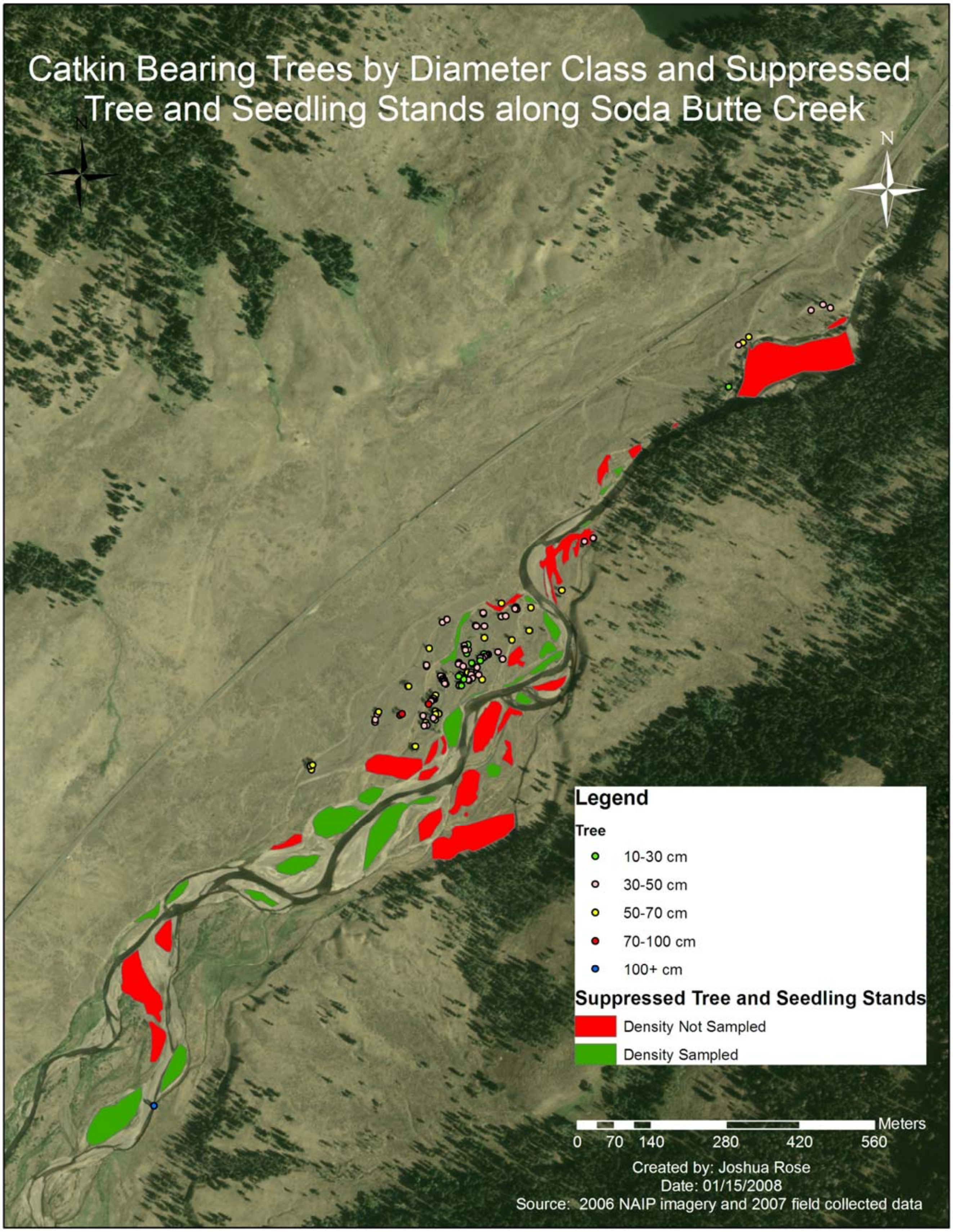

Catkin Bearing Trees by Diameter Class and Suppressed Tree and Seedling Stands along Section 3 of the Lamar Reach
N
Legend
10-30 cm
30-50 cm
50-70 cm
70-100 cm
100+ cm
Suppressed Tree and Seedling Stands
Sampled
N
Y
0 80 160 320 480 640
Meters
Created by: Joshua Rose
Date: 01/15/2008
Source: 2006 NAIP imagery and 2007 field collected data



Catkin Bearing Trees by Diameter Class and Suppressed Tree and Seedling Stands along Section 4 of the Lamar Reach
N
Legend
Tree
10-30 cm
30-50 cm
50-70 cm
70-100 cm
100+ cm
Suppressed Tree and Seedling Stands
Density Not Sampled
Density Sampled
Meters
0 100 200 400 600 800
Created by: Joshua Rose
Date: 01/15/2008
Source: 2006 NAIP imagery and 2007 field collected data


Catkin Bearing Trees by Species and Suppressed Tree and Seedling Stands along Soda Butte Creek
N
N
Legend
Tree
Hybrid
Poan
Suppressed Tree and Seedling Stands
Density Not Sampled
Density Sampled
Meters
0 70 140 280 420 560
Created by: Joshua Rose
Date: 01/15/2008
Source: 2006 NAIP imagery and 2007 field collected data


Catkin Bearing Trees by Sex and Suppressed Tree and Seedling Stands along Soda Butte Creek
N
N
Legend
Tree
FEMALE
MALE
Suppressed Tree and Seedling Stands
Density Not Sampled
Density Sampled
Meters
0 70 140 280 420 560
Created by: Joshua Rose
Date: 01/15/2008
Source: 2006 NAIP imagery and 2007 field collected data



Catkin Bearing Trees by Diameter Class and Suppressed Tree and Seedling Stands along Soda Butte Creek
N
N
Legend
Tree
10-30 cm
30-50 cm
50-70 cm
70-100 cm
100+ cm
Suppressed Tree and Seedling Stands
Density Not Sampled
Density Sampled
Meters
0 70 140 280 420 560
Created by: Joshua Rose
Date: 01/15/2008
Source: 2006 NAIP imagery and 2007 field collected data