

A close-up photograph of English Holly (Ilex aquifolium) leaves. The leaves are dark green, glossy, and have a characteristic spiky, pointed shape. They are arranged in a dense cluster, with some leaves showing signs of being eaten, such as small holes and jagged edges. The background is a soft, out-of-focus green, suggesting a forest setting.

**An Invasion's Progress:
English Holly (*Ilex aquifolium*)
in a Semi-natural Pacific Northwest Forest**

**David Stokes, Elliott Church, David Cronkright, and Santiago Lopez
University of Washington, Bothell**

A Rake's Progress

W. Hogarth (1735)



English holly

Ilex aquifolium

- A small to medium sized tree
- Dioecious (separate sexes)
- Reproduces via seed and vegetatively
- Native to Eurasia
- Present in PNW forests
- Appears to be spreading



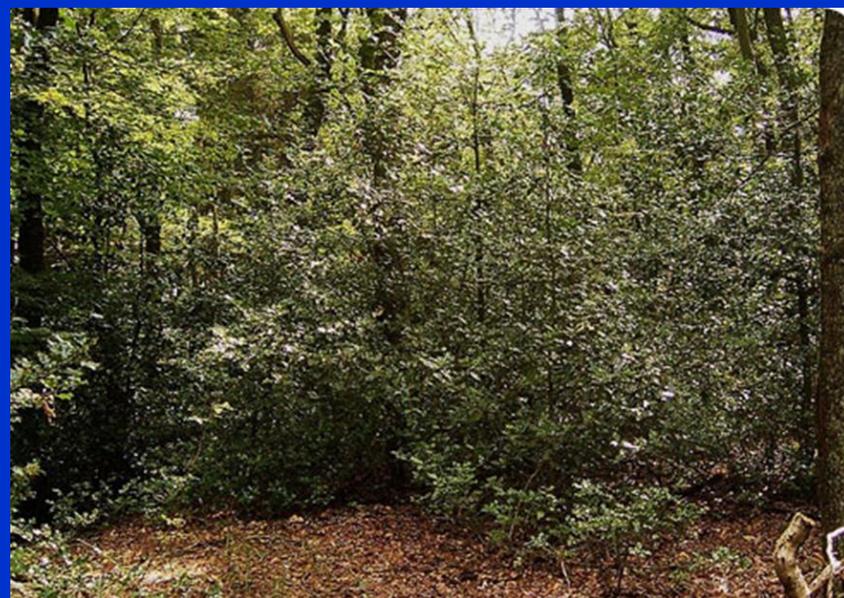


English holly in western Washington forestland





English holly in England





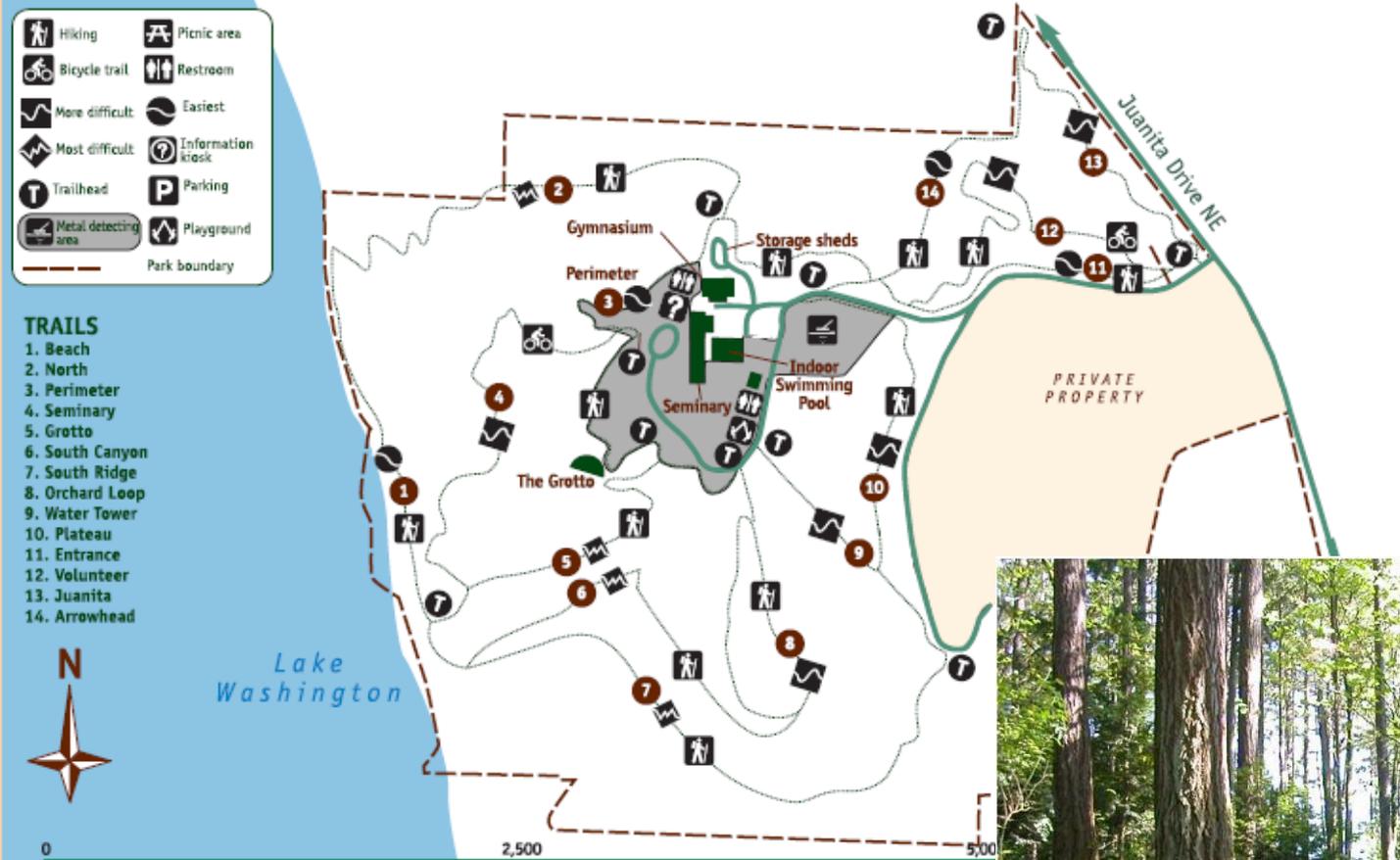


Research questions:

- How prevalent is English holly in west-side Washington forests?
- What are the characteristics of the English holly population?
Height, stem diameter, canopy cover, age structure, sex ratio, condition
- Is English holly increasing in numbers? Increasing in area? If so, at what rate?
- What are the effects of holly on native species?
- What has been the pattern of spread through the course of the invasion?
- How will the English holly invasion proceed in the future?



Saint Edward State Park



14445 Juanita Drive NE, Kenmore WA 98028 • Information Center (360) 902-1111

Saint Edward State Park:

- large, relatively intact native forest
- unique in the Seattle area





Figure 1. St. Edward State Park and environs. Dominated by primarily native semi-mature forest, the park (border indicated by yellow line) is largely surrounded by residential development. Aerial photo from Smith (2006).



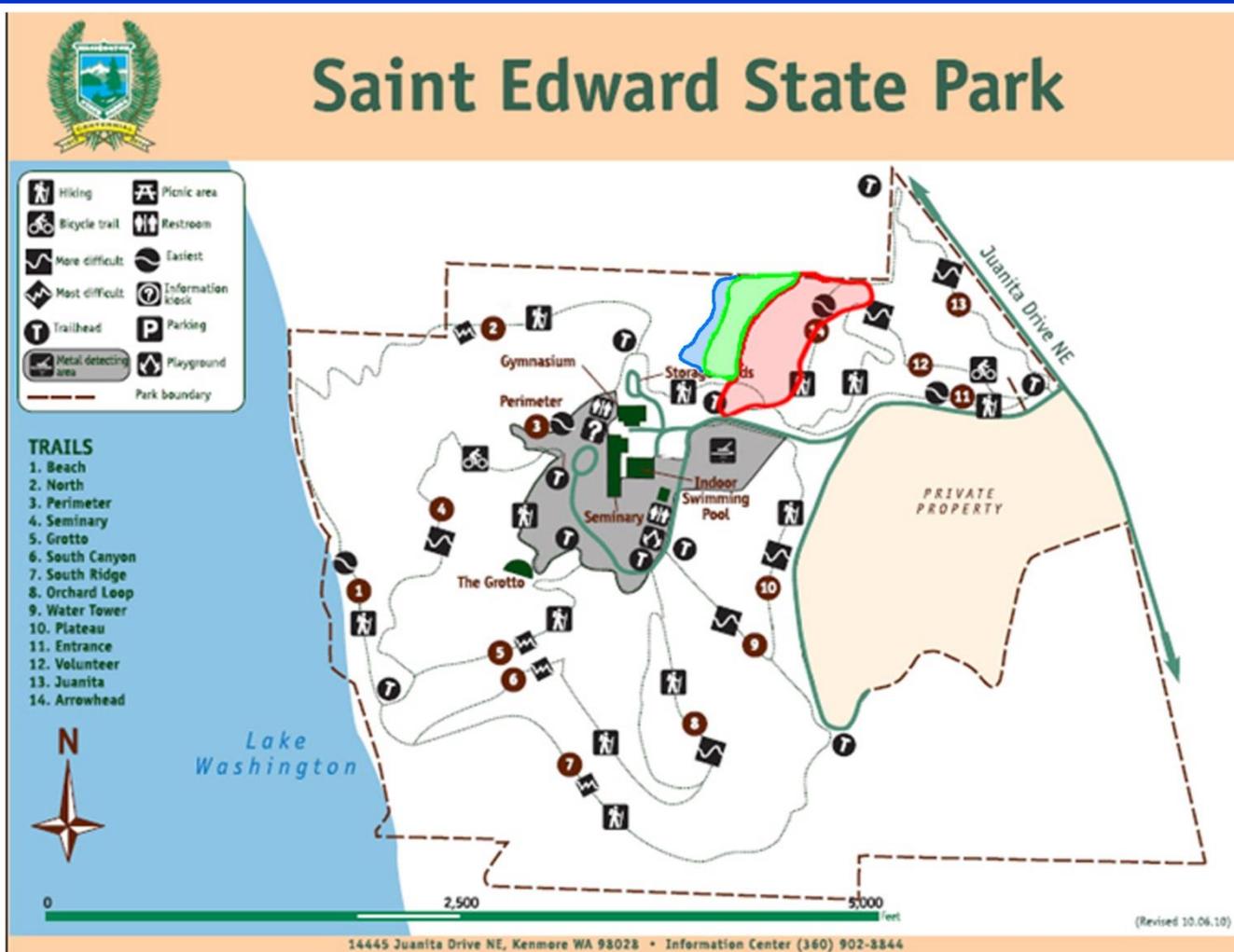
Methods

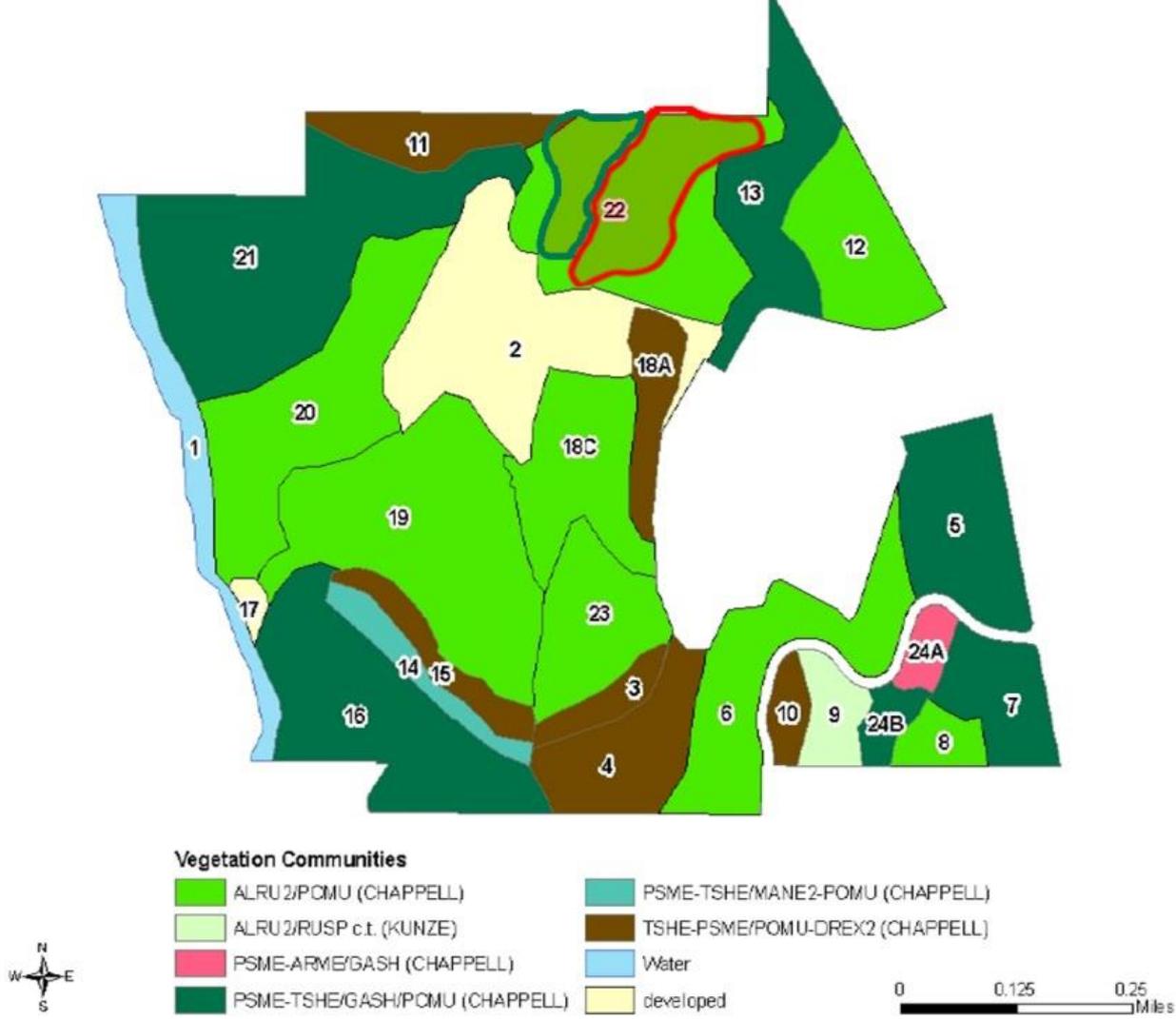
Surveyed for all *Ilex aquifolium* in 22.8 acre (9.2 ha) study area

15.5 acres in 2011 (red)

5.3 acres in 2012 (green)

2.0 acres in 2013 (blue)

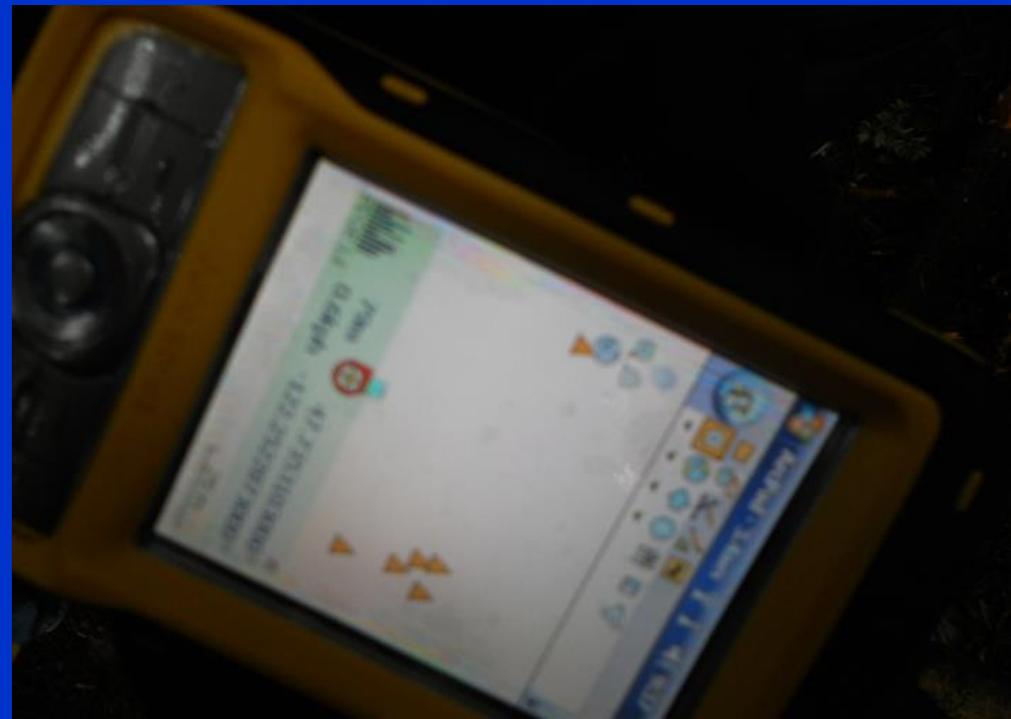




Study area and vegetation community polygons delineated by Smith (2006)
 Polygon 22, ALRU/POMU₂ (Chappell)

- GIS Component

- Geo-located all holly plants > 1 m from neighbor
 - GPS locations > 20 m from known locations
 - Accurate to within 3 m
 - Compass & meter tape ≤ 20 m
 - Accurate to within 1 m (est.)
- Differentially corrected data and created GIS and map of all holly in study area



- Recorded data on each tree, including:
 - Basal diameter, D20, Dbh
 - Height
 - Crown diameter and density
 - Presence/absence of berries
 - Origin: vegetative spread or seed

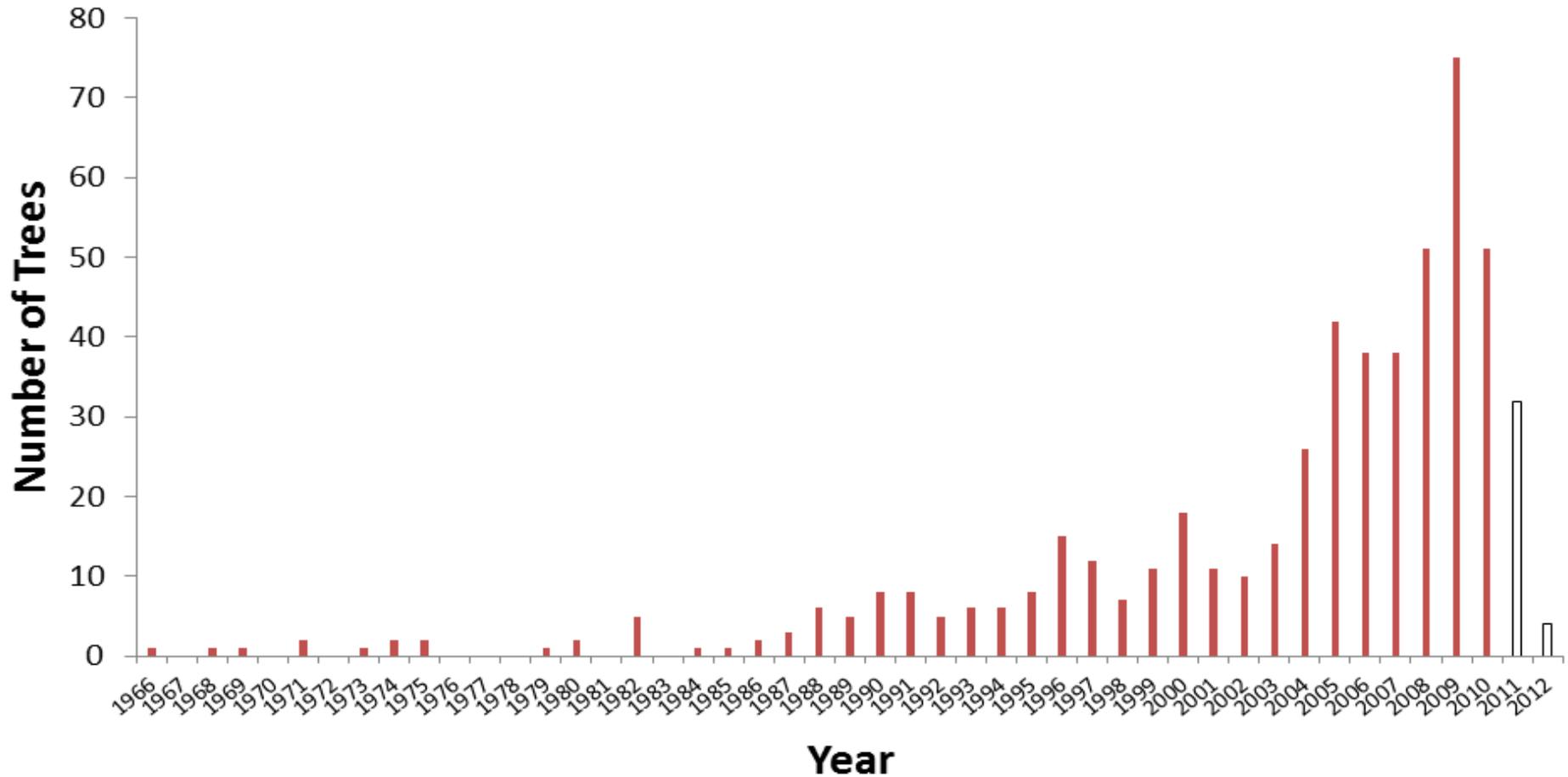


- Recorded data on local conditions around plants
 - Slope and aspect
 - Distance from trails and streams
 - Canopy, shrubs, ground cover vegetation within 5 meters
 - Canopy cover and relative availability of light in winter and summer



- Removed all holly plants in study area (n = 532)
2011: 215, 2012: 251, 2013: 65
 - Uprooted when possible (n = 487)
 - Cut remaining trees (n = 45)
 - Herbicide treatment (n = 29)
 - No herbicide treatment (n = 16)
- Collected basal cross section to determine age

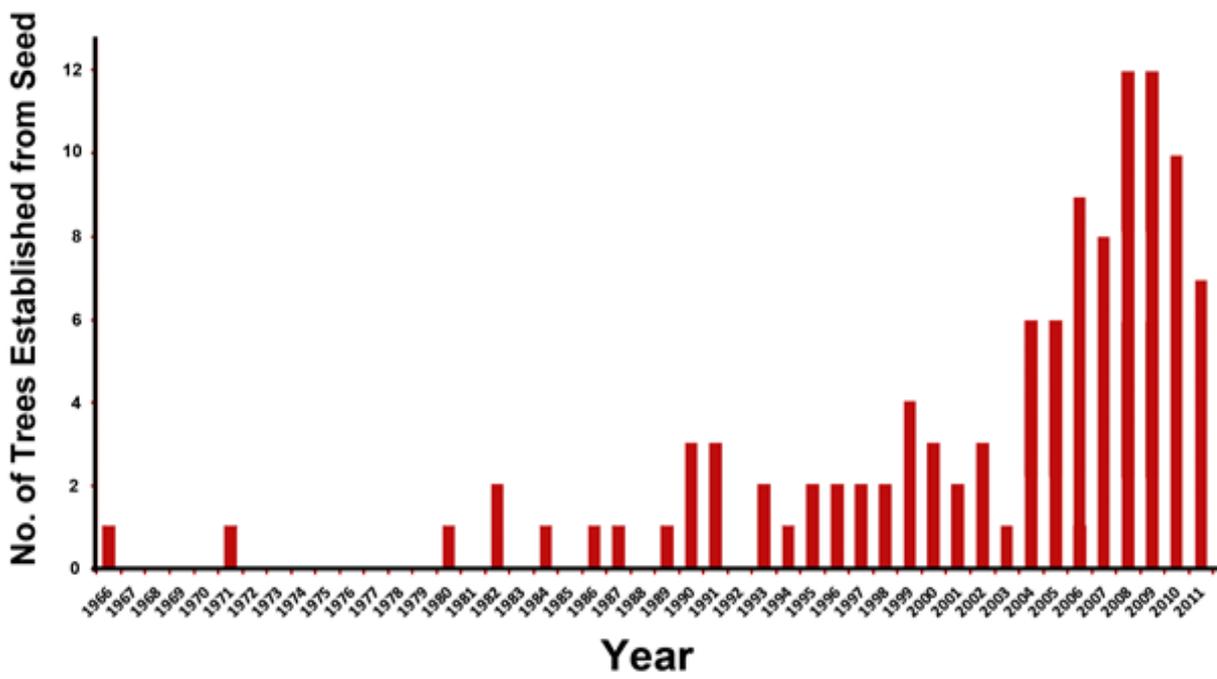




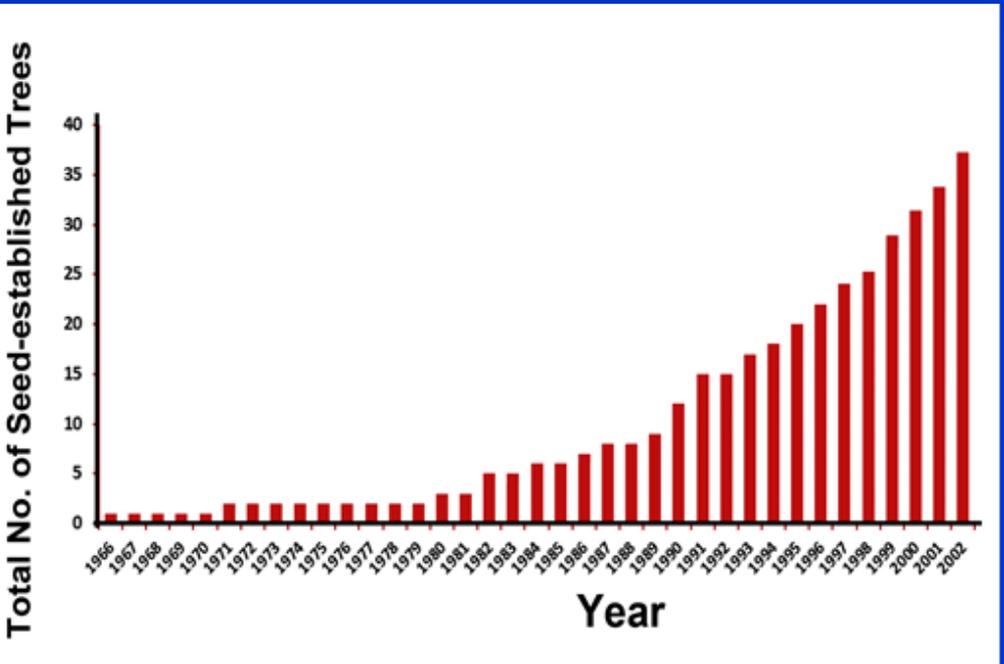
Year of establishment of *I. aquifolium* (n = 532) in a 22.8 acre study area in St. Edward State Park. Study area sampled in 2011, 2012, & 2013. Establishments in recent years under-represented due to incomplete sampling of small sprouts under sampled trees.



Year of establishment of all *I. aquifolium* resulting from seed (n = 111) in a 7.3 acre study area in St. Edward State Park, 1960 – 2012. Establishments in recent years probably undercounted because of incomplete sampling of small sprouts under sampled trees.



Cumulative number of *I. aquifolium* resulting from seed (n=37), 1966 to 2002 in 7.3 acre study area in St. Edward State Park, with exponential trend line. Years since 2002 excluded because of incomplete sampling of small trees.

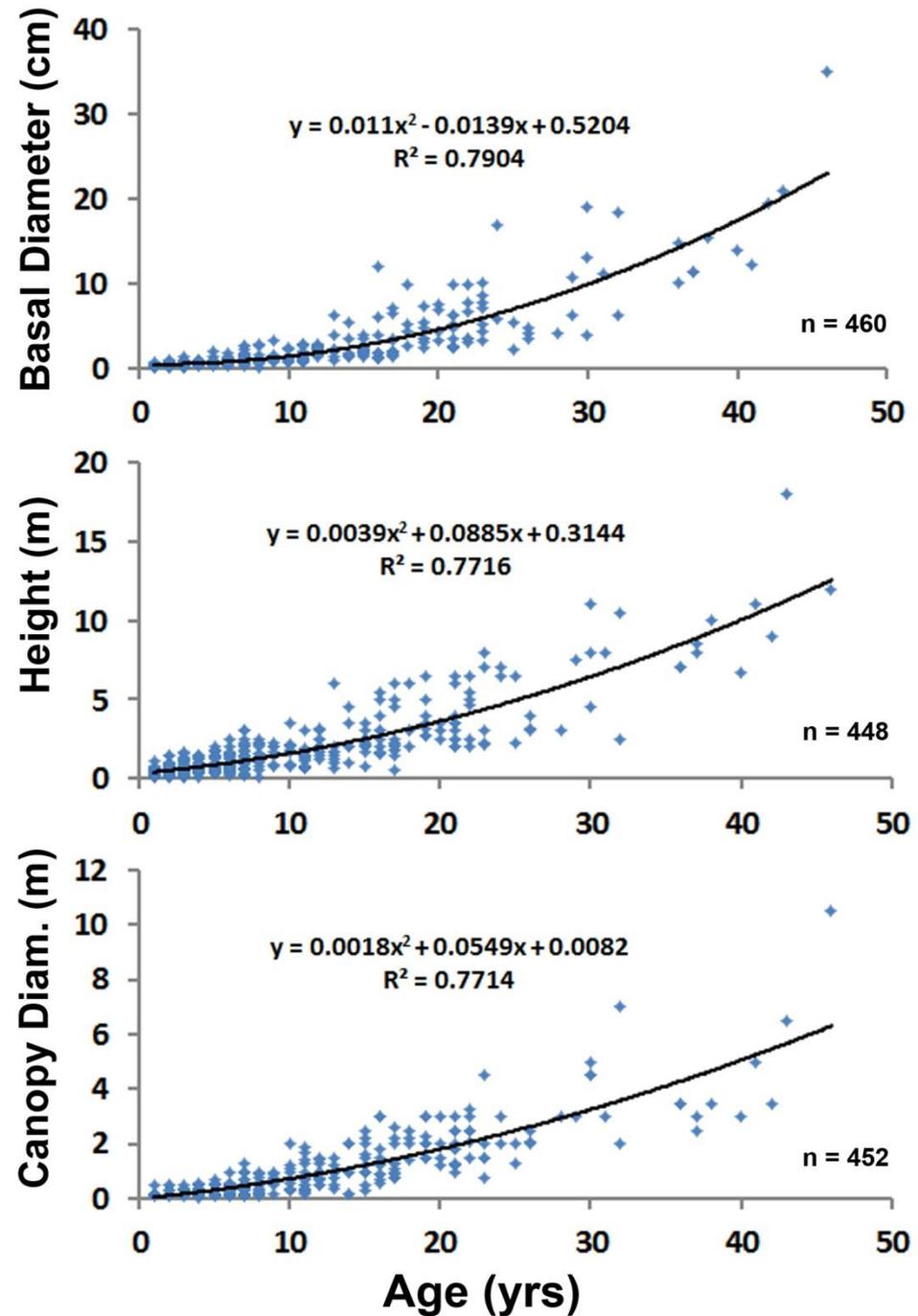


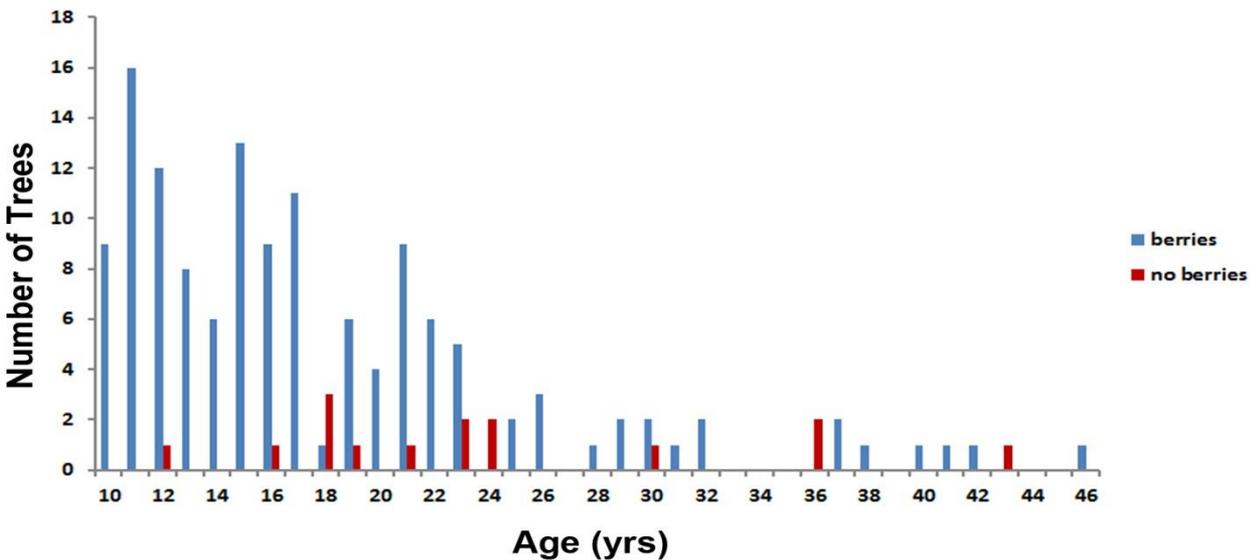
I. aquifolium size by age

- Diameter at base

- Height

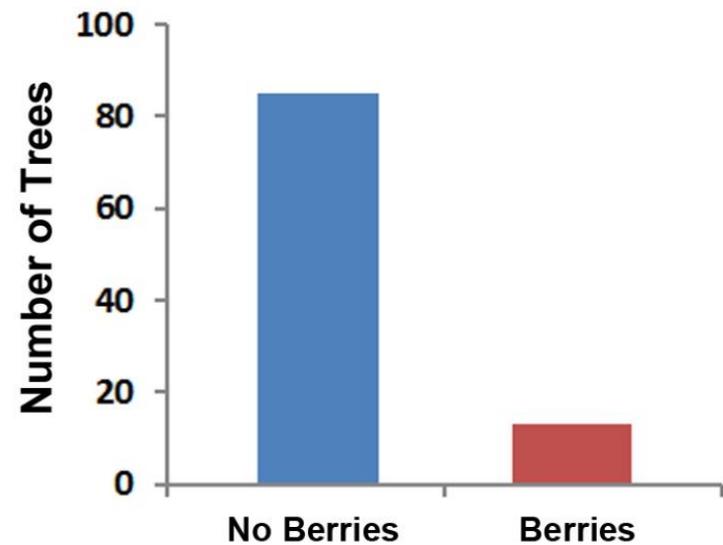
- Canopy diameter

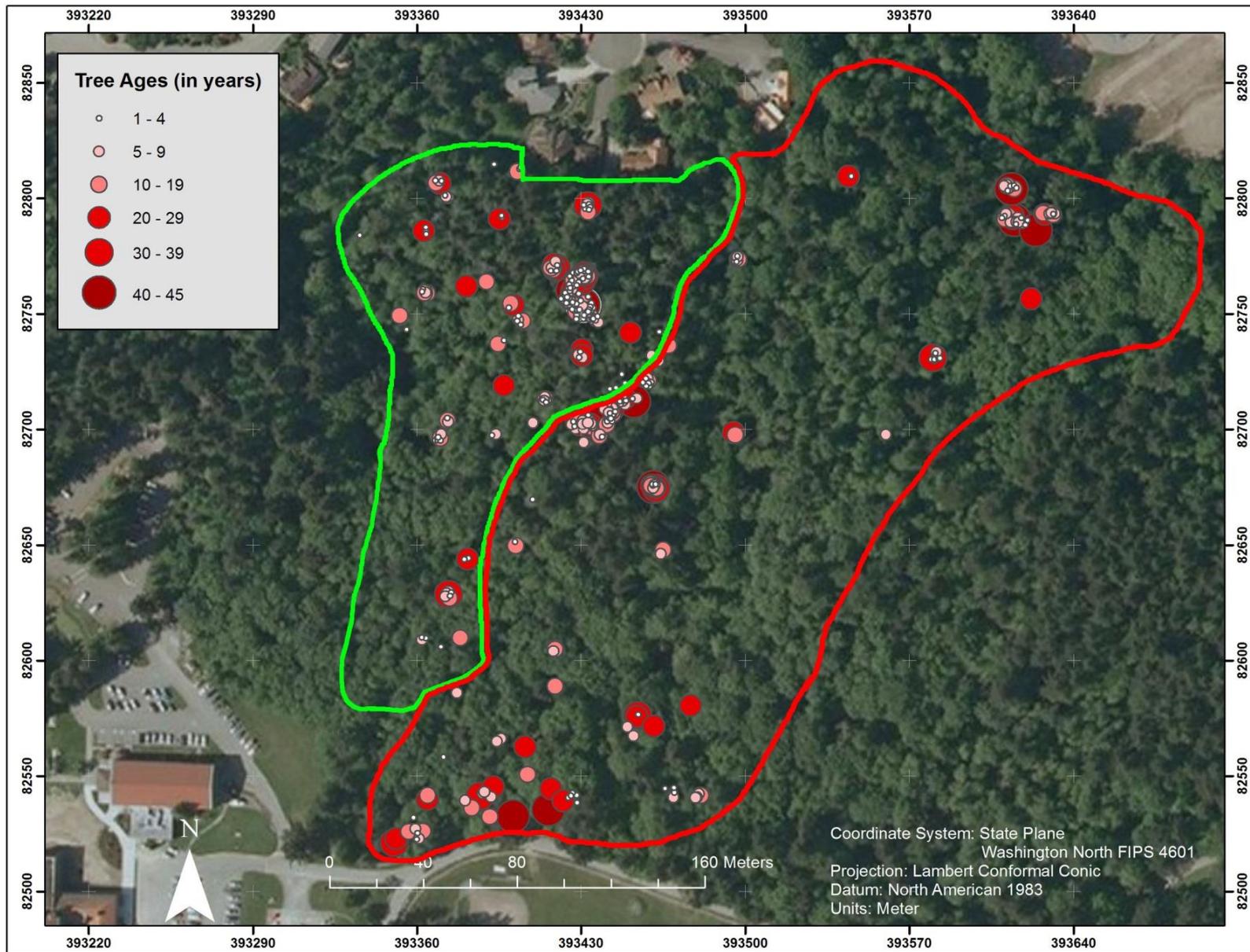




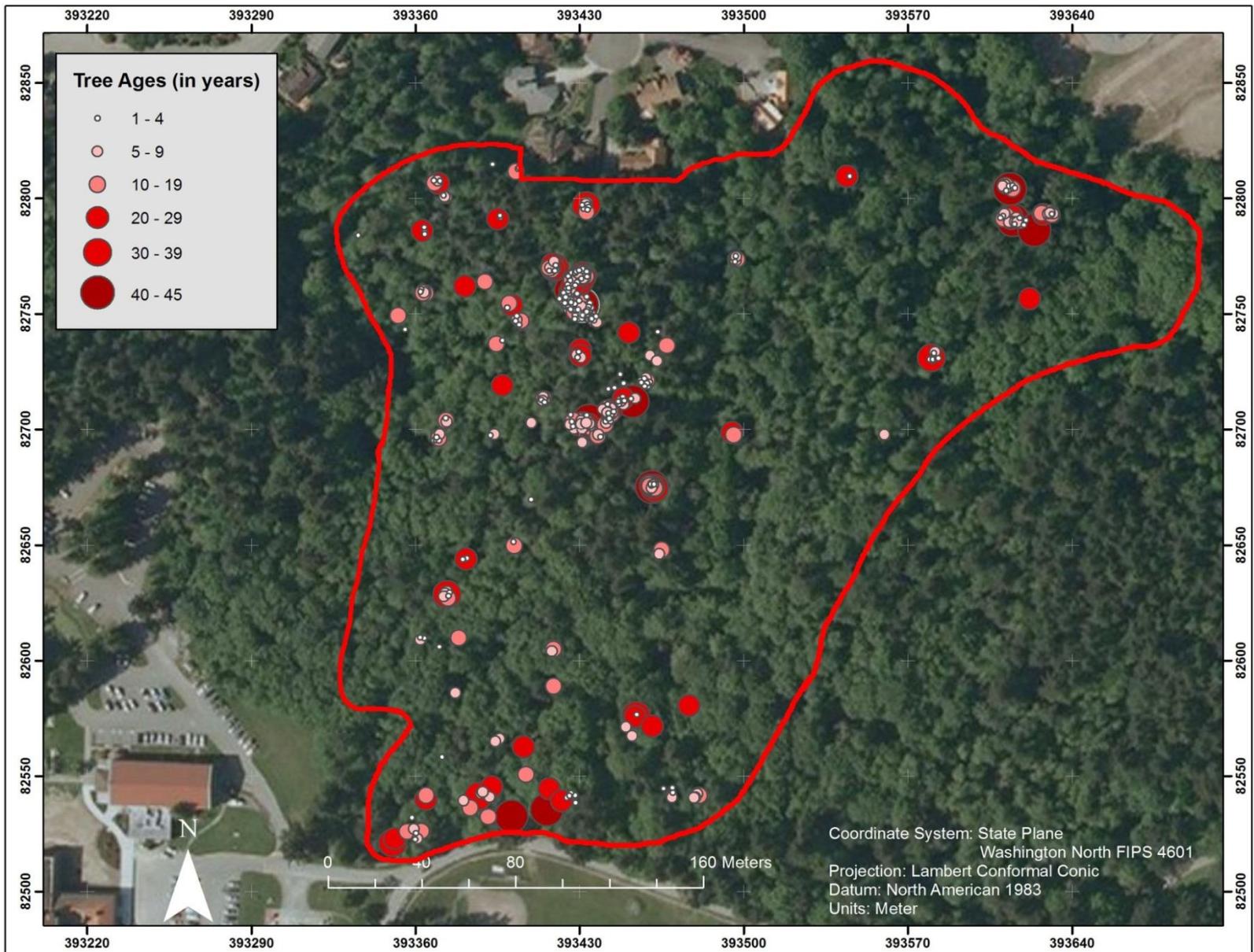
I. aquifolium trees in St. Edward Park study area 2011 & 2012 with and without berries by age (n = 150 trees \geq 10 years of age).

Number of *I. aquifolium* ages \geq 15 (n = 98) with and without berries, 2011 & 2012.





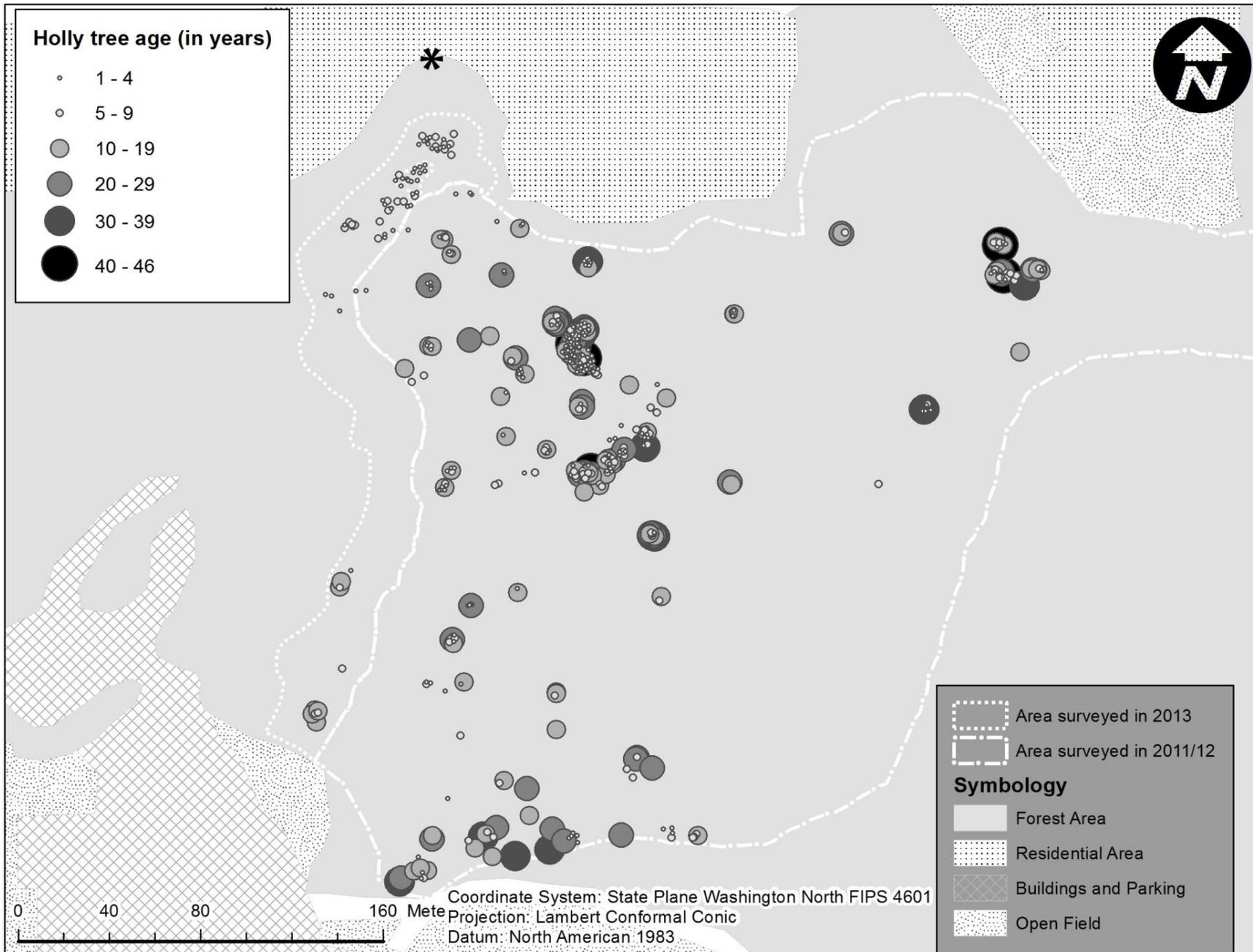
Locations of all ($n = 466$) *I. aquifolium* sampled and removed in the St. Edward Park study area, 2011 (red line) and 2012 (green line).



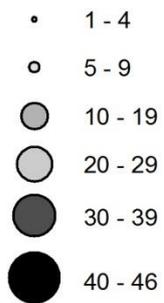
Locations of all ($n = 466$) *I. aquifolium* sampled and removed in the St. Edward Park study area.

Holly tree age (in years)

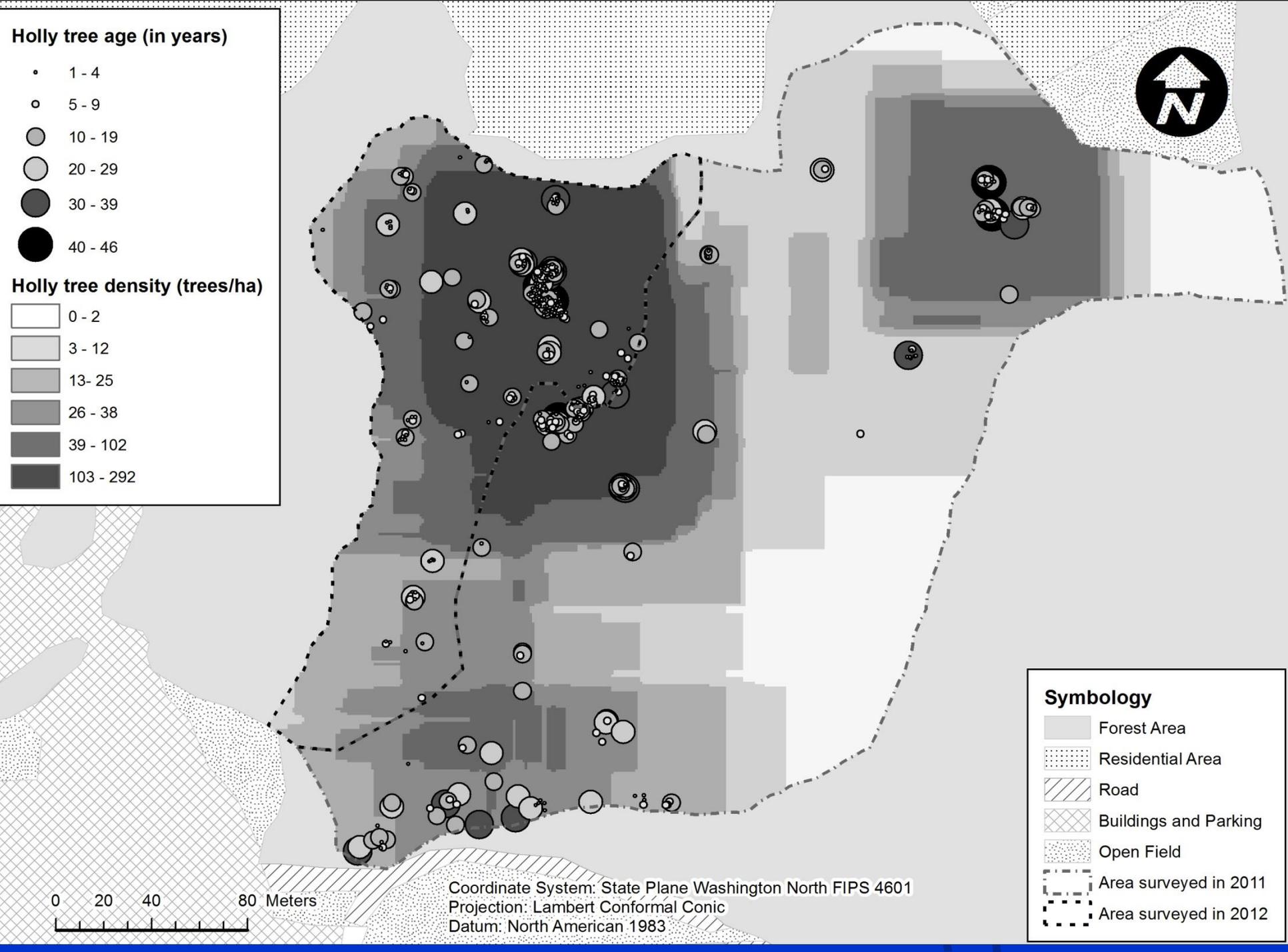
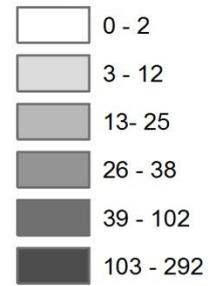
- 1 - 4
- 5 - 9
- ◐ 10 - 19
- ◑ 20 - 29
- ◒ 30 - 39
- ◓ 40 - 46



Holly tree age (in years)



Holly tree density (trees/ha)

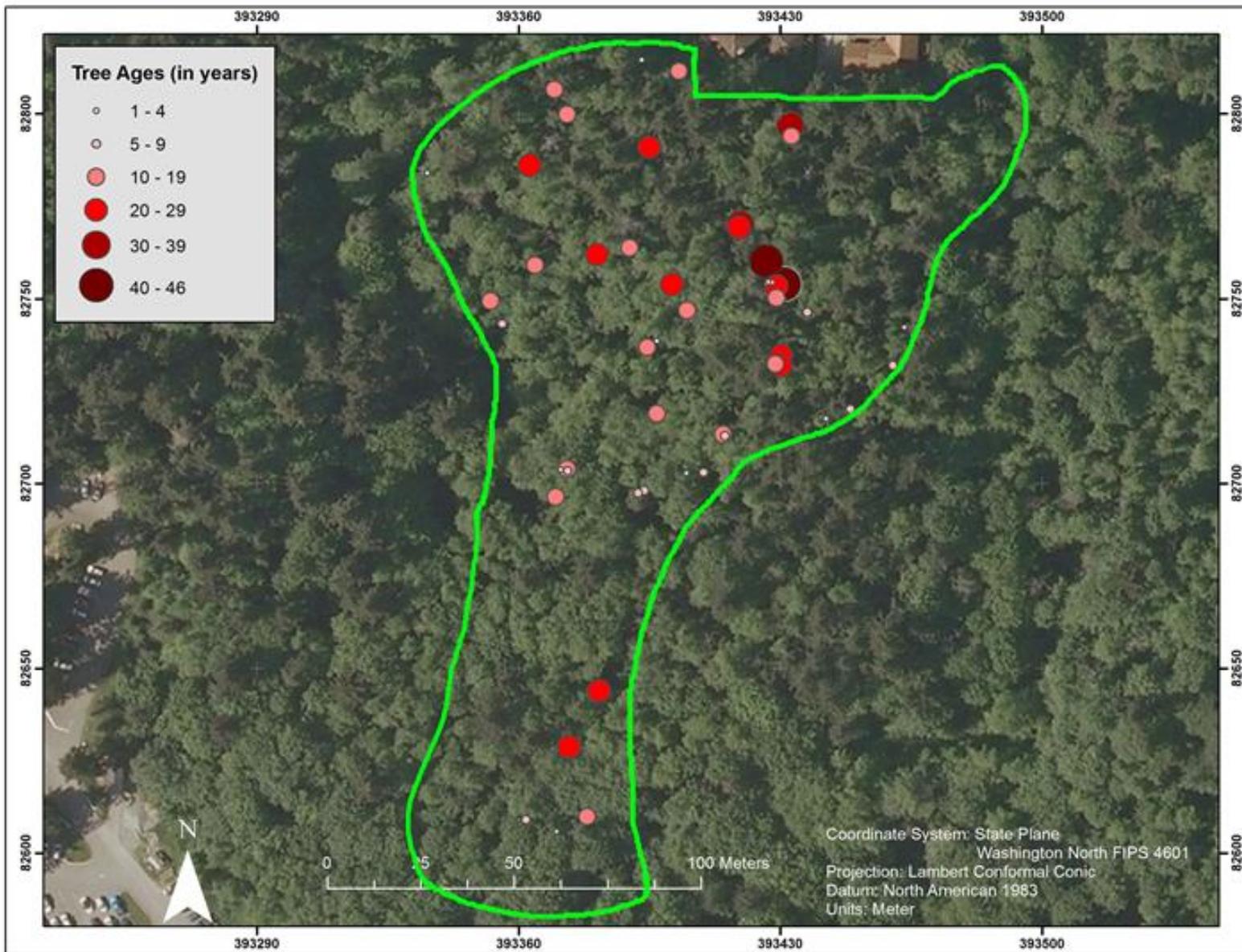


Coordinate System: State Plane Washington North FIPS 4601
Projection: Lambert Conformal Conic
Datum: North American 1983

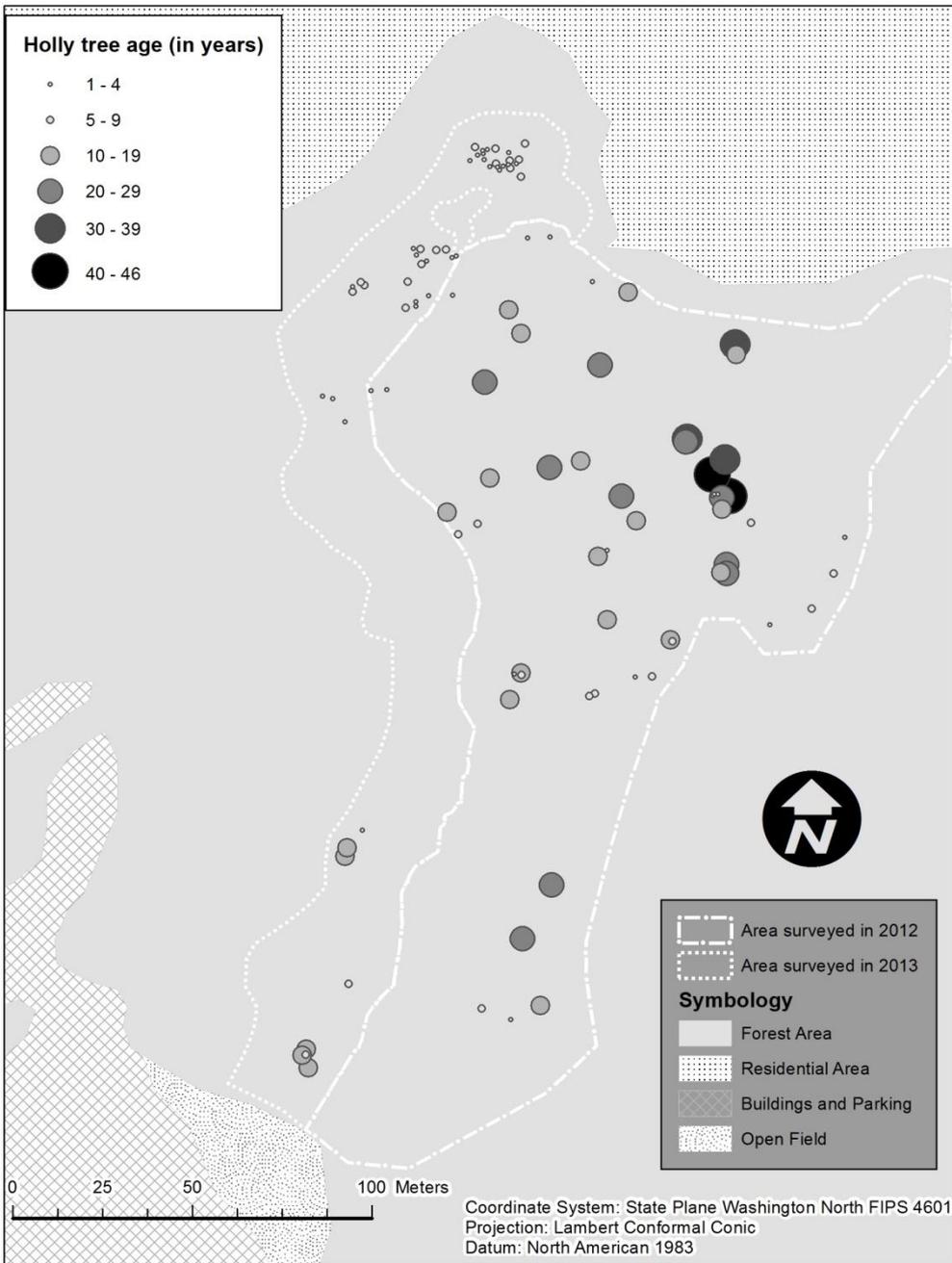
Symbology

- Forest Area
- Residential Area
- Road
- Buildings and Parking
- Open Field
- Area surveyed in 2011
- Area surveyed in 2012





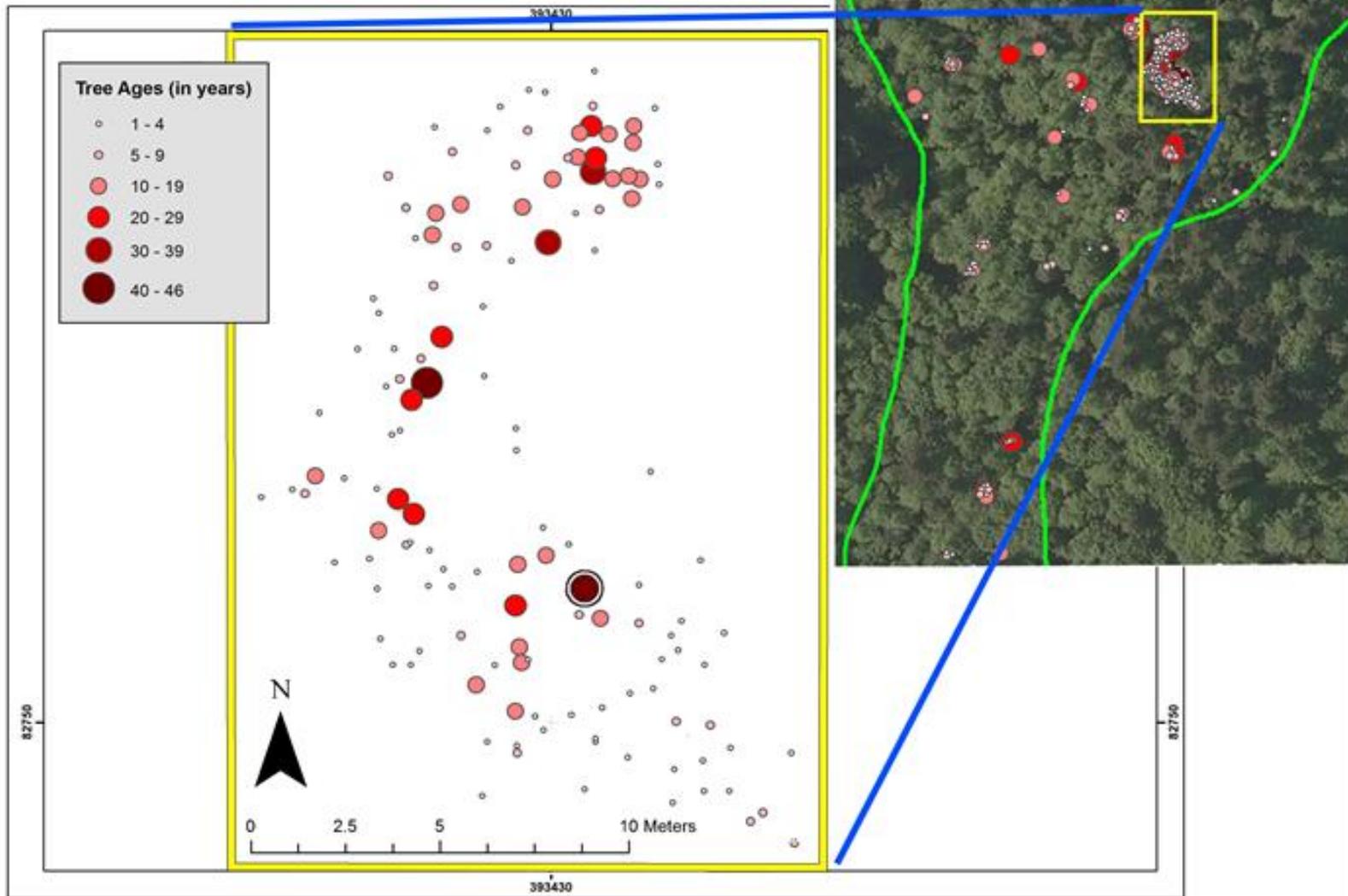
Location and age of seed-established *I. aquifolium* (n = 51) in the St. Edward Park study area (2012). Seed origin determined from root structure (n = 48) or distance from nearest conspecific (n = 3).











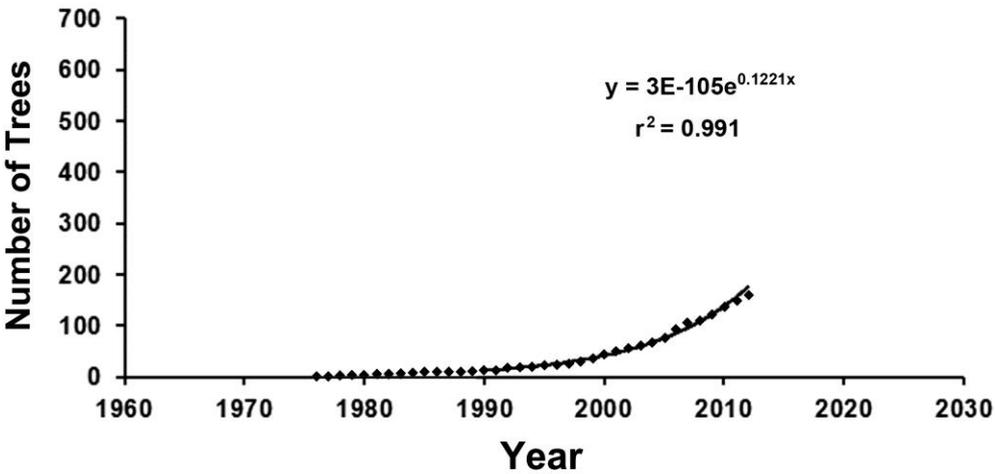
I. aquifolium dispersion and age within a clump (n = 131 sampled trees).
 Oldest tree (46 years) indicated by ring.





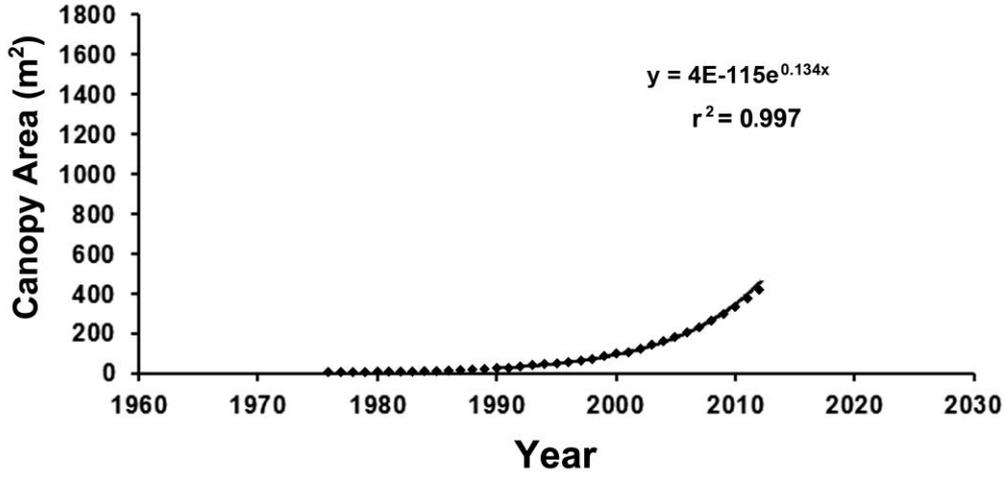
Number of *I. aquifolium* trees ≥ 10 yrs old in St. Edward Park study area since the beginning of the invasion.

- Current: 154
- 10 years: 580 (projected)
- 25 years: 3500 (projected)



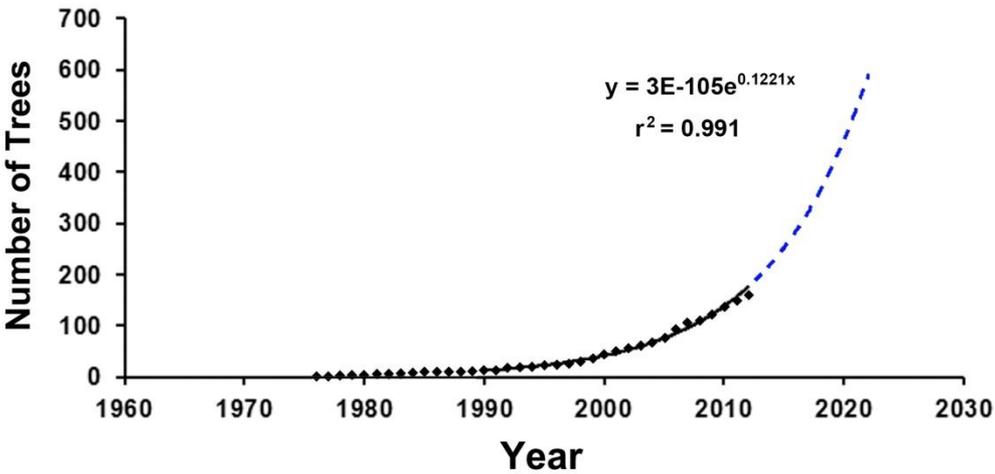
Total area covered by *I. aquifolium* canopy in St. Edward Park study area since the beginning of the invasion.

- % of study area covered
- Current: 0.6%
- 10 years: >2% (projected)
- 25 years: >15% (projected)



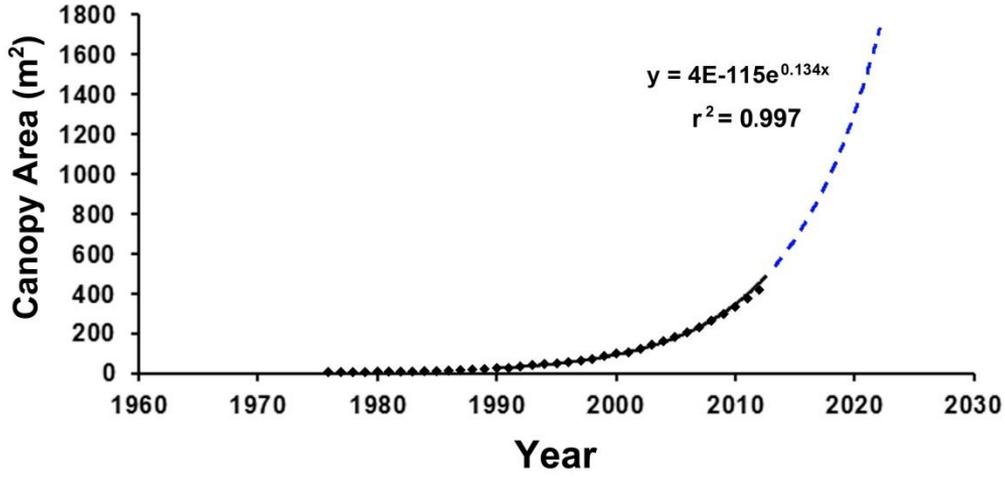
Number of *I. aquifolium* trees ≥ 10 yrs old in St. Edward Park study area since the beginning of the invasion.

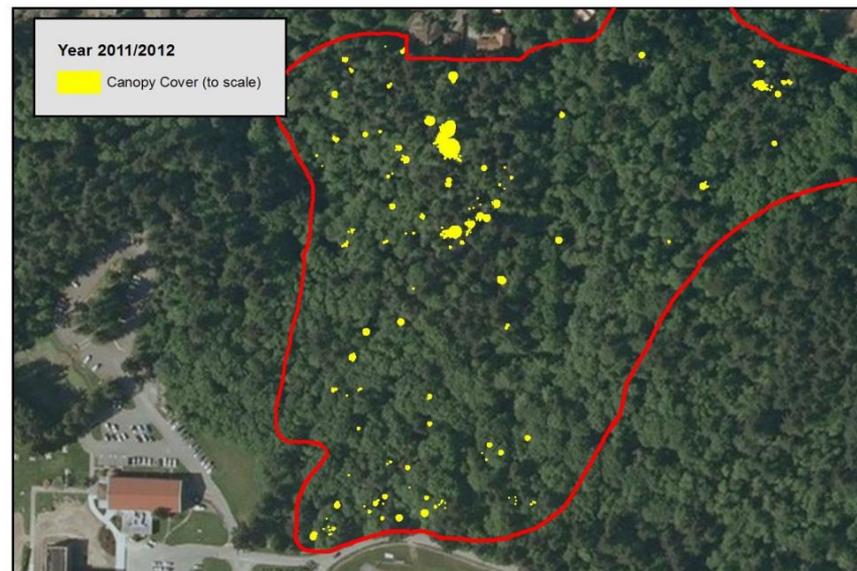
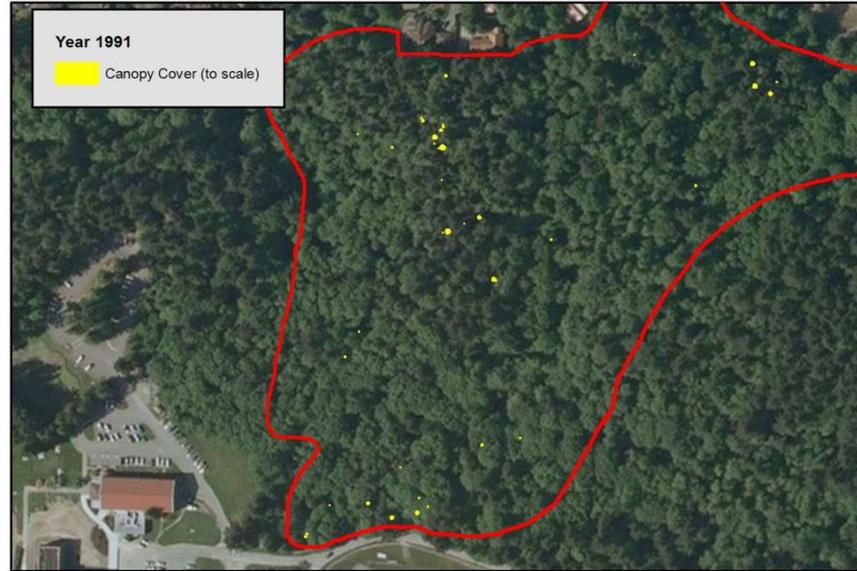
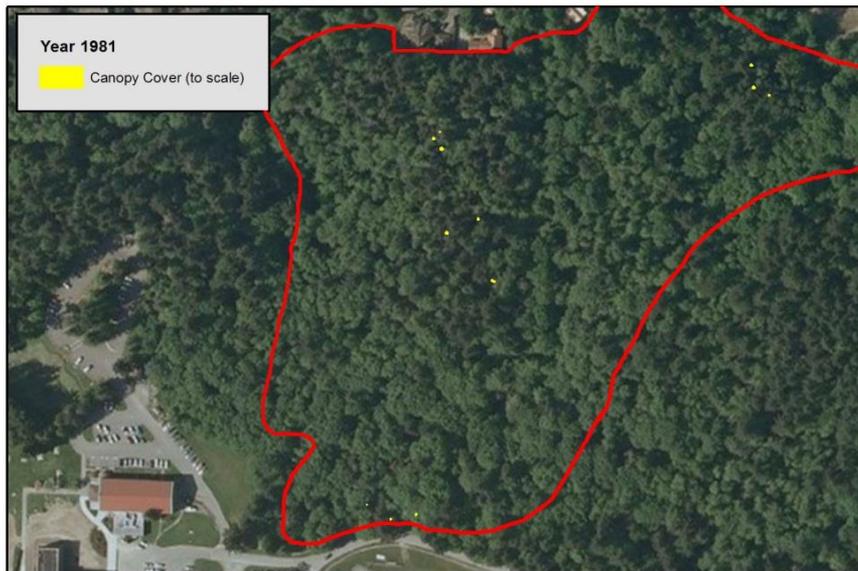
- Current: 154
- 10 years: 580 (projected)
- 25 years: 3500 (projected)



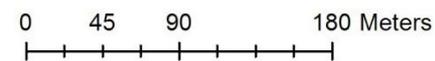
Total area covered by *I. aquifolium* canopy in St. Edward Park study area since the beginning of the invasion.

- % of study area covered
- Current: 0.6%
- 10 years: >2% (projected)
- 25 years: >15% (projected)



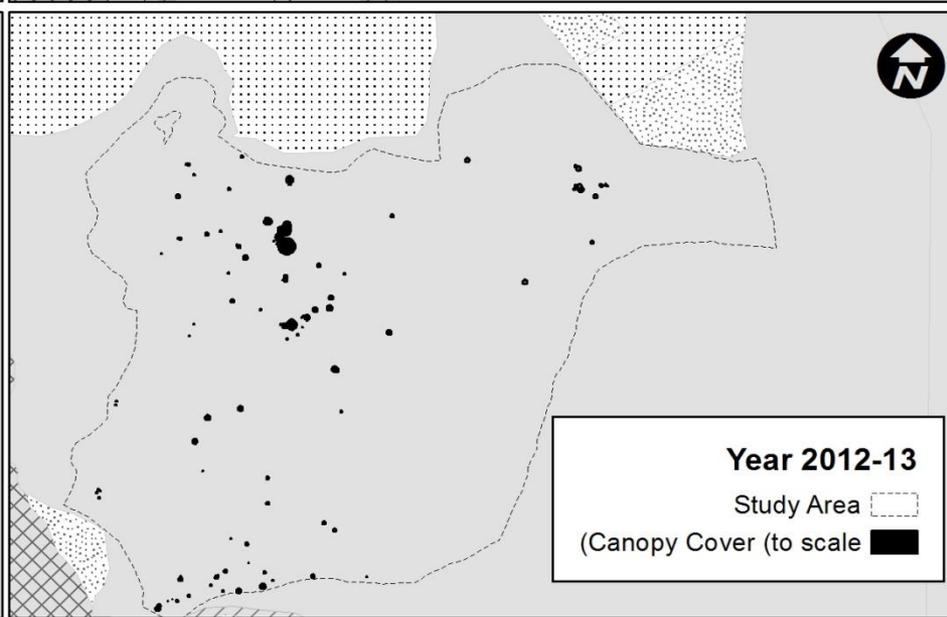
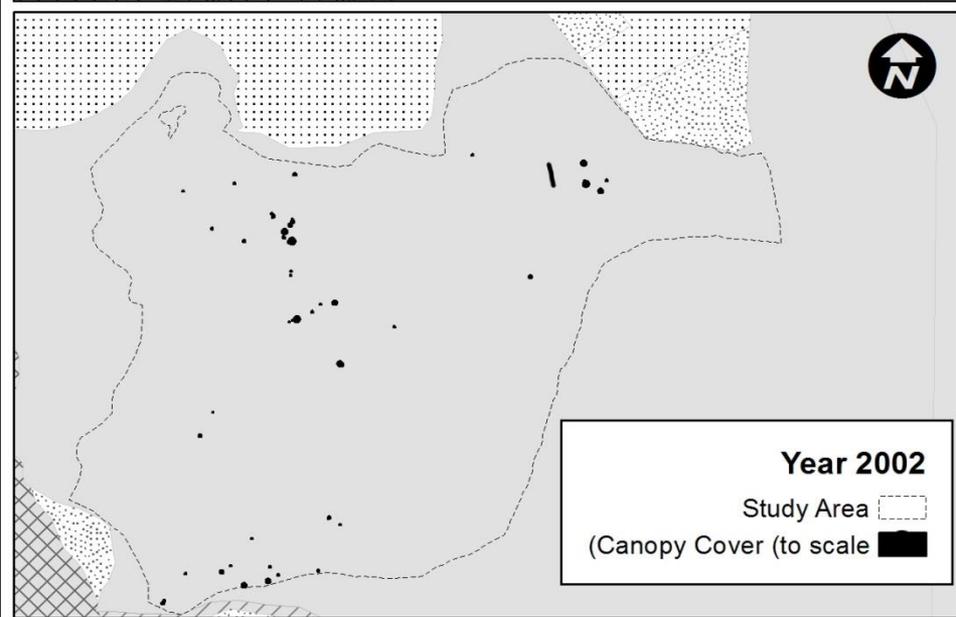
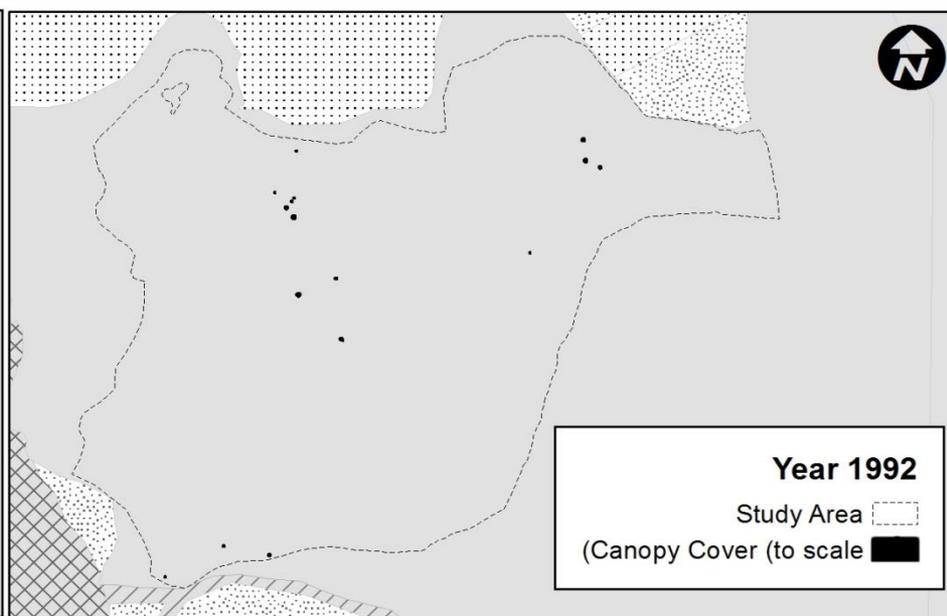
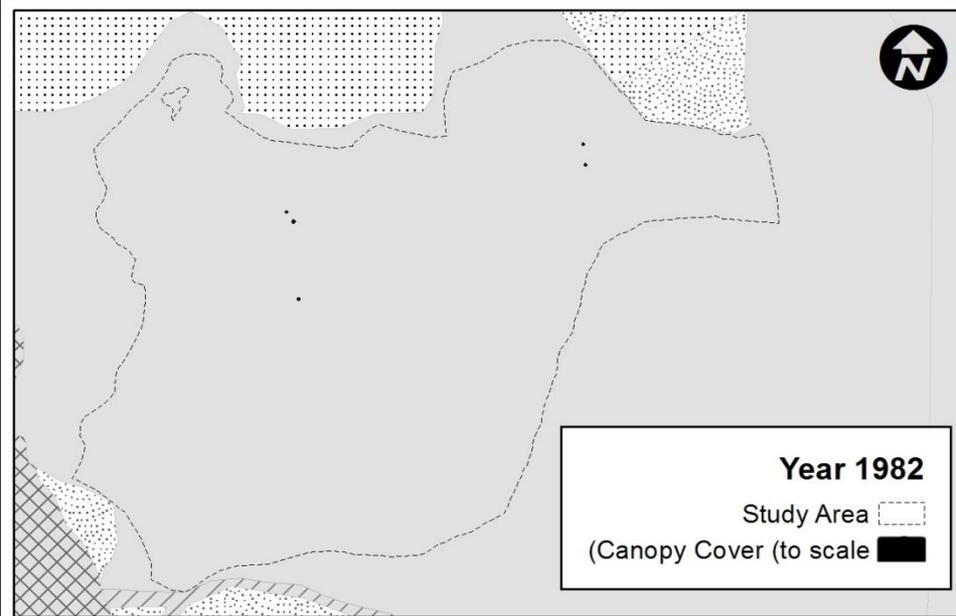


Modeled spatial extent of English holly canopy in 1981, 1991, 2001, and 2011. Canopy depicted at actual size.



Coordinate System: State Plane
 Washington North FIPS 4601
 Projection: Lambert Conformal Conic
 Datum: North American 1983
 Units: Meter





Symbology

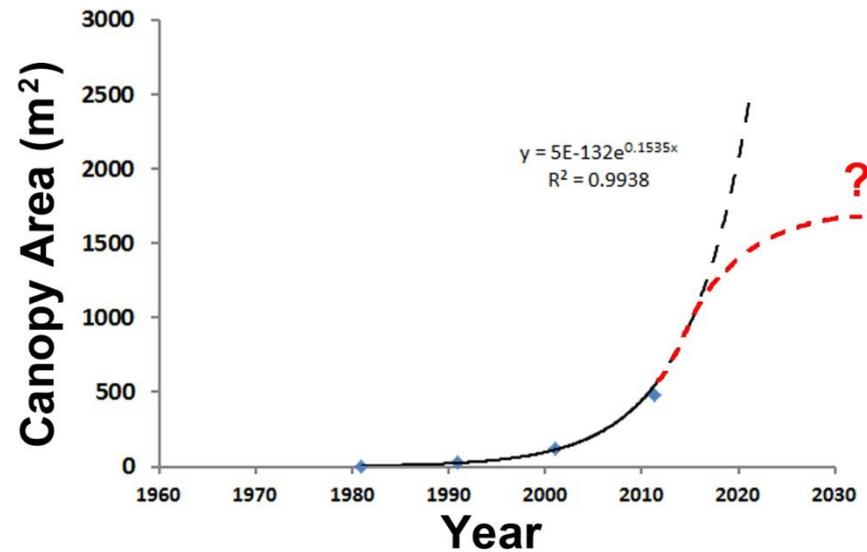
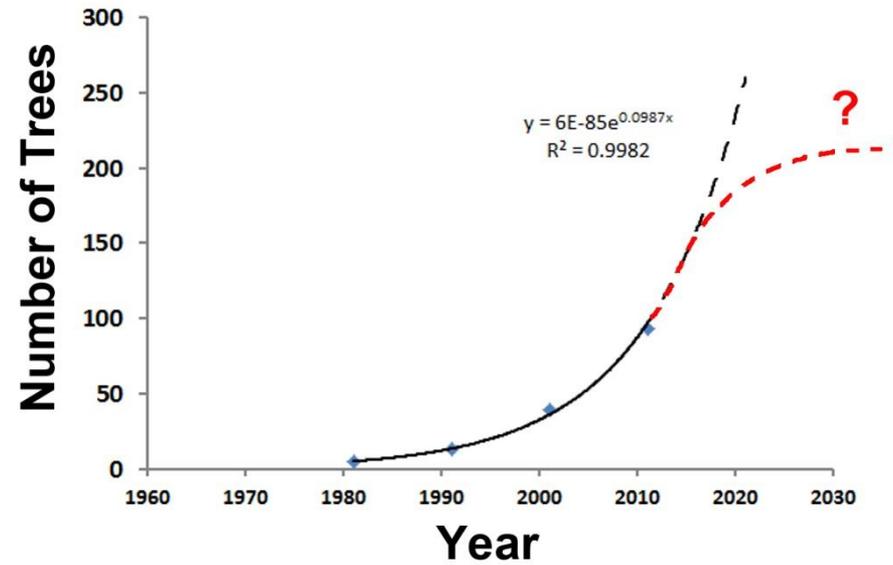
-  Canopy Cover (to scale)
-  Forest Area
-  Residential Area
-  Road
-  Open Field
-  Buildings and Parking
-  Study Area

0 145 290 Meters

Coordinate System: State Plane Washington North FIPS 4601
 Projection: Lambert Conformal Conic
 Datum: North American 1983



Density-dependent factors could slow invasion, but we don't know if or when they would become important.

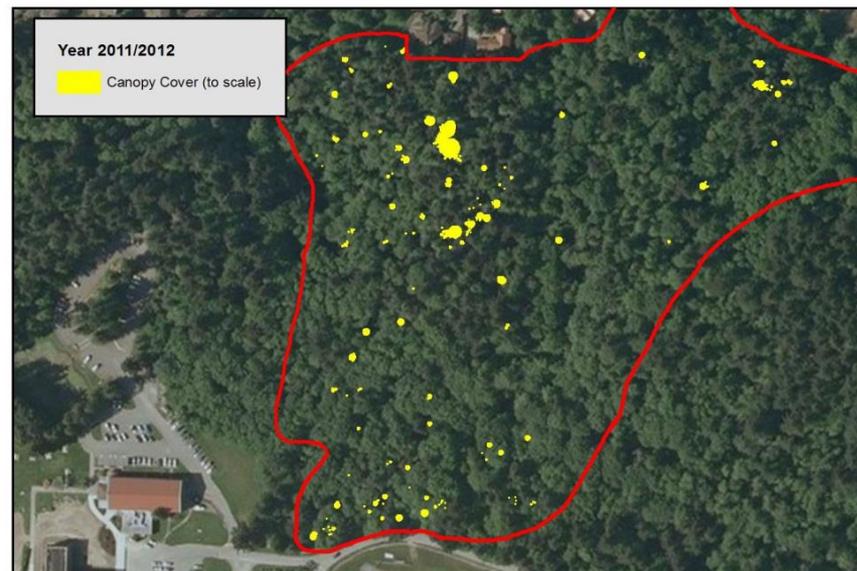
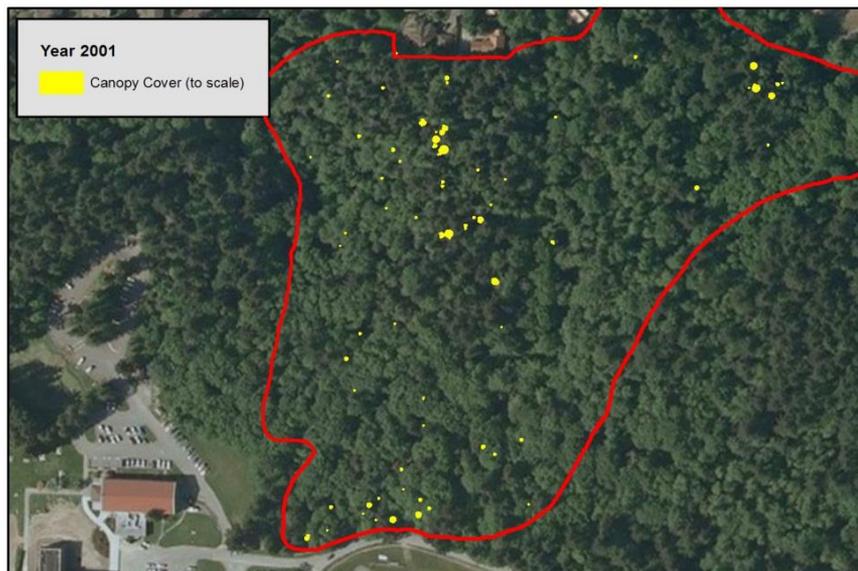
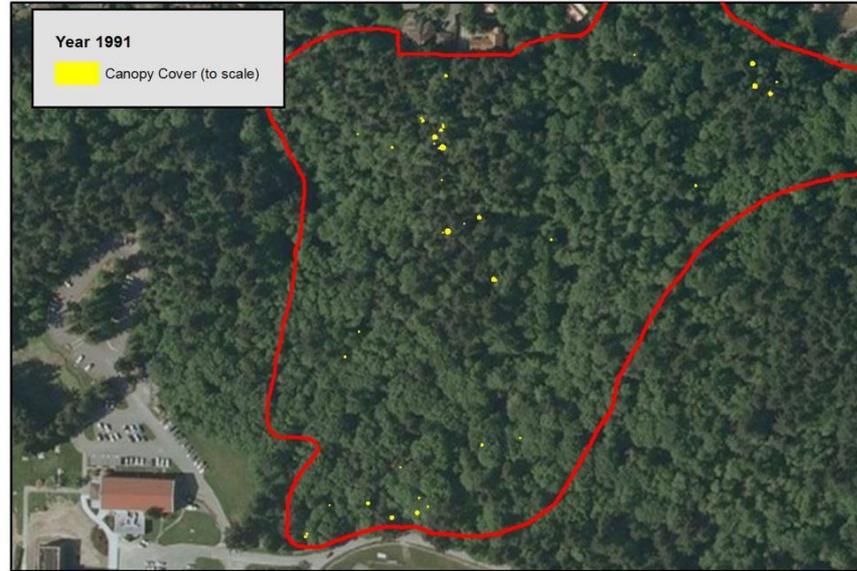
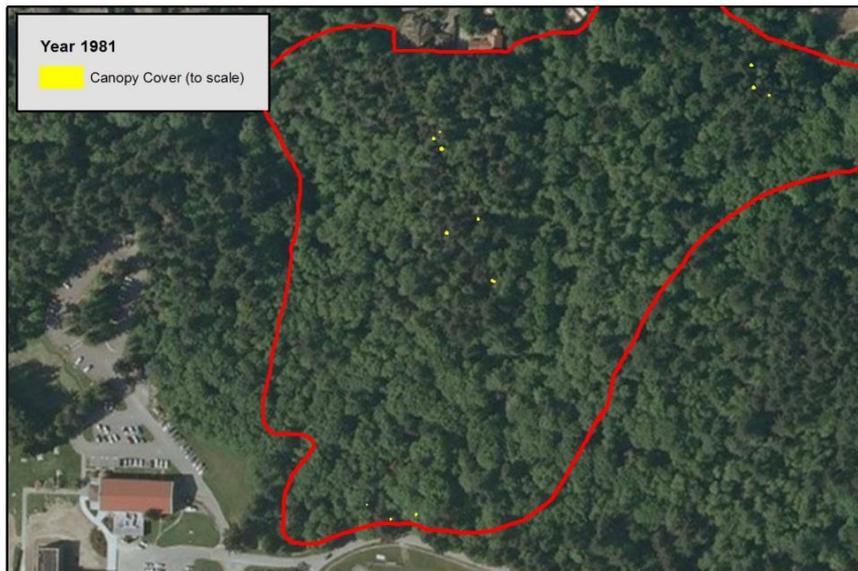


Conclusions

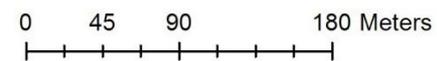
- English holly has been present in forest at St. Edward Park since the 1960's
- Holly appears to be proliferating by both dispersed seed and vegetative spread.
- Average density of holly in our study area was 57.7 plants/ha.
- The oldest trees exceeded 10 m (30 ft) in height and 20 cm (8 in) basal diameter and are in a life stage of rapid size increase.
- Mortality of holly trees at St. Edward Park appears to be extremely low.
- Holly appears to have a strong negative effect on native plant species.
- To this point the invasion has followed a pattern of approximately exponential increase in holly numbers and canopy area.
- Holly has the potential to become a dominant species in the forest within a short time.
- Control of holly should be undertaken soon for maximum efficiency and likelihood of success.
- Research is needed on several questions important for holly management.

Management/Policy Recommendations

- Formal designation of English holly as a noxious weed in Pacific Northwest west-side forests.
- Immediate development and implementation of a holly control plan for western PNW forested wildlands.
- Holly control on lands adjacent to forested wildlands.
- Education of the public about the threat to native forests posed by English holly, and the threat posed by invasive species generally.
- Additional research on key management questions.



Modeled spatial extent of English holly canopy in 1981, 1991, 2001, and 2011. Canopy depicted at actual size.

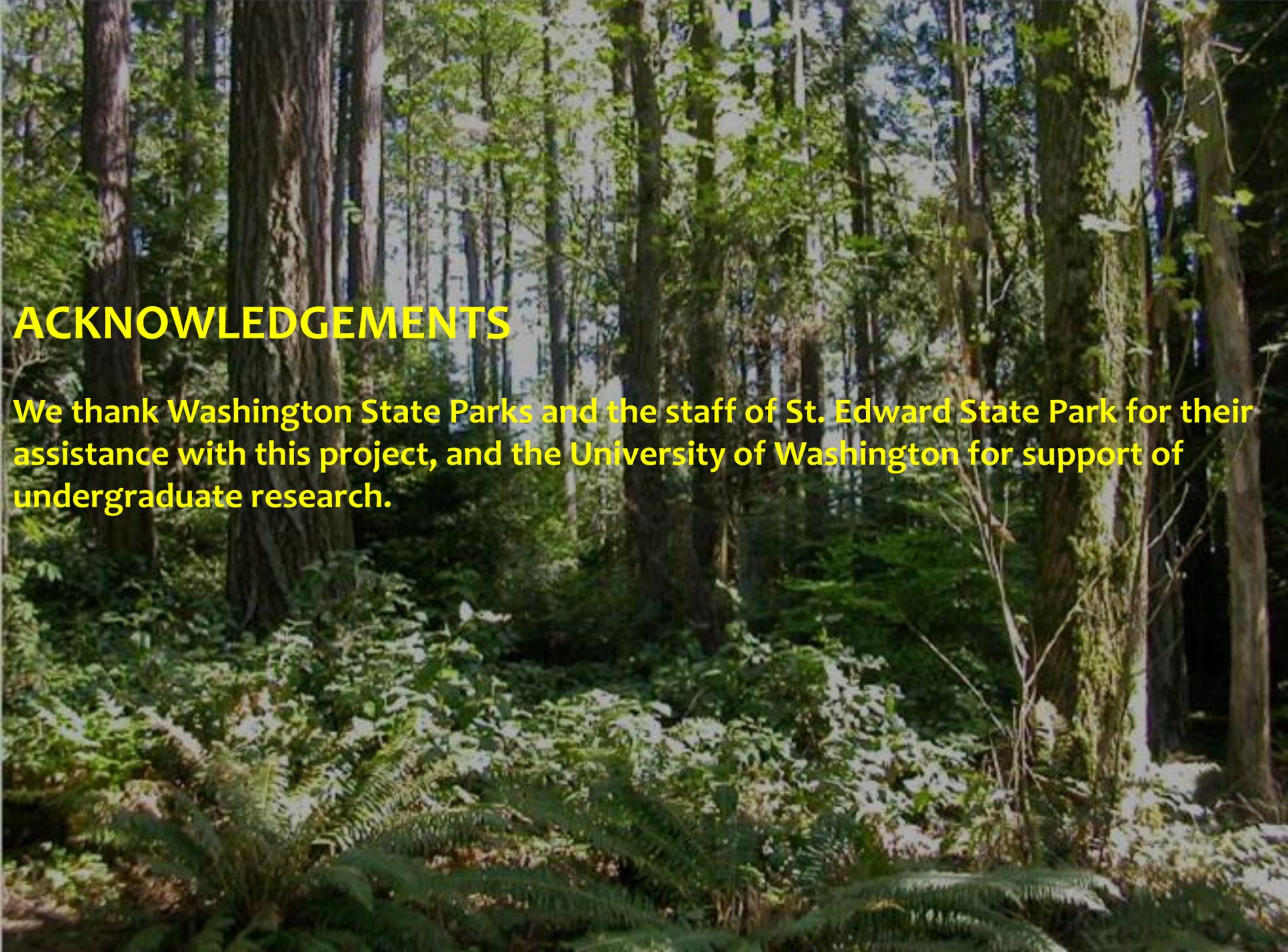


Coordinate System: State Plane
 Washington North FIPS 4601
 Projection: Lambert Conformal Conic
 Datum: North American 1983
 Units: Meter



Research Needed

- Additional data collection to increase sample locations and range of plant communities sampled
- Spatial model of site-scale vulnerability to holly invasion
- Effectiveness of removal techniques
- Improvement of predictive population and cover models with more data
 - Roles of vegetative spread and seed dispersal
- Effects of holly on other species: magnitude and mechanisms
- Effects of holly on riparian habitats

A photograph of a lush forest. The foreground is filled with a dense carpet of green ferns and other low-lying plants. In the mid-ground and background, numerous tall, slender tree trunks rise vertically, their leaves forming a thick canopy that filters the sunlight. The overall scene is vibrant and verdant, suggesting a temperate rainforest or a similar moist forest environment.

ACKNOWLEDGEMENTS

We thank Washington State Parks and the staff of St. Edward State Park for their assistance with this project, and the University of Washington for support of undergraduate research.