Bird Density in Forested Migration Stopover Sites on the Lower Delmarva Peninsula (*Product #1: Final Report on Field Observations*) and a Comparison With Radar-based Predictive Models (*Product #2: Final Report on Comparison of Field Observations With Radar-Predictive Model*)

Prepared by:

J. Andrew Arnold, BS and Eric L. Walters, PhD
Department of Biological Sciences
Old Dominion University
Norfolk, VA

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INTRODUCTION

Fall migration is a period when billions of landbirds travel from breeding to wintering grounds. These birds have developed a strategy of moving among habitats to remain in favorable climates with necessary resources such as food. This undertaking is most notable in neotropical migrants, species that breed in North America before traveling thousands of kilometers to wintering sites in Central and South America (Moore and Woodrey 1993). While the rewards of completing this trip are high, the journey between destinations is both physically demanding and filled with peril. As a result, much of the yearly mortality for many migratory species will occur during these few weeks (Sillett and Holmes 2002).

To meet these high energetic demands, many landbirds use stopover sites along their route in order to rest and refuel. Stopover sites located along major Flyways typically provide resources to a large number of neotropical and temperate migrants during this time (Watts and Mabey 1994, Moore et al. 1995, Mehlman et al. 2005). Both types of migrants, many of which are birds only a few months old, are faced with the strenuous undertaking of obtaining resources in an unfamiliar environment, a task further complicated by adverse weather, the pressures of competition from both residents and other migrants, and the constant threat from predators. Acquiring these resources is essential for every migrant's journey, and thus migrants often try to maximize these resources during their journey (Suthers et al. 2000, Sillett and Holmes 2002). Paradoxically, many of these stopover sites are overlooked by conservationists because of the ephemeral nature of their use even though stopover sites are critical to survival during migration (Moore and Woodrey 1993, Sheehy et al. 2011).

During fall migration, millions of landbirds travel southward along the Atlantic Flyway, a migratory route running along eastern North America. Many individuals taking this path will inevitably make use of stopover sites located along the Delmarva Peninsula, a stretch of land along North America's coast in the heart of the Atlantic Flyway, which includes portions of the states of Delaware, Maryland, and Virginia. The area's geographic landscape, with an oceanic barrier to the east and mountains to the west, helps funnel birds along the coastline. This results in very high concentrations of landbirds using this area over a span of a few weeks (Watts 1994). While the importance of this area has long been recognized, how geographic features and habitats are selected and used by migratory species on both a small and large scale is poorly understood (Mabey et al. 1993, Watts and Mabey 1994).

Landscape characteristics among stopover locations may contribute significantly to a migrant's decision to stop. Individuals may employ different strategies based upon their needs – some may choose to quickly refuel and continue their journey while others may need to seek shelter and stop for an extended rest. Weather patterns can have profound effects on migrating birds, often pushing them off course or forcing them to the ground to wait out storms. Large scale landscape characteristics such as the type and proportion of land cover or the extent of anthropogenic landscape modifications (e.g., urbanization and agricultural use) may also influence stopover decisions. Natural geographic barriers such as mountains or large bodies of water may also present obstacles for migrating birds and can force individuals to take a less energy efficient route, often resulting in a funneling effect or the use of sub-optimal stopover sites. Understanding how specific variations in landscape features are affecting migratory bird movement is critical for any proper management or conservation efforts (Moore and Woodrey 1993, Moore et al. 1995, Mehlman et al. 2005, Sheehy et al. 2011).

Recently, weather radars have become a reliable tool for tracking migratory bird movement on a continental scale (Buler and Dawson 2014). These radars are able to detect flocks of migratory birds both at the beginning of their night flight ascent as well as when flocks begin their descent near sunrise, using levels of reflectivity to measure the intensity of birds in much the same way as meteorologists measure the intensity of storms. By employing radar methodology, migratory patterns can be studied on a global scale, an option not available in the past, and the value of which is just beginning to be understood and recognized (Gauthreaux and Belser 2003). Moreover, radar data can be used to create predictive models and identify features of the landscape that appear to be particularly important to migrating birds. Because large portions of the United States do not have radar coverage, predictive models can be used to interpolate bird use in areas without coverage (Buler and Dawson 2014).

The lower Delmarva Peninsula, consisting of Virginia's Accomack and Northampton Counties, is a globally important area known to be extremely rich in landbirds during fall migration (Watts 1994). Individuals not prepared to cross a water barrier or continue down the coast will rest and refuel in this area until they have adequately met their resting and refueling needs. The duration of these stopover bouts can easily last days depending on weather conditions, energetic demands of individuals, and the availability of limited resources at a site (Suthers et al. 2000, Smith et al. 2007). This entire area has also historically lacked radar coverage. The unique circumstances found at this location create an ideal opportunity to test the validity of radar-based models for predicting migrant densities while also assessing the quality of stopover sites in an area known to be of global significance to migratory birds (Buler and Dawson 2014).

OBJECTIVES

The objectives of this study highlight our need to better understand how migratory birds are selecting and using stopover habitat and are critical at many levels. Properly guiding conservation initiatives for migratory species is nearly impossible without understanding their relationship with the surrounding habitat. Focusing management practices on the most important variables is necessary when funding opportunities are limited. Public awareness of the importance of stopover habitats is also crucial to land managers since public support is a necessary step in conservation activities, particularly those that involve land acquisition or protection. This is certainly the case along the lower Delmarva Peninsula, an area that attracts thousands of birders during fall migration and whose economic input is vital to an area that is generally quite impoverished.

Our primary objective was to conduct a quantitative assessment of migratory landbird use at forested sites on the lower Delmarva Peninsula. We surveyed along transects during fall migration to quantify the diversity and abundance of migratory landbirds present at each location, allowing for a comparison among sites. To better understand the site-specific qualities, we also gathered information on habitat characteristics and food availability. Because sites were selected based on predicted densities from NEXRAD-radar-based predictive models, a second objective was to evaluate the utility of using these models for predicting migratory landbird use of stopover habitats.

STUDY AREA

The study took place at 12 forested sites across Virginia’s Eastern Shore in Accomack and Northampton Counties (Figure 1). This slice of land, approximately 100 km long and 5,452 km^2 in size, is separated from mainland Virginia by the Chesapeake Bay to the west and bordered by the Atlantic Ocean to the east. Due to its distinct geographic location, this landmass naturally serves as a funnel for millions of birds moving south during fall migration, especially landbirds using the area for rest and refueling purposes (Mabey et al. 1993, Watts 1994).

Figure 1: Virginia's Eastern Shore and survey site locations

METHODS

Site Selection and Radar-based Model Predictions

Twelve forested sites were selected along the lower Delmarva Peninsula using a stratified design to representatively sample forested habitat from north to south and east to west, based on NEXRAD-radar-based predictive models of migrant density (Buler and Dawson 2014). Sites were categorized as high, medium, or low predicted density (Figure 2). All forested sites were at least 4 ha in size and separated by a minimum of 10 km from any other site (where possible). Mature forests were selected, as this habitat type has been shown to support large numbers of migratory birds and is likely very important for conserving these species (Rodewald and Brittingham 2007). Hardwood forest sites were preferred and selected when available; otherwise mixed pine/hardwood sites were used.

Avian Data

To examine the distribution of migrants among sites over the season, transect surveys were conducted 6 days per week from 15 August through 7 November 2013. We placed one 500-m transect at each site, marking the path with biodegradable flagging at 25-m intervals. Trimming of the path was minimized, usually only consisting of removing greenbrier vines that impeded transect access, so as not to alter habitat. Each transect was surveyed over 30 minutes, and all surveying took place within the first four hours after sunrise. This schedule allowed us to visit each site approximately twice per week. Surveying only occurred on days with favorable weather conditions (no rain and wind speeds < 24 kph as determined at the site prior to surveys).

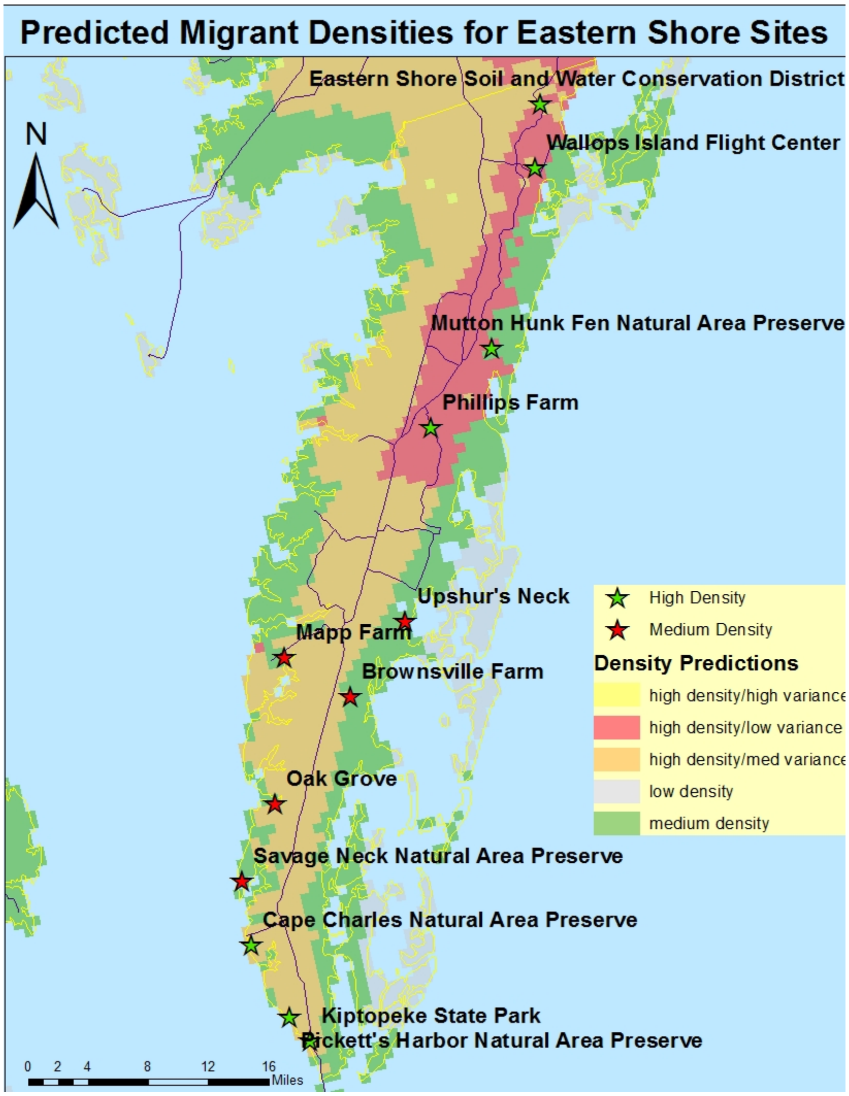


Figure 2: Migrant density predictions for all Eastern Shore sites

All birds detected were identified to species and, when possible, age and sex were recorded. The method of detection (visual or aural) was noted and, if aural, whether the detection was made by song or call. Any birds in aggregate were recorded as a "flock". Species were classified as: 1) neotropical migrants, 2) temperate migrants, or 3) year-round residents.

Distance measurements were also recorded for all detections, and included: 1) observer location along each transect, 2) distance of detection from the observer, 3) perpendicular distance of detection from transect, and 4) vertical height of detection. Distance measurements were binned in meters as follows: 0-5, 5-10, 10-15, 15-20, 20-25, 25-50, > 50, flyover. By using distance sampling methods, detection probabilities could be determined based on site or species, assuming sample sizes were robust (>50 detections). Distance sampling allows for an estimation of migrant density found within an area, an option not available when using standard point-count survey methods (Buckland et al. 2004, Buckland 2006). Detection probabilities for each focal migrant were calculated and densities adjusted using package ‘unmarked’ in R 3.1.0 (R Development Core Team 2014).

The information on avian abundance (adjusting for survey effort) was compared to assess both use and occurrence trends, including variation in food availability and habitat characteristics, among sites. Migrant density at each site was compared to radar-based predicted densities.

Food Availability

To assess the amount of food available at each site across the season, we sampled fruit and insect abundance during each site visit. Six 20 m x 20 m plots were placed alongside each transect at every 75m. Sampling within the plots alternated each visit so that the 75 m, 225 m, and 375 m plots were sampled on one visit and the 150 m, 300 m, and 450 m plots on the following visit.

Fruit sampling consisted of recording all species of plants containing fleshy fruit within the 20 m x 20 m plots, including their abundance, ripeness, and relative height. Number of fruits was binned as follows: 1 (1-10), 2 (11-25), 3 (26-100), 4 (101-250), 5 (251-1000), 6 (1001-3000), and 7 (3001-10000). The ripeness was recorded as the percentage of unripe, ripe, and overripe fruits for each species detected and relative height was recorded as the percentage found in the understory, midstory, and canopy for each species (Smith and McWilliams 2009). Fruit is known to be an important factor for many migratory bird species, and the presence of fruiting species has even been suggested to be more important than habitat structure in determining habitat use (Suthers et al. 2000).

Insect sampling was performed in two ways: 1) visual count of terrestrial arthopods, and 2) enumeration of arthropods from branch clippings. Visual counts were conducted within 0.5 m x 0.5 m ground plots located within the larger 20 m x 20 m plot. Visual surveys were conducted by standing over 0.5 m x 0.5 m plot for 3 minutes and recording the size (mm) and Order of any arthropod species. Bagged branch clippings were collected from within the 20 m x 20 m plot and consisted of collecting all arthropods on or in the branch sample. All arthropods were identified to Order and size (mm) was recorded. Each branch clipping consisted of approximately 40 leaves from either the dominant site species or one of four common focal species (American Holly [*Ilex opaca*], Red Maple [*Acer rubrum*], Sweetgum [*Liquidambar styraciflua*), Blueberry [*Vaccinium angustifolium*]).

Data on food availability, including arthropod abundance and fruit ripeness, was compared among sites to examine variation in resource availability among sites and over time. This information was then compared to migratory bird data for each site to identify any relationships between food availability and avian abundance.

Site Characteristics

We characterized the vegetative composition and habitat structure at each site (10-27 October). We randomly selected four of the six (75 m, 150 m, 225 m, 300 m, 375 m, 450 m) 20 m x 20 m plot locations along the transect, and used one 5-m radius circle (0.01 ha) for shrub density measurements and one larger 11.3-m radius circle (0.04 ha) for tree density measurements. Within the smaller 5-m radius circle, the abundance of woody shrubs (>0.5m in height and <3cm DBH [diameter at breast height]) was recorded by counting the number of stems. In the larger 11.3-m radius circle, all trees and their DBH were recorded. For smaller trees, individuals were counted in one of two categories (DBH<2.5 cm, DBH 2.5-8 cm). Trees >8 cm in DBH were measured and recorded separately. Each plant was recorded to species when possible, although some were only identified to genus (*Quercus sp*., *Carya sp*., etc.).

RESULTS & DISCUSSION

Avian Data

Between 15 August and 7 November 2013, a total of 203 transect surveys at 12 forested locations along the Eastern Shore of Virginia were conducted. One hundred and one avian species were detected across the season, consisting of 5,057 individual detections. A complete list of species detections by site is provided in Appendix B.

Commonly Detected Migrants (% of total category)	
Neotropical	**Temperate**
American Redstart (18.3%)	Blue Jay (18.1%)
Red-eyed Vireo (13.0%)	Yellow-rumped Warbler (17.4%)
Acadian Flycatcher (7.3%)	Golden-crowned Kinglet (15.2%)
Summer Tanager (7.0%)	Northern Flicker (13.2%)
Yellow-billed Cuckoo (6.2%)	American Goldfinch (8.4%)

Table 1: Common neotropical and temperate migrant detections for all Eastern Shore survey sites

Of the 101 species, 39 species were classified as neotropical migrants, 21 species as temperate migrants, and 41 species as year-round residents. The five most common neotropical migrants were American Redstarts, Red-eyed Vireos, Acadian Flycatchers, Summer Tanagers, and Yellow-billed Cuckoos. Likewise, the five most common temperate migrants were Blue Jays, Yellow-rumped Warblers, Golden-crowned Kinglets, Northern Flickers, and American Goldfinches (Table 1).

The northernmost Eastern Shore Soil and Water Conservation District (ESSWCD) site had the greatest number of neotropical migrant detections per survey effort followed by Oak Grove, while Pickett's Harbor had the greatest number of temperate migrant detections per survey effort followed by Kiptopeke State Park (Figure 3 [note: most figures are within Appendix A to improve readability of prose]). Neotropical migrants were most common at the beginning of the season and tapered off in mid-October. In contrast, temperate migrants exhibited a steady increase in numbers beginning in mid-October until the end of the survey period in November (Figure 4). While the abundance of neotropical migrants was generally high across most sites, the diversity of migrants was highest at the five southernmost sites (Figure 5).

Adjusting raw detection data to account for the probability of detecting a migrant had substantial effects on the overall density estimates found among sites (Figure 6). Most interestingly, when detections were not corrected for imperfect detection probability, Savage Neck Dunes Natural Area Preserve and the Wallops Flight Facility survey sites yielded the highest densities of migrants (2.05 and 1.70 migrants per ha, respectively), but when total migrant densities were corrected for imperfect detection probabilities, Savage Neck Dunes and Phillips Farm exhibited the highest densities of migrants per hectare (3.92 and 3.52 migrants per ha, respectively; Figure 7). This striking increase suggests Phillips Farm supports a high density of migratory birds, yet with a low detection probability.

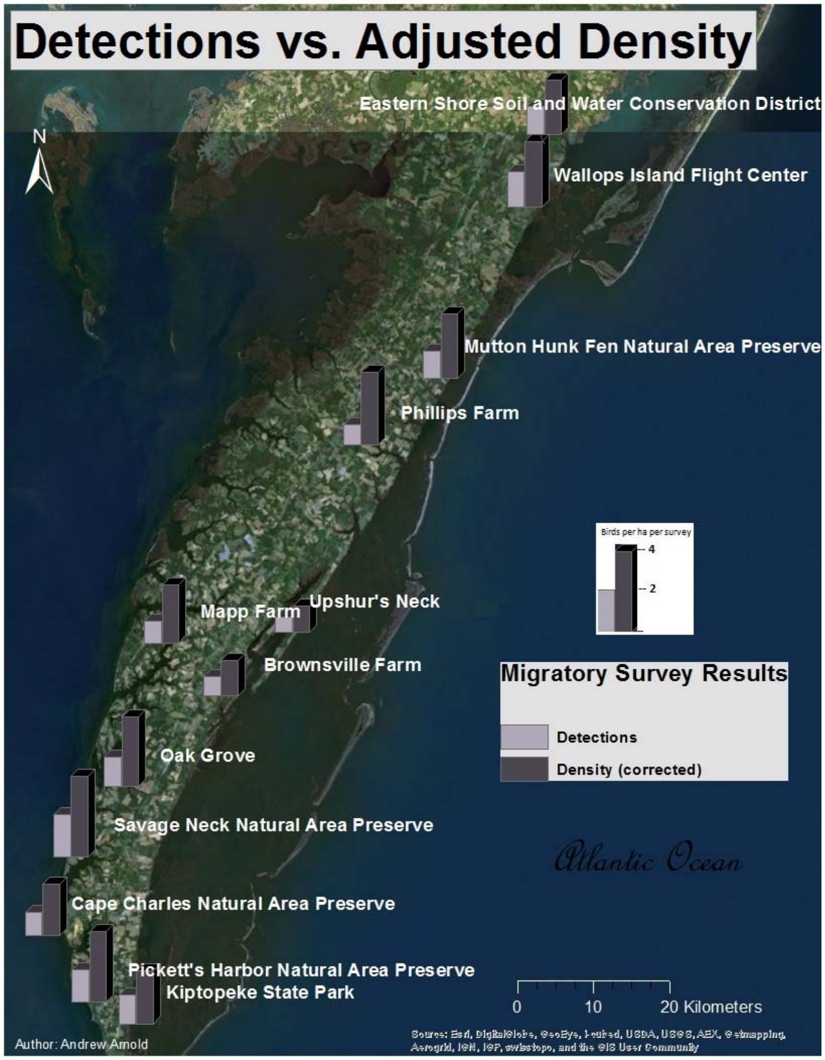


Figure 6: Detections and detection-corrected density estimates of migratory birds for each site.

When considering all survey sites together without correcting for detection probabilities, the two northernmost sites (ESSWCD and Wallops Flight Facility) and 4 of the 5 southernmost sites (Oak Grove, Savage Neck Dunes NAP, Pickett's Harbor NAP, and Kiptopeke) appear to contain the highest migrant densities. When density is corrected to account for imperfect detection probabilities, however, only 3 of the 5 southernmost sites (Oak Grove, Savage Neck Dunes NAP, and Pickett's Harbor NAP) appear to yield the greatest densities while 4 of the 5 northernmost sites (Wallops Flight Facility, Mutton Hunk Fen NAP, Phillips Farm, and Mapp Farm) appear to contain the highest densities. This finding suggests the northern portion of Virginia's Eastern Shore may support migrant densities that rival southern sites, yet detecting migrants at northern sites may be much more difficult and thus give the perception of lower densities and / or lower quality in comparison.

For all combined sites, estimates of migrant density generally increased from 1.3 to 3.1 birds per ha when detections were corrected. While we may only be able to speculate as to why changes in detection probabilities were so much greater at the northern sites, it is interesting nonetheless to see how sites with the highest migrant densities per ha per visit changed with the implementation of detection probabilities. This dramatic increase in migrants per ha shows, if nothing else, how many migrants are likely being missed when conducting forest bird surveys and the obvious value of distance sampling, an option not possible with standard point count techniques.

Distance sampling can also be used to examine densities of individual species when sample sizes are sufficient (>50 detections). The two most numerous neotropical migrants (American Redstart, Red-eyed Vireo) and temperate migrants (Yellow-rumped Warbler, Golden-crowned Kinglet) exhibited a twofold increase in density when incorporating imperfect detection probabilities (Figure 8).

Visual detections generally declined with distance from observer (Figure 9) while aural detections generally increased with distance (Figure 10). There is likely a trade-off between visual and aural detections as birds get farther from the observer. Of all 5,057 detections, 75.4% were aural detections, 18.1% were visual detections, and 6.5% were a combination of both aural and visual. In general, neotropical migrants were a little more likely to be detected aurally than visually. But, in the case of temperate migrants, birds were much more likely to be detected aurally (Table 2).

Methods of Detection (% of total category)			
Neotropical		**Temperate**	
Aural	56.50%	Aural	67.40%
Visual	39.10%	Visual	20.60%
Both	4.40%	Both	12%

Table 2: Visual and aural detection rates for all migrants.

Food Availability

Twenty fruiting plant species were identified across all sites, with 16 species producing ripe fruit available for migratory species consumption. American Holly (*Ilex opaca*) was the most widespread available fruit, occurring at all sites. Partridge Berry (*Mitchella repens*) and Grape sp. (*Vitis* sp.) followed, occurring at 8 (67%) and 7 (58%) of the 12 survey sites each, respectively. Four of the 16 plant species were found only to be fruiting at one site (Figure 11). Cape Charles had the greatest fruiting species richness (10), followed by Oak Grove (8) and Savage Neck Dunes NAP (8). Upshur's Neck had only one fruiting species (Figure 12).

The amount of ripe fruit available to birds tended to increase throughout the season (Figure 13). American Holly made up the largest portion of total available fruit recorded over the season, accounting for 48.3% of all ripe fruit detections (Figure 11). Aside from American Holly, all remaining fruiting tree species only accounted for 1.2% of all available fruit. All shrub species accounted for 41% of all ripe species, and vines made up the remaining 9.5% (Figure 14). Oak Grove yielded the highest density of available fruit recorded over the season, which totaled 29% of all ripe detections. Pickett's Harbor NAP and Mapp Farm followed with 18.6% and 5.1%, respectively. In terms of total fruit, Pickett’s Harbor NAP had the highest density of all fruit (unripe, ripe, overripe combined) out of all 12 sites (Figure 15). Beautyberry (*Calicarpa* *americana*) accounted for the majority of Oak Grove's ripe fruit, while Privet sp. (*Ligustrum* sp.) was the primary fruit at Pickett's Harbor NAP, although the majority of this fruit did not ripen during the sampling period. Of the most common fruiting species (Figures 16-21), species such as Greenbrier sp. (*Smilax* sp.) and Grape (*Vitis* sp.) saw declines in their numbers during the season, either indicating consumption by avian species or simply showing a decline due to over ripening, while other species such as American Holly (*I. opaca*) and Beautyberry (*C. americana)* did not show any substantial declines, suggesting these species were not readily selected and eaten.

Arthropods were generally available to birds throughout the migration period, with slightly larger arthropods detected in August and September (Figure 22). A total of 3349 arthropods were recorded across all surveys, with 1414 (42%) of detections from ground surveys and 1935 (58%) from branch clippings. Arachnids accounted for the majority (53%) of all arthropod detections, followed by Formicidae (16%) and Diptera (13%). All remaining Orders each made up less than 5% of all invertebrate detections (Figure 23). Brownsville Farm yielded the most invertebrates per survey (21.7 per survey), followed by Mutton Hunk Fen (20.2), Oak Grove (19.9), Upshur's Neck (19.6), and Wallops Island (18.5). Overall, however, all sites yielded fairly uniform arthropod numbers (Figure 24). While this suggests that migratory birds are not depleting the invertebrate food supply, there was variation between sites with respect to substrate. For example, Brownsville Farm yielded the greatest number of invertebrates per gram of branch clipping (Figure 25), while Oak Grove had the greatest number of invertebrates per square meter of ground surveyed (Figure 26). This variation in substrate of invertebrate species may influence migrant use of microhabitats. Regardless of substrate, invertebrates were present throughout the study period (Figure 27).

While food was available in an adequate supply at each survey site, there was great variation as to what each site contained and how abundant each source was overall (Figure 28).

Site Characteristics

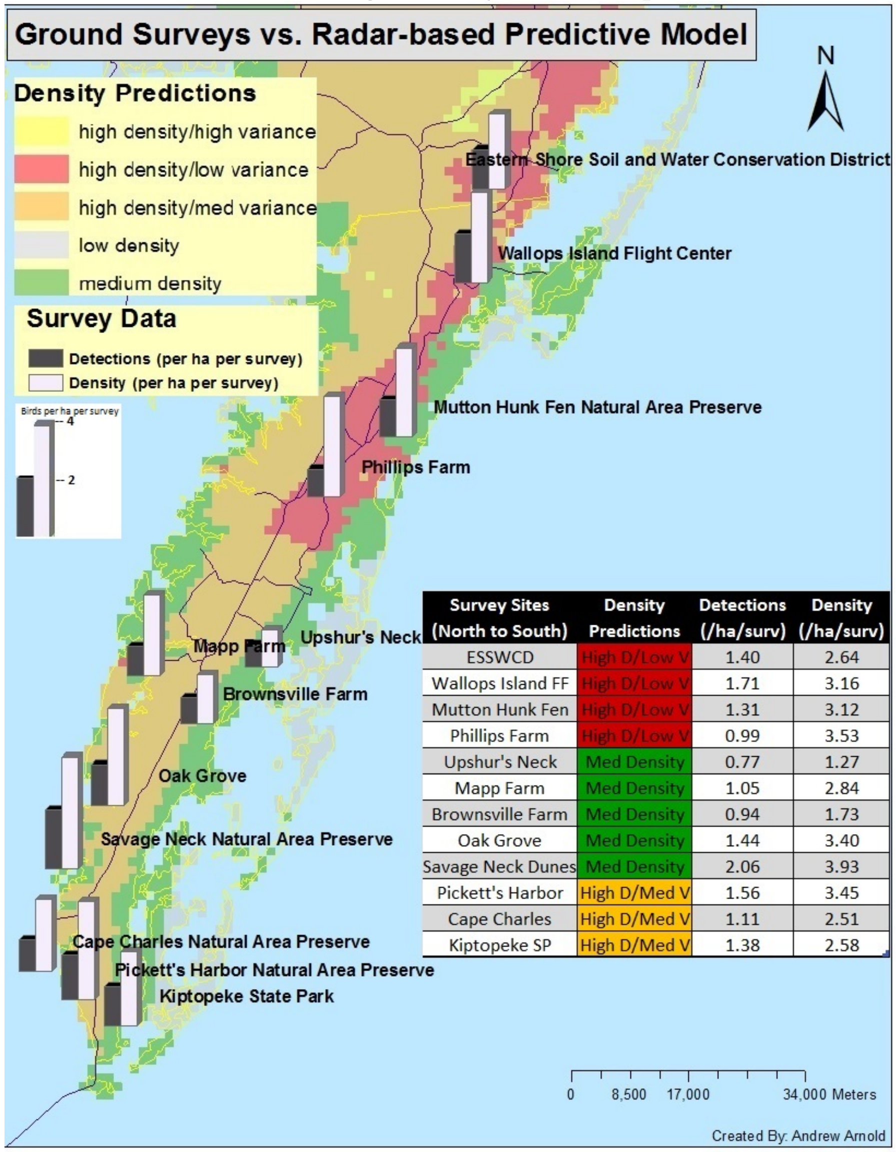
Forest structure varied among sites and northerly sites tended to have a higher density of trees in the 2.5-8 cm size class (Figure 29). This almost certainly helped influence the low detectability of migrants at the northerly sites (Figure 7). Low detectability of migrants, although not as pronounced in the data, was also likely a major factor at the southern sites as well, as almost every site has a fairly high understory density (Figure 30) as well as a generally high overall basal area (Figure 31). While this seemed to be the case with forest structure in general, there was great variability in the proportion of shrubs to small trees to large trees found at each site (Figure 32).

Of the 12 sites (Figures 33-44), Wallops Island Flight Facility had the greatest diversity of large trees (DBH >8 cm), including 6 species that accounted for at least 10% of all trees at the site (Figure 44). Phillips Farm yielded the least diversity with 70% of trees composed of pine (Figure 40).

Comparison with Radar-based Model

Model predictions were generally fairly robust (Figure 45). Some sites, however, did not support the model predictions. Oak Grove and Savage Neck Dunes were predicted to be medium density sites but we found migrants in relatively high densities at these two sites (Figure 46). With one year of data, we are not able to assess the year-to-year variability in number in order to test the model variability predictions. The southern high density sites are predicted to have medium variance whereas the northern high density sites are predicted to have low variance. Thus, we would expect more year-to-year variation with the southern sites than the northern sites. It will certainly take additional years of surveying to make reliable comparisons.

When analyzing the real and predicted densities against the model itself, however, some interesting results emerge. When the ground survey data from 2013 is compared to the data used to build the predictive model (Buler and Dawson 2014), it is evident that the detection-corrected density is far more accurate than when raw detection data are used (Figures 47-48). While a fairly weak correlation (R-squared value for raw detections = 0.2399 vs detection-corrected density =0.5382), the 2x increase is extremely promising for the use of radar and radar-based models.



Survey Sites (North to South)	Density Predictions	Detections (/ha/surv)	Density (/ha/surv)
ESSWCD	High D/Low V	1.40	2.64
Wallops Island FF	High D/Low V	1.71	3.16
Mutton Hunk Fen	High D/Low V	1.31	3.12
Phillips Farm	High D/Low V	0.99	3.53
Upshur's Neck	Med Density	0.77	1.27
Mapp Farm	Med Density	1.05	2.84
Brownsville Farm	Med Density	0.94	1.73
Oak Grove	Med Density	1.44	3.40
Savage Neck Dunes	Med Density	2.06	3.93
Pickett's Harbor	High D/Med V	1.56	3.45
Cape Charles	High D/Med V	1.11	2.51
Kiptopeke SP	High D/Med V	1.38	2.58

Figure 46: A comparison of radar-predicted densities for each site with actual survey data on migratory detections.

Summary

Fall migration is a time when countless individuals set off for their wintering grounds, undergoing one of the most physically demanding and most vulnerable periods of their annual cycle (Moore and Woodrey 1993, Sillett and Holmes 2002). During this journey, many individuals will fall victim to unpredictable weather, collisions with anthropogenic structures, depredation, and the inability to meet basic nutritional requirements. Stopover habitats along their route provide areas for rest, refueling, and shelter from predators and inclement weather (Moore et al. 1995, Mehlman et al. 2005). It is thus critical that important stopover habitats, those 12 sites where either high densities of migrants occur or sites where threatened or rare species may occur, are identified and protected.

Virginia’s Eastern Shore is a critical stopover area for millions of migrants and thus efforts to identify high quality stopover habitat should be a top priority. While the area has been traditionally known as an important stopover region, very little is known about site selection and quality of habitats available to migrants. Moreover, information on the relative importance of the lower Delmarva Peninsula to the Atlantic Flyway at large is lacking (Mabey et al. 1993, Watts and Mabey 1994).

Recent advances in radar-based technology have allowed for continental scale tracking of migratory species. The ability to use radar technology to develop predictive models has the potential to revolutionize our understanding of bird movement patterns over large regions of the United States (Gauthreaux and Belser 2003, Buler and Dawson 2014). Studies such as that described here are critical to the assessment of these models. This study has demonstrated the utility of such models at predicting stopover use. By being able to use predictive models in regions where radar coverage is lacking, particularly globally significant areas like the Delmarva Peninsula, land managers would have a valuable tool to add to their decision making regarding habitat acquisition and protection.

More generally, stopover habitats have largely been ignored due to their ephemeral use (Sheehy et al. 2011). Studies such as the type outlined here allow for a rigorous assessment of how stopover habitats are being used by migrants and a determination of what factors might be important to avian life histories. By using advanced survey methods, a more accurate assessment of migrant use can be determined. Distance sampling methods are a particularly important tool to employ in forested habitats where surveying conditions are often difficult. By creating detection probability curves, one can account for differences among species or habitats that might affect an observer’s ability to detect birds (Buckland et al. 2004).

The findings presented here indicate that migrant use of stopover sites varies considerably over the course of the season. Neotropical migrants fluctuate from day to day but were evident over much of the first half of the migration season. Temperate migrants, on the other hand, exhibited large increases in numbers in late October but were present in small numbers throughout the fall season.

Attempting to determine what the best predictors of migrant visitation are has remained elusive. Many species will be trying to refuel so we attempted to assess various diet parameters.

Ripe fruit was abundant and available throughout the season. We had predicted that fruit availability would decline over the season as more birds moved through but we saw no evidence of a decline with season. We also predicted that many migrants would feed on arthropods during stopovers. Again, we did not see any evidence of a decline in arthropods over time. There appeared to be just as many arthropods in August as in late October. More thorough observations of foraging behavior of migrants in these habitats will allow an assessment of their foraging habits. Using quantitative metrics associated with plasma metabolites will allow one to determine the quality of refueling sites since plasma metabolites directly reflect refueling performance (Cerasale et al. 2006). Maintaining stopover habitats that support high fruit and insect abundance during migration is important, especially for migratory birds using an area for refueling purposes, and who must consume both fruits and invertebrates to adequately meet their dietary demands (Smith et al. 2007).

More detailed information needs to be obtained, both at a large and fine scale, to truly start to decipher the selection and use of forested habitats by these migratory landbirds. While individual conservation decisions must be implemented and enforced at the local level (Mabey and Watts 2000), there is undoubtedly a cumulative influence at the landscape level that must be considered as well. Obtaining a better understanding of the relationship between species and habitat, while difficult, is essential for any management or conservation initiatives to be properly implemented. Thus continuing research efforts such as those presented in this study is imperative.

LITERATURE CITED

Buckland, S.T. 2006. Point transect surveys for songbirds: robust methodologies. Auk 123:345-357.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas. 2004. Advanced Distance Sampling, Oxford University Press, Oxford.

Buler, J. J., and D. Dawson. 2014. Radar analysis of fall bird migration stopover sites in the northeastern U.S. Condor 116:357-370.

Cerasale, D. J., C. G. Guglielmo, and K. A. Hobson. 2006. Dietary effects on prediction of body mass changes in birds by plasma metabolites. Auk 123:836-846.

Gauthreaux, S.A., and C.G. Belser 2003. Radar ornithology and biological conservation. Auk 120:266-277.

Mabey, S.E., J.M. McCann, L.J. Niles, C. Bartlett, and P. Kerlinger. 1993. Final report: Neotropical migratory songbird regional coastal corridor study. Report No. NA90AA-H-CZ839, Virginia Coastal Resources Management Program, Council on the Environment, Richmond, Virginia, USA.

Mabey, S.E., and B.D. Watts. 2000. Conservation of landbird migrants: Addressing local policy. Studies in Avian Biology 20:99-108.

Mehlman, D.W., S.E. Mabey, D.N. Ewert, C. Duncan, B. Abel, D. Cimprich, R.D. Sutter, and M. Woodrey. 2005. Conserving stopover sites for forest-dwelling migratory landbirds. Auk 122:1281-1290.

Moore, F.R., and M.S. Woodrey. 1993. Stopover habitat and its importance in the conservation of landbird migrants. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 47:447-459

Moore, F.R., S.A. Gauthreaux, P. Kerlinger, and T.R. Simons. 1995. Habitat requirements during migration: Important link in conservation. In: T. E. Martin and D. M. Finch, editors. Ecology and management of neotropical migratory birds: A synthesis and review of critical issues. Oxford, NY: Oxford University Press:121-144.

R Development Core Team. 2014. R: a Language and Environment for Statistical Computing. Vienna: R Foundation for Statistical Computing. http://www.R-project.org.

Rodewald, P.G., and M.C. Brittingham. 2007. Stopover habitat use by spring migrant landbirds: the roles of habitat structure, leaf development, and food availability. Auk 124:1063-1074.

Sheehy, J., C.M. Taylor, and D.R. Norris. 2011. The importance of stopover habitat for developing effective conservation strategies for migratory animals. Journal of Ornithology 152:S161-S168.

Sillett, T.S., and R.T. Holmes. 2002. Variation in survivorship of a migratory songbird throughout its annual cycle. Journal of Animal Ecology 71:296-308.

Smith, A.D., and S.R. McWilliams. 2009. Protocol for the rapid assessment of fruit abundance on New England National Wildlife Refuges. University of Rhode Island. Kingston, Rhode Island, USA.

Smith, S.B., K.H. McPherson, J.M. Backer, B.J. Pierce, D.W. Podlesak, and S.R. McWilliams. 2007. Fruit quality and consumption by songbirds during autumn migration. Wilson Journal of Ornithology 119:419-428.

Suthers, H.B., J.M. Bickal, and P.G. Rodewald. 2000. Use of successional habitat and fruit resources by songbirds during autumn migration in New Jersey. Wilson Journal of Ornithology 112:249-260.

Watts, B. D. 1994. Virginia hospitality: Sharing the natural bounty of Virginia’s Eastern Shore with hosts of fall migrants. CCBED-94-03. Center for Conservation Biology Educational Document. Center for Conservation Biology. College of William & Mary, Williamsburg, Virginia.

Watts, B.D., and S.E. Mabey. 1994. Migratory landbirds of the lower Delmarva: Habitat selection and geographic distribution. Center for Conservation Biology Technical Report CCBTR-94-05, College of William and Mary, Williamsburg, Virginia.

APPENDIX A: Figures

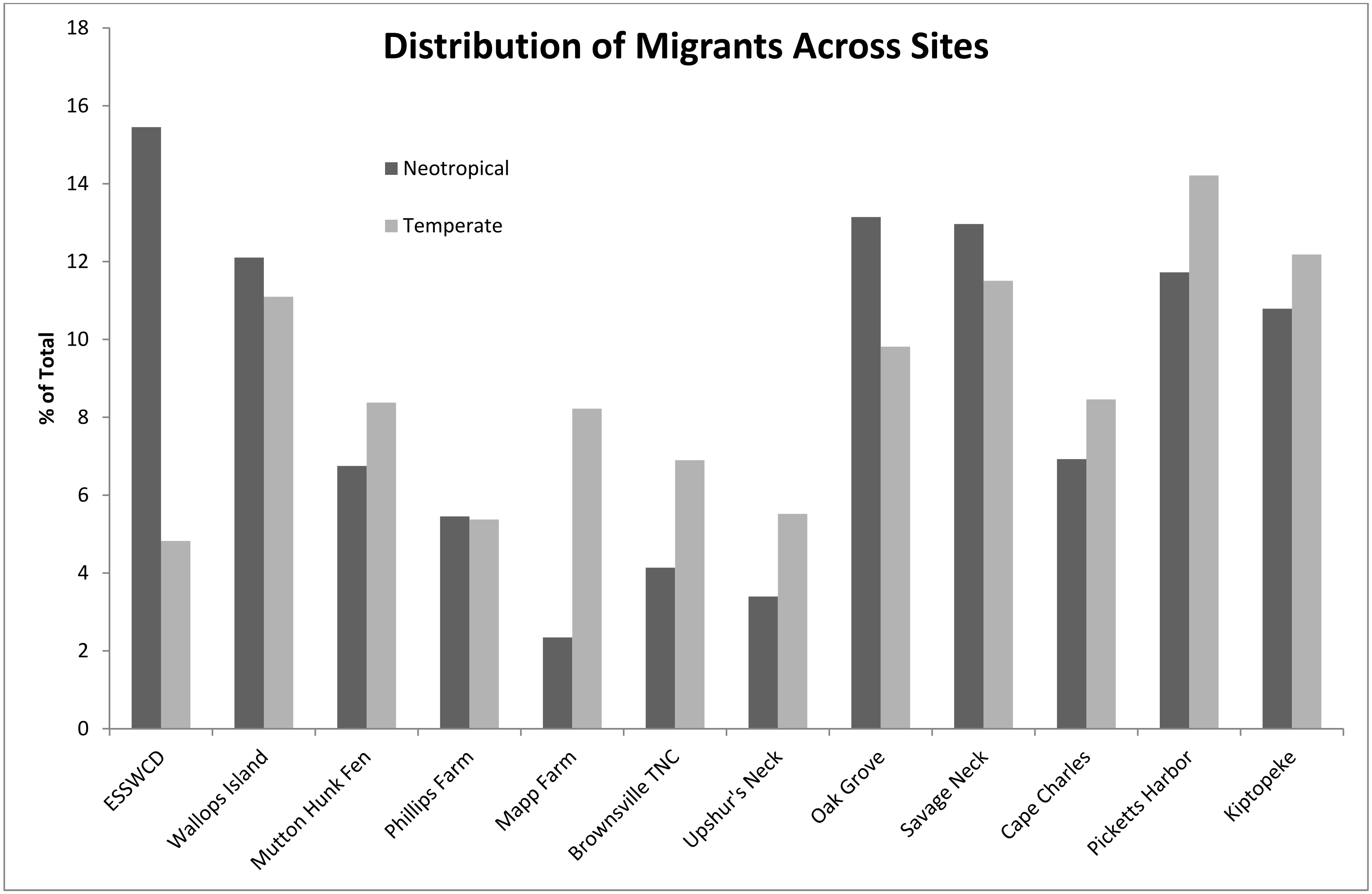


Figure 3: Distribution of neotropical and temperate detections across all sites shows ESSWCD had the highest number of neotropical detections per survey effort while Pickett's Harbor had the highest number of temperate detections per survey effort.

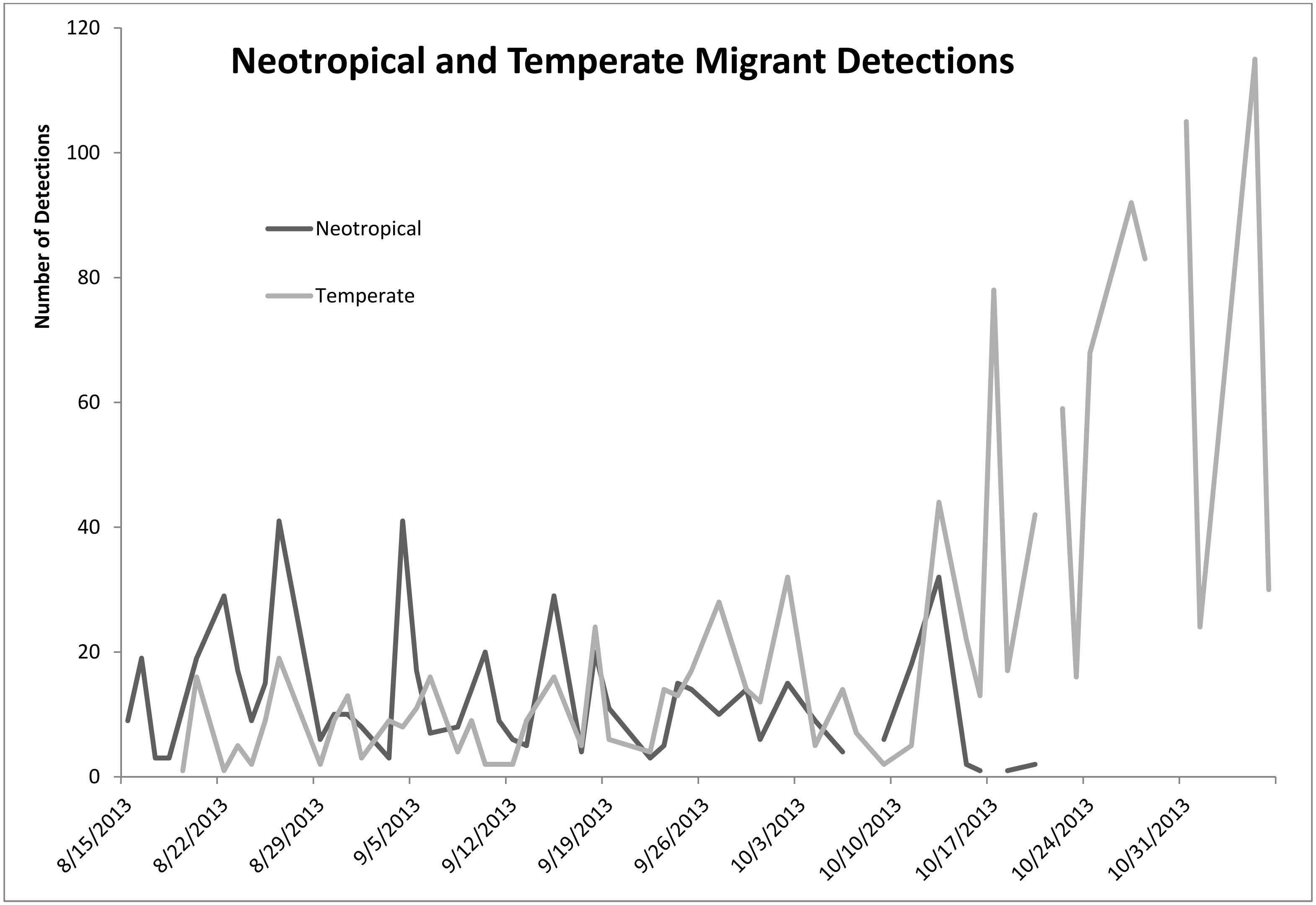


Figure 4: Occurrence of neotropical and temperate migrants across the season.

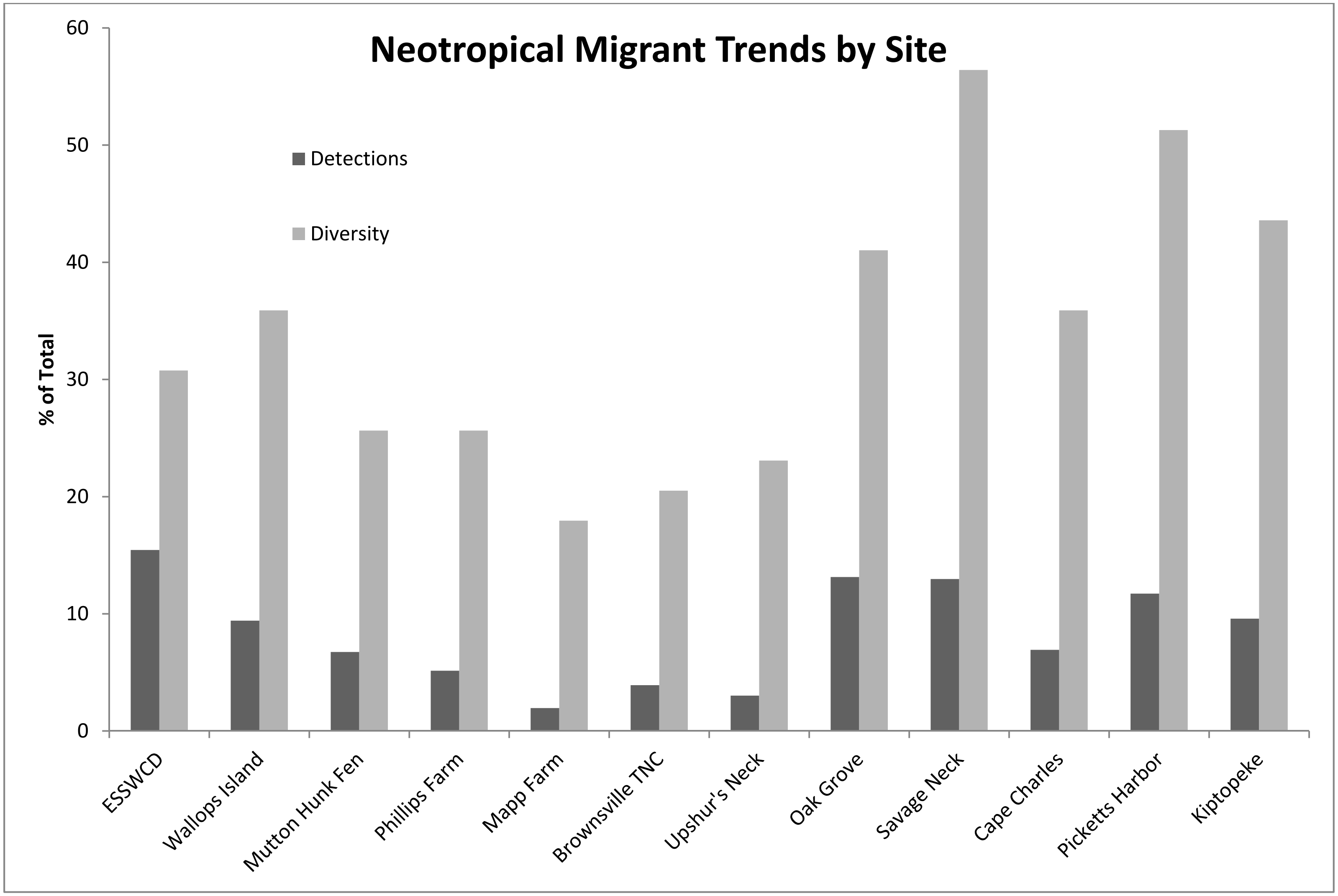


Figure 5: The percent of total detections and proportional diversity of neotropical migrants by site. Sites are ordered from north to south.

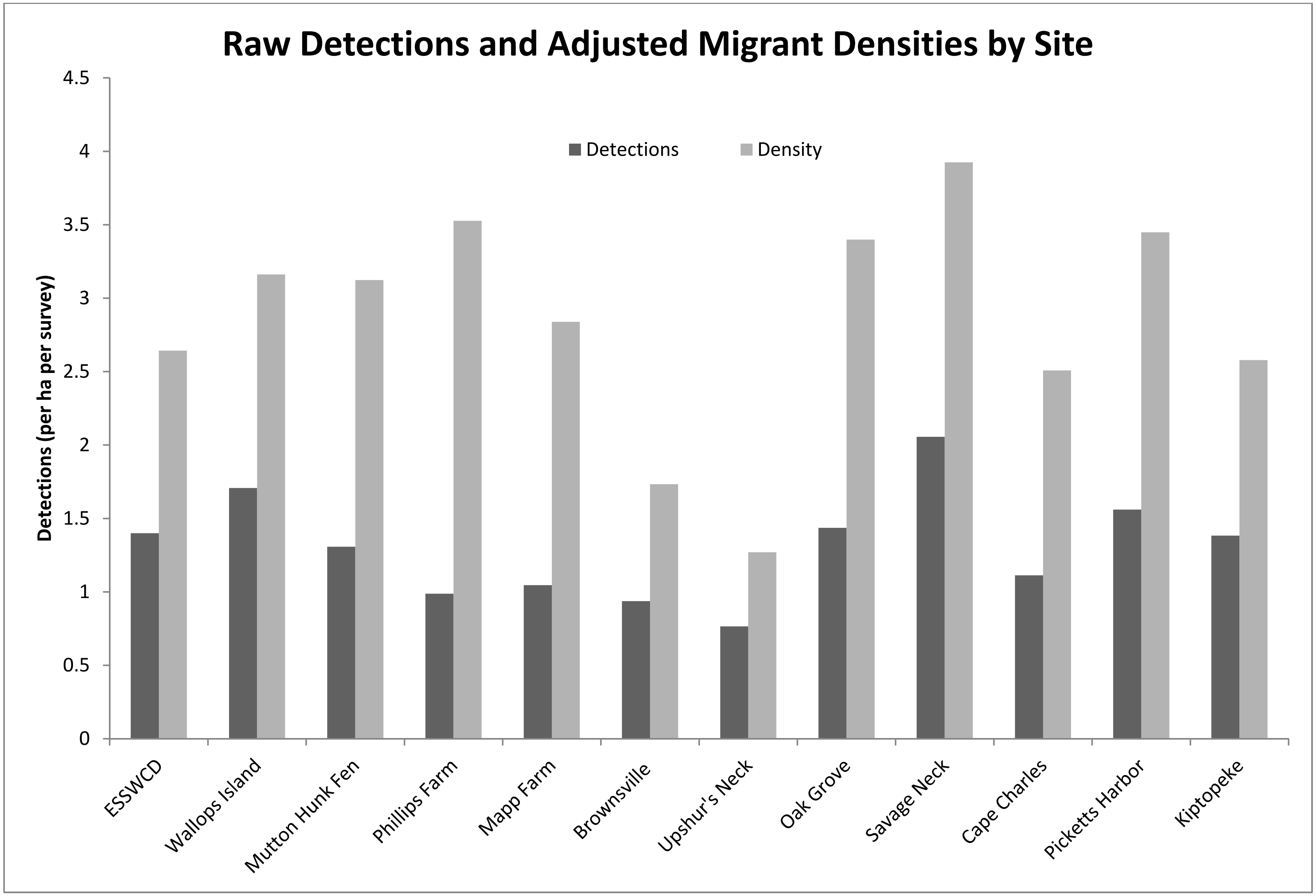


Figure 7: A comparison of detections (per hectare per visit) with mean corrected densities for all Eastern Shore survey sites.

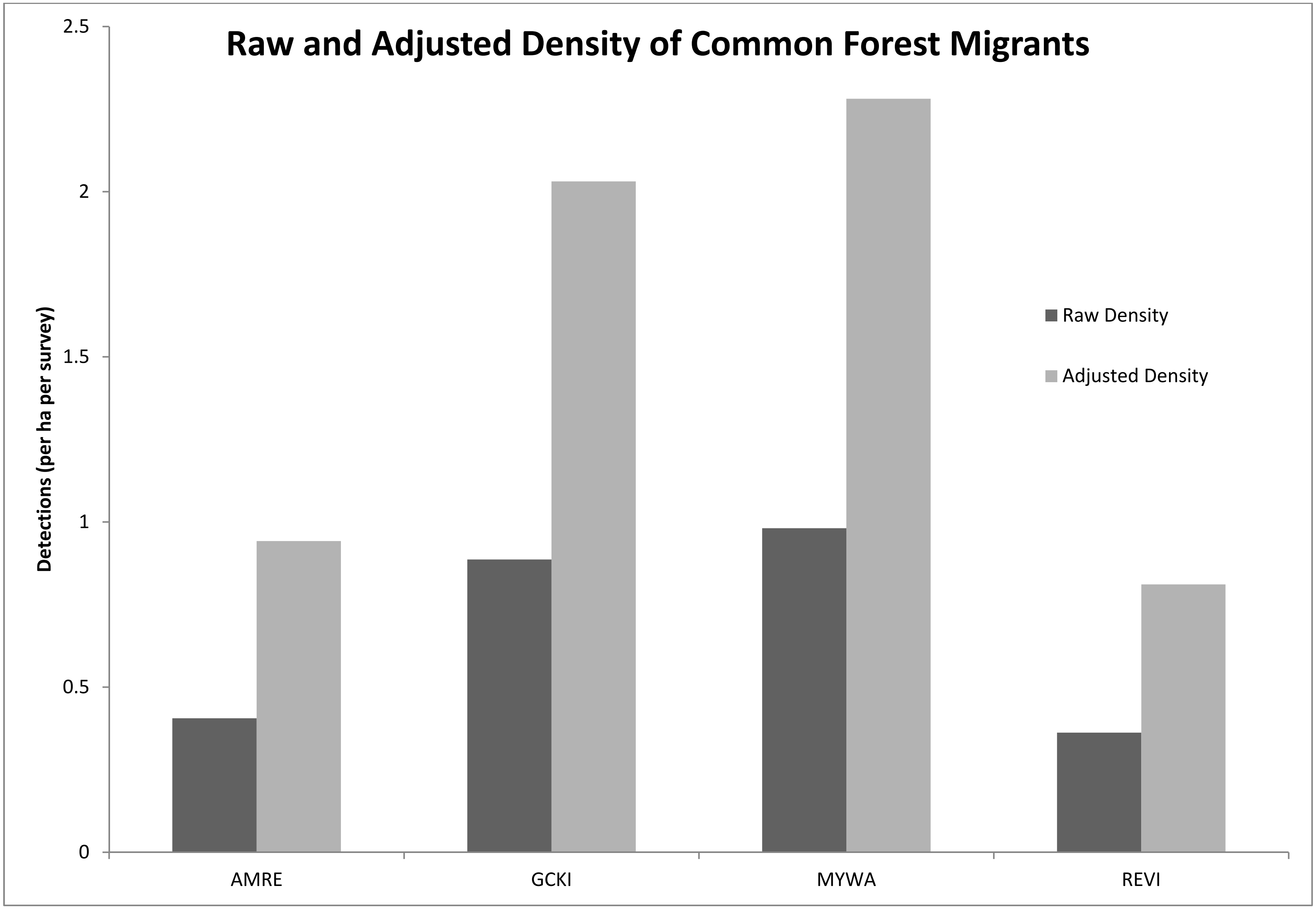


Figure 8: Increase (at least 2x) in density of common migrant species when using distance sampling and detection probabilities. AMRE: American Redstart, GCKI: Golden-crowned Kinglet, MYWY: Yellow-rumped Warbler (Myrtle Warbler), REVI: Red-eyed Vireo.

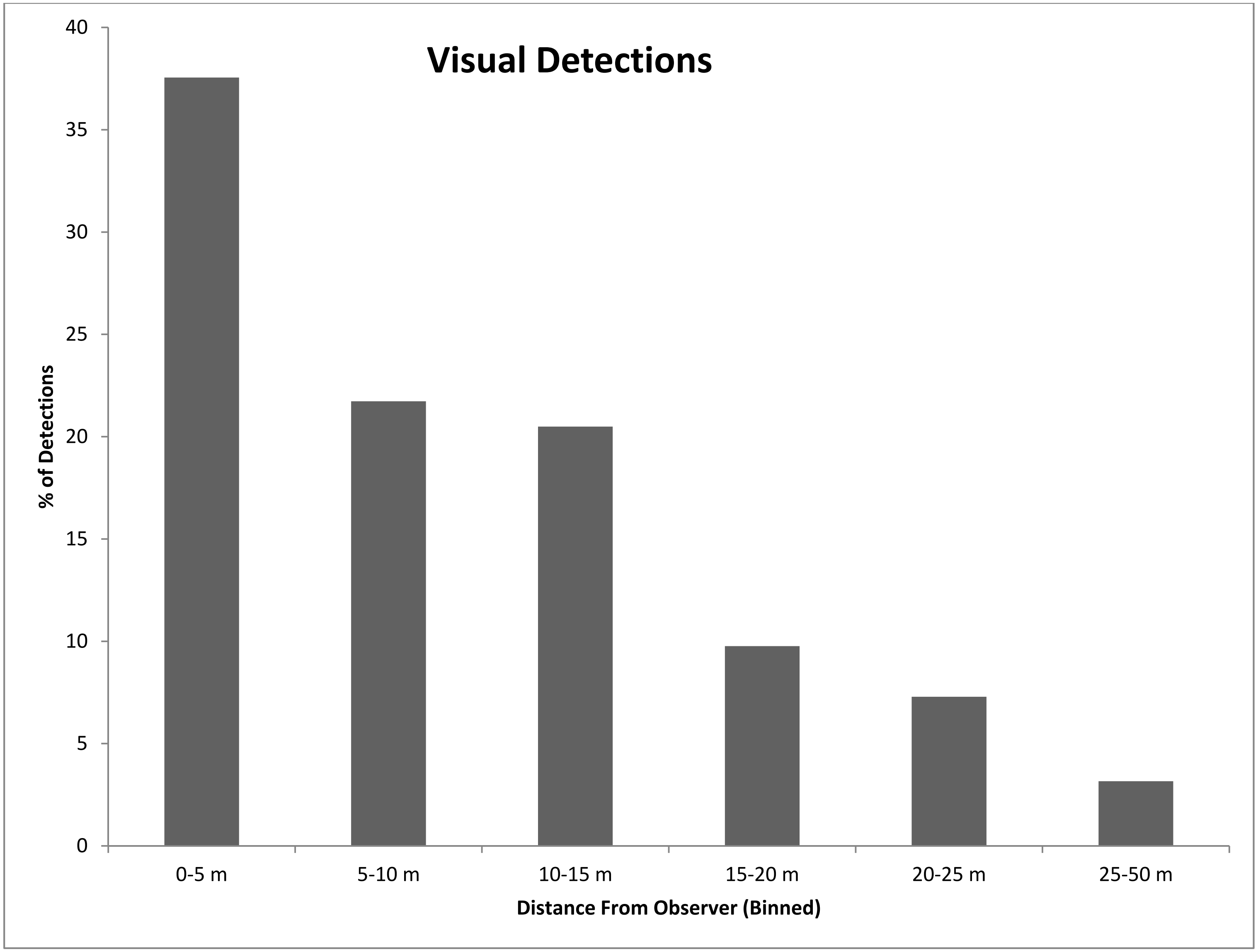


Figure 9: Decrease in visual detections as distance away from transect increased.

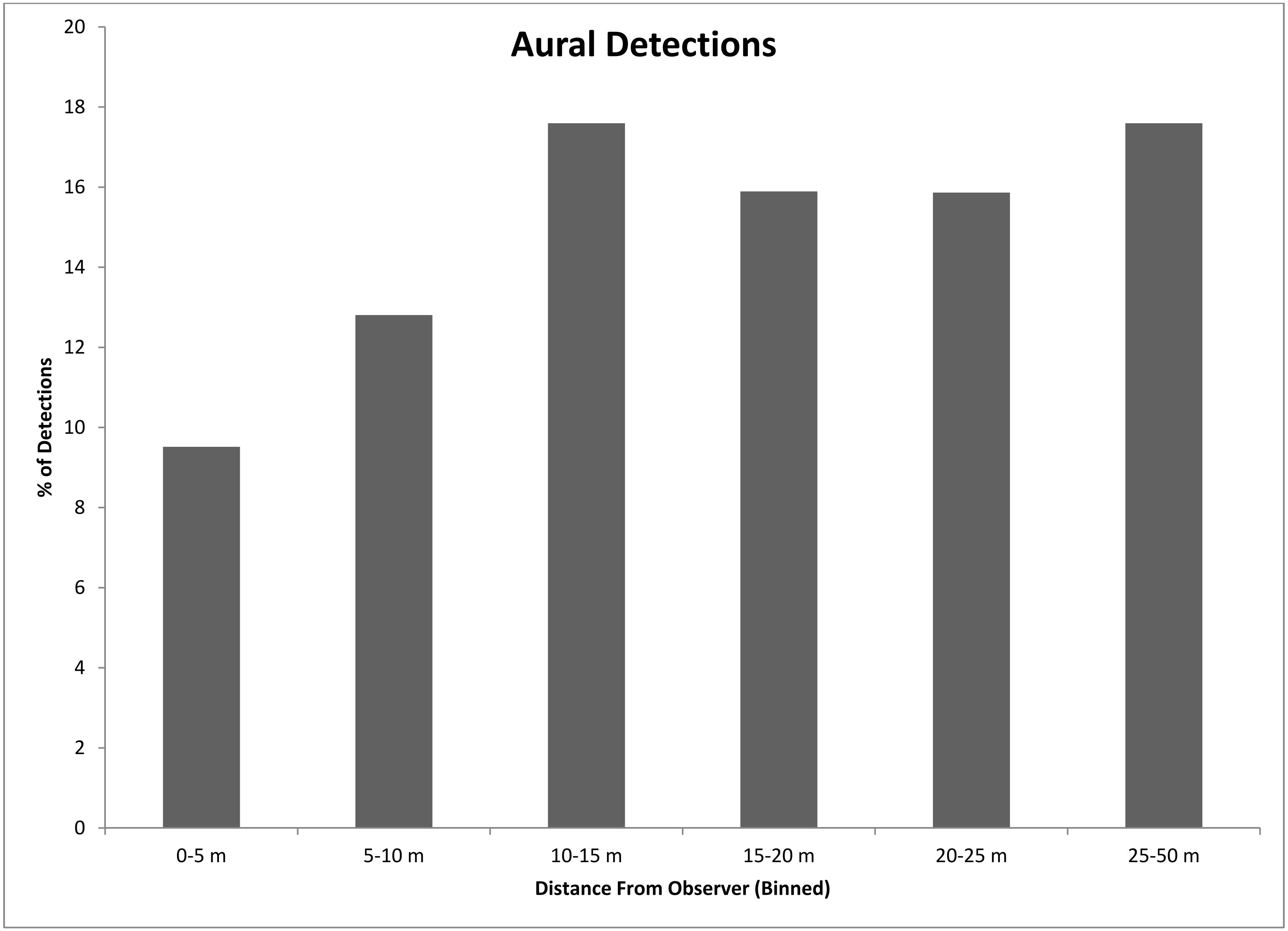


Figure 10: Increase in Aural detections as distance from transect increased.

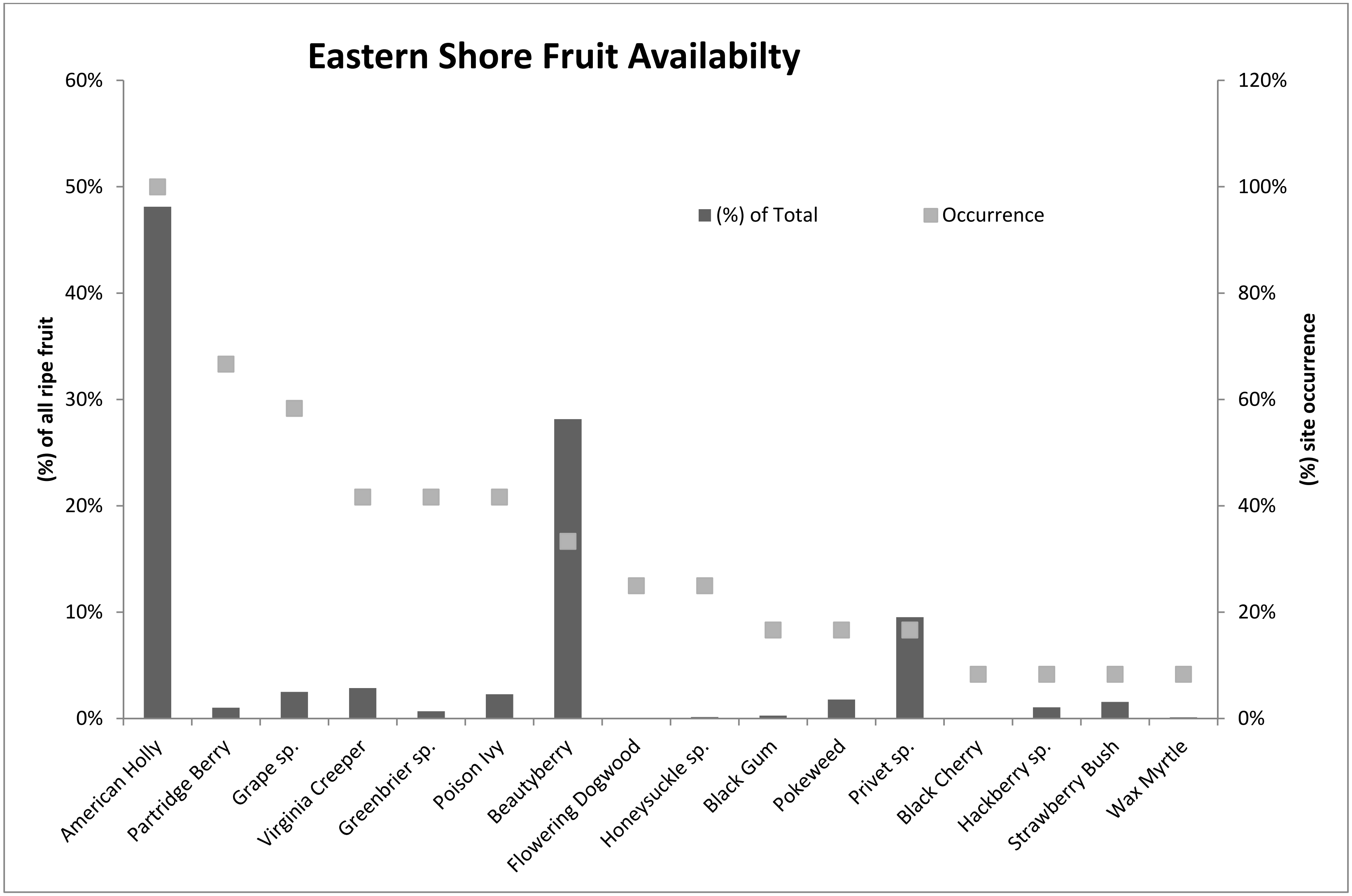


Figure 11: Occurrence and ripeness rates for all Eastern Shore fruit species recorded within sampling plots.

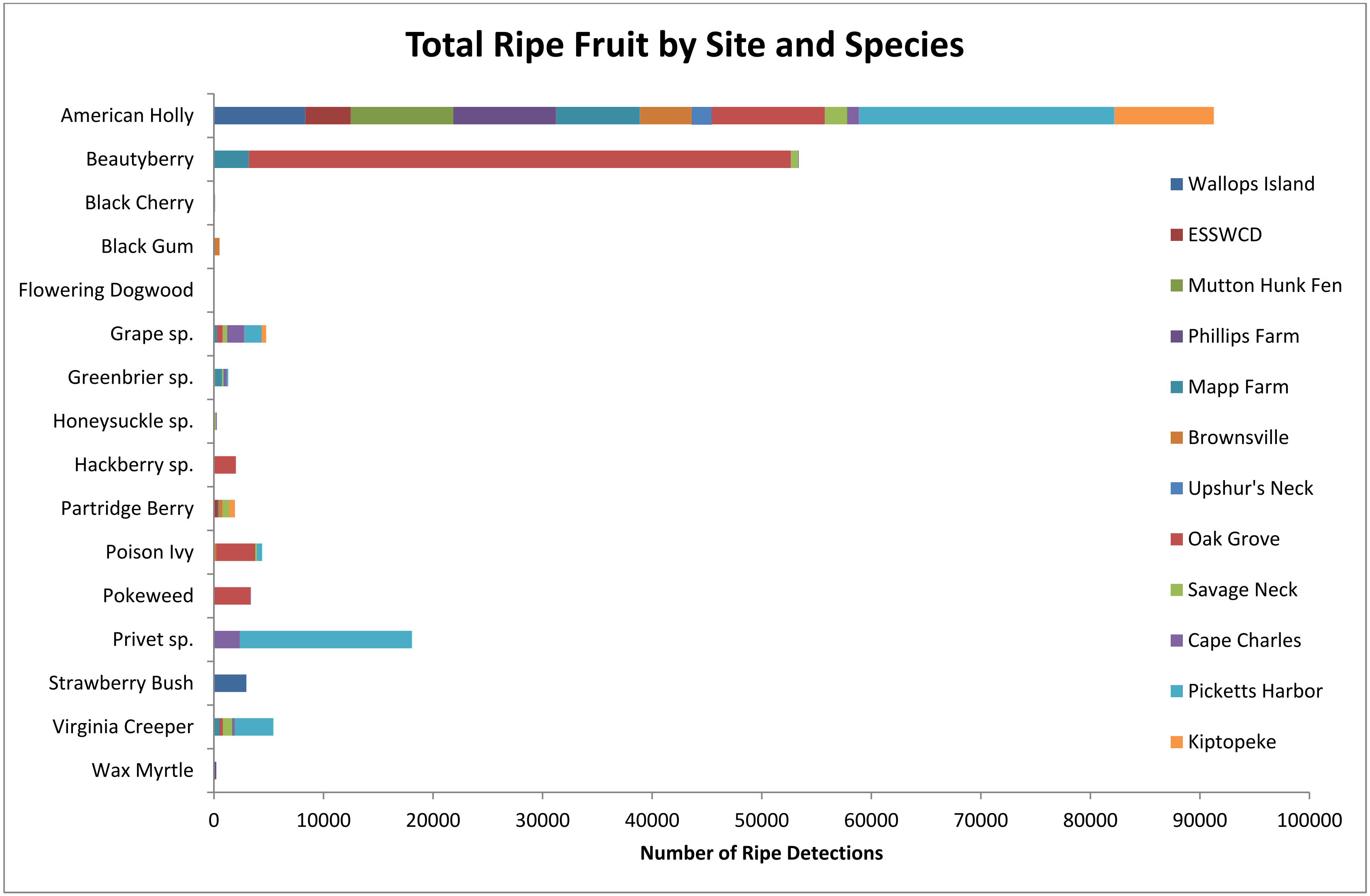


Figure 12: Ripe fruit occurrence and total detections for each Eastern Shore survey site.

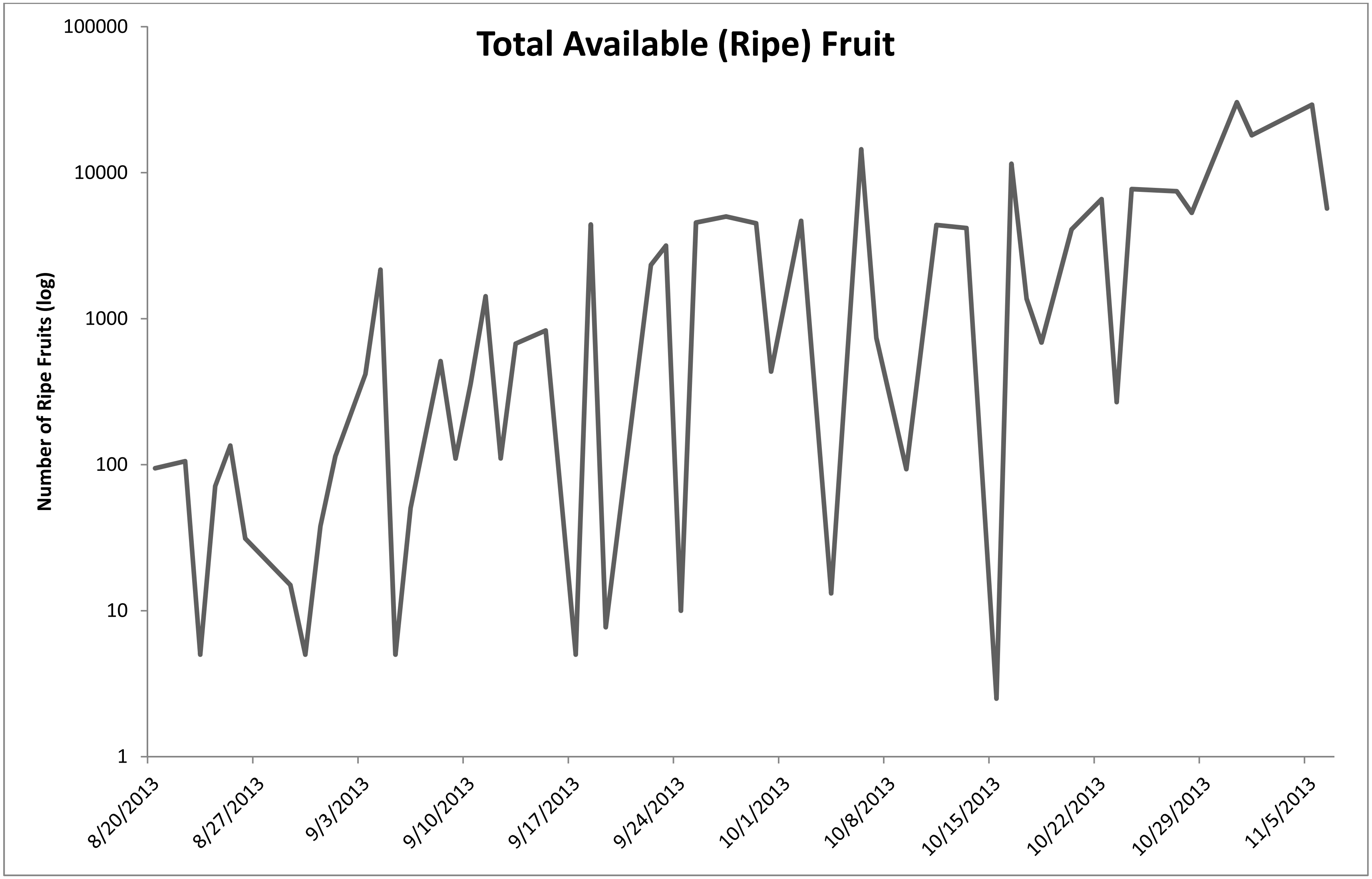


Figure 13: Ripe fruit trend across the survey season for all sites.

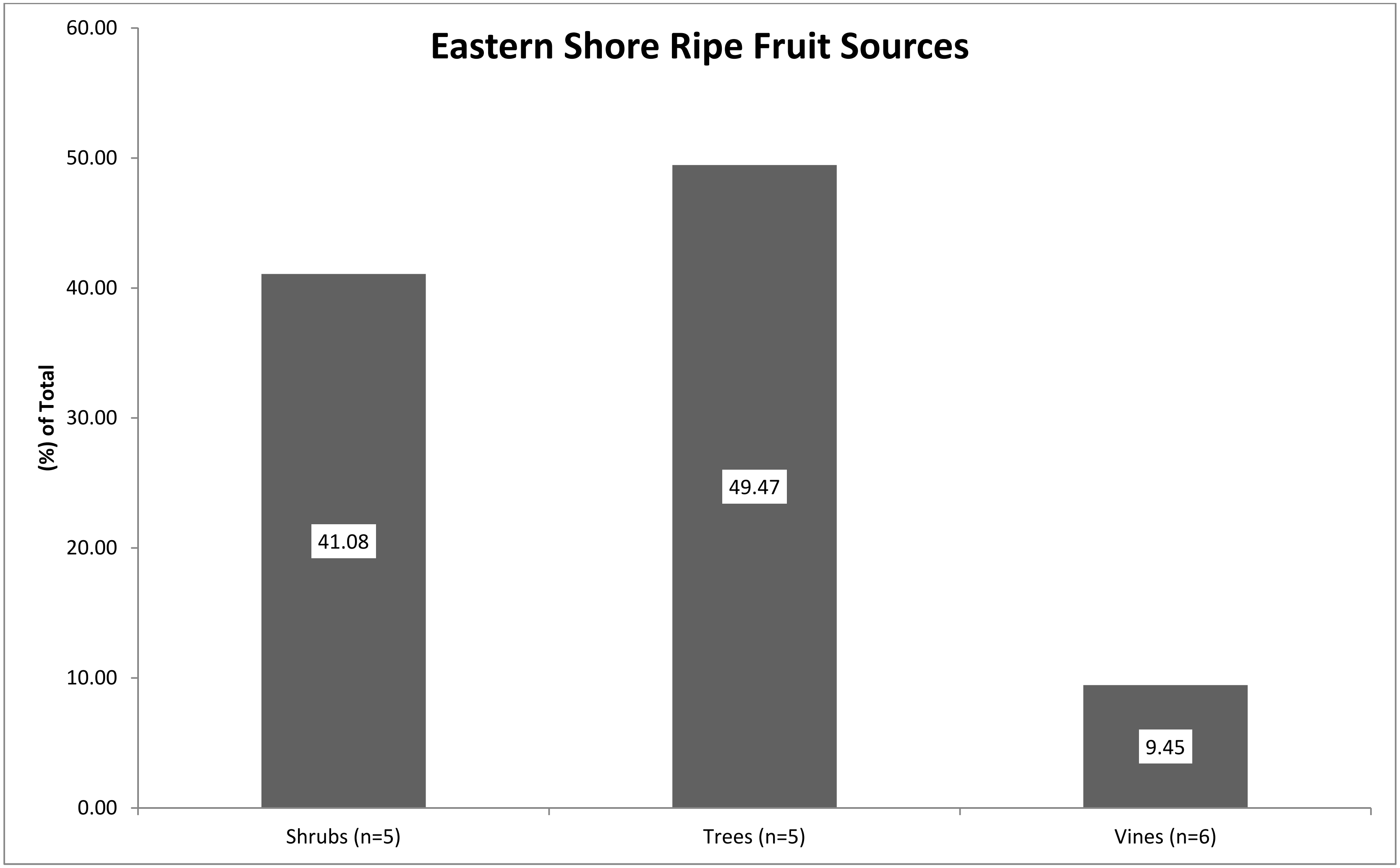


Figure 14: Sources of ripe fruit (shrubs, trees, or vines) and each categories overall contribution (% of total) for all Eastern Shore survey sites.

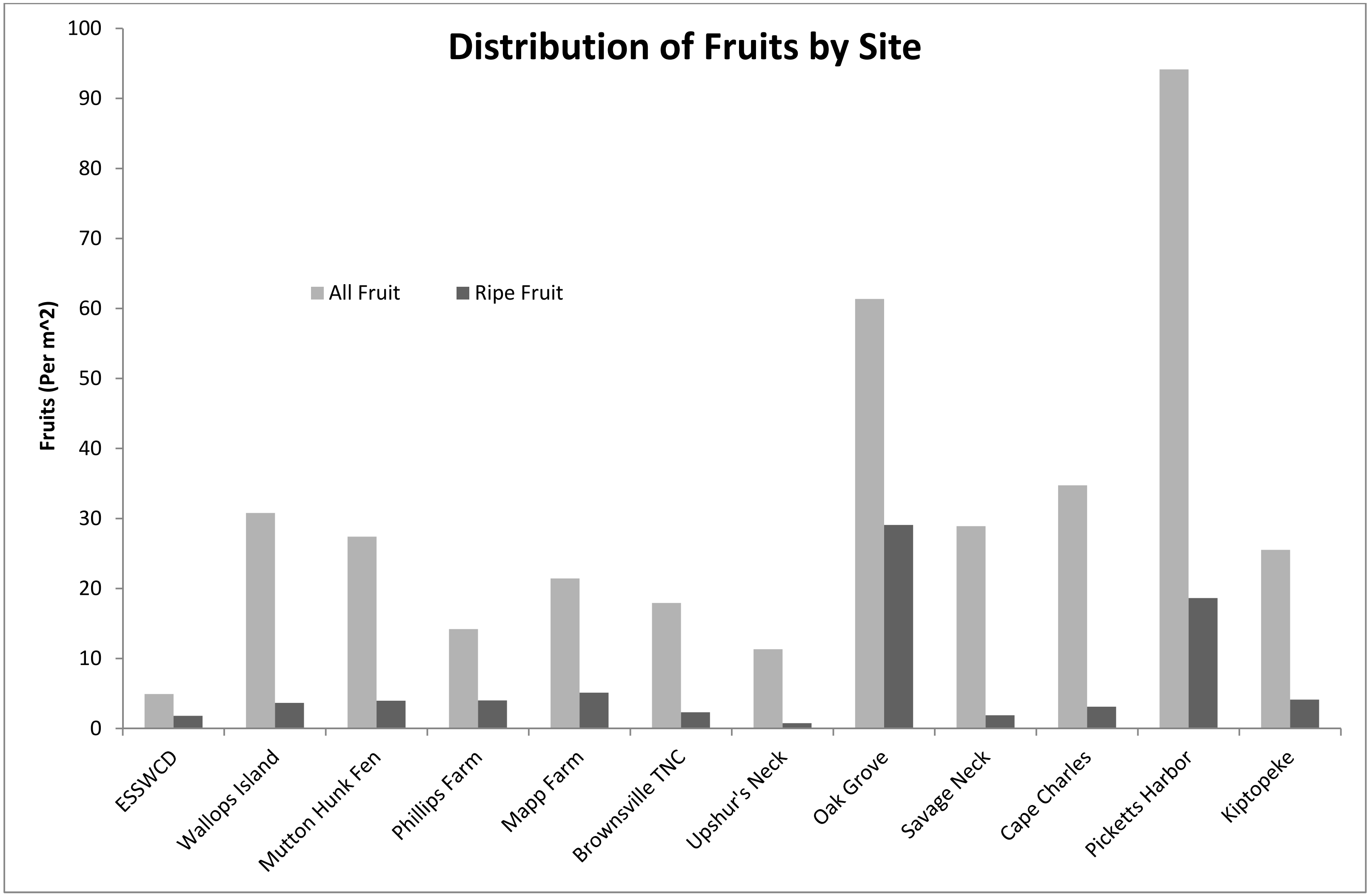


Figure 15: Fruit distribution (both ripe and total detections) for each site.

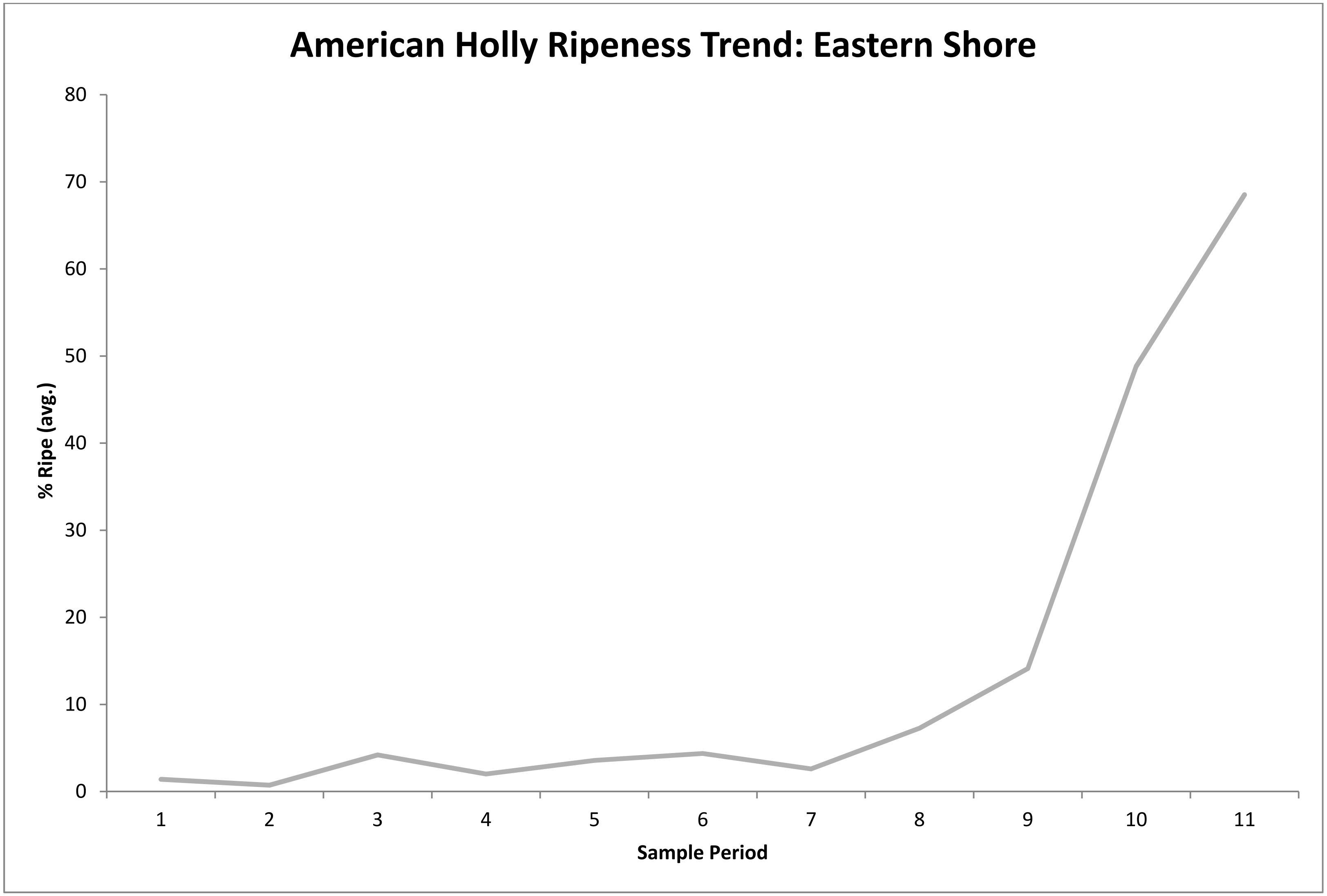


Figure 16: Ripeness trend for American Holly across all sampling periods for all Eastern Shore sites.

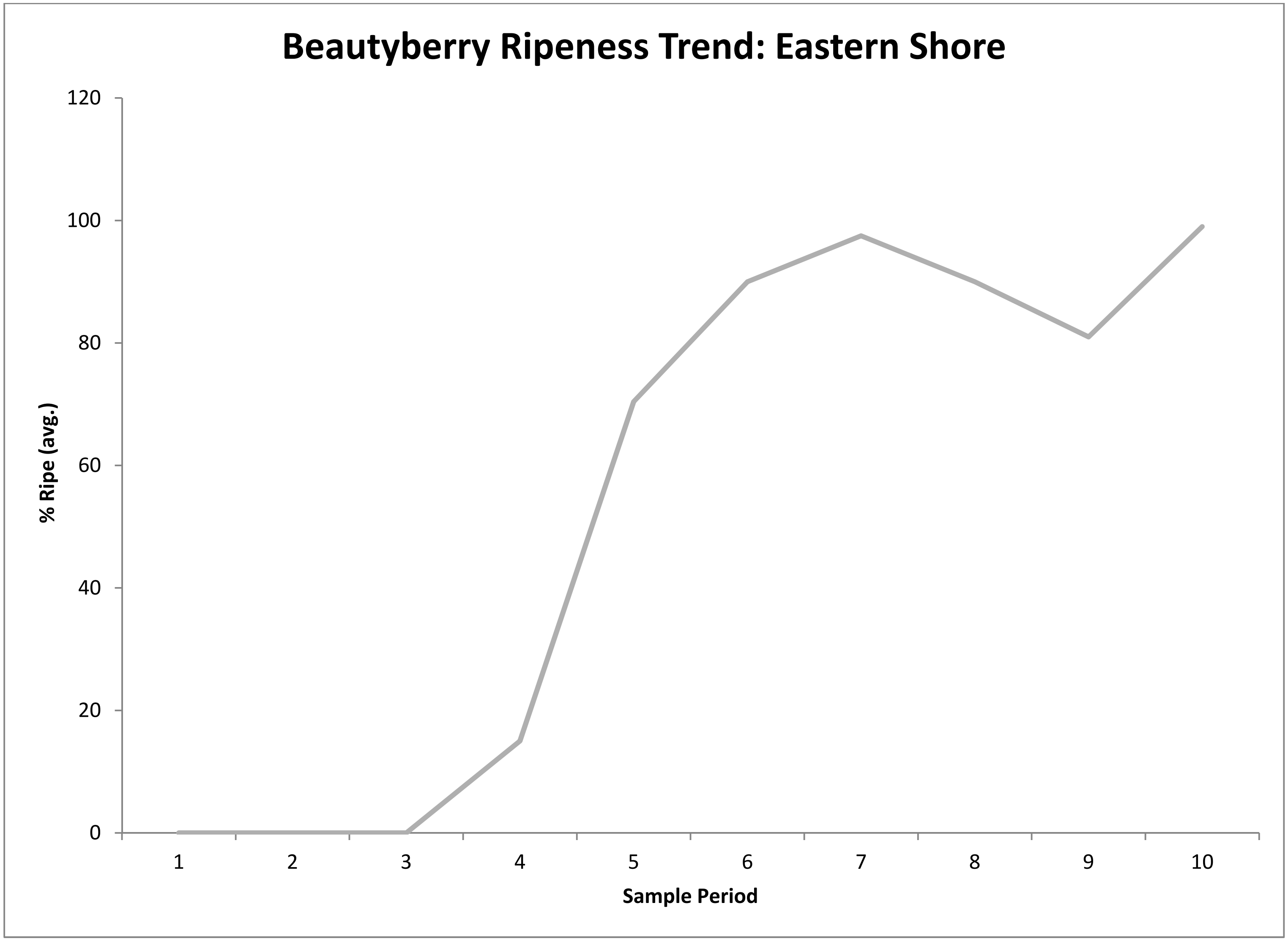


Figure 17: Ripeness trend for Beautyberry across all sampling periods for all Eastern Shore sites.

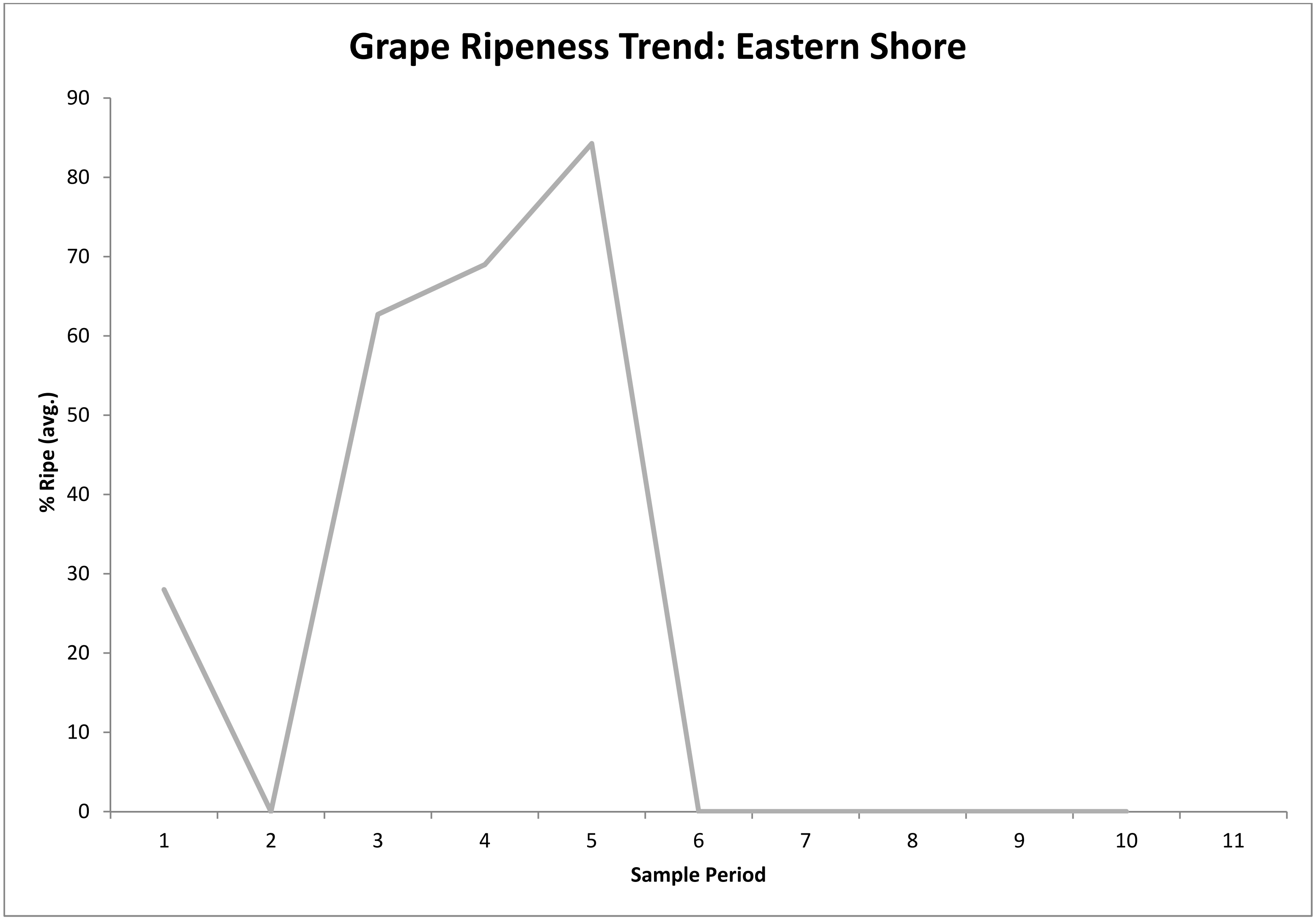


Figure 18: Ripeness trend for Grape across all sampling periods for all Eastern Shore sites.

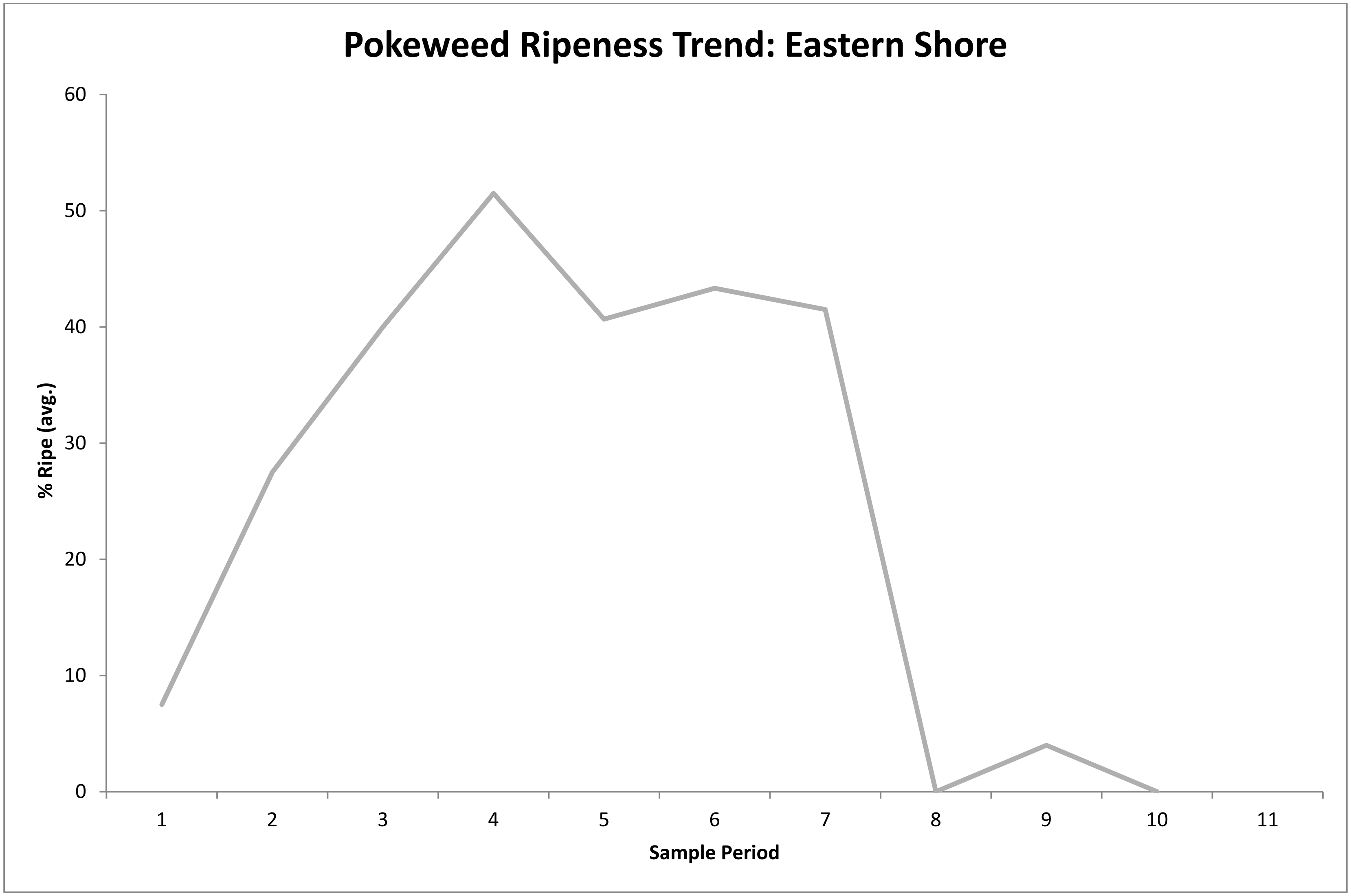


Figure 19: Ripeness trend for Pokeweed across all sampling periods for all Eastern Shore sites.

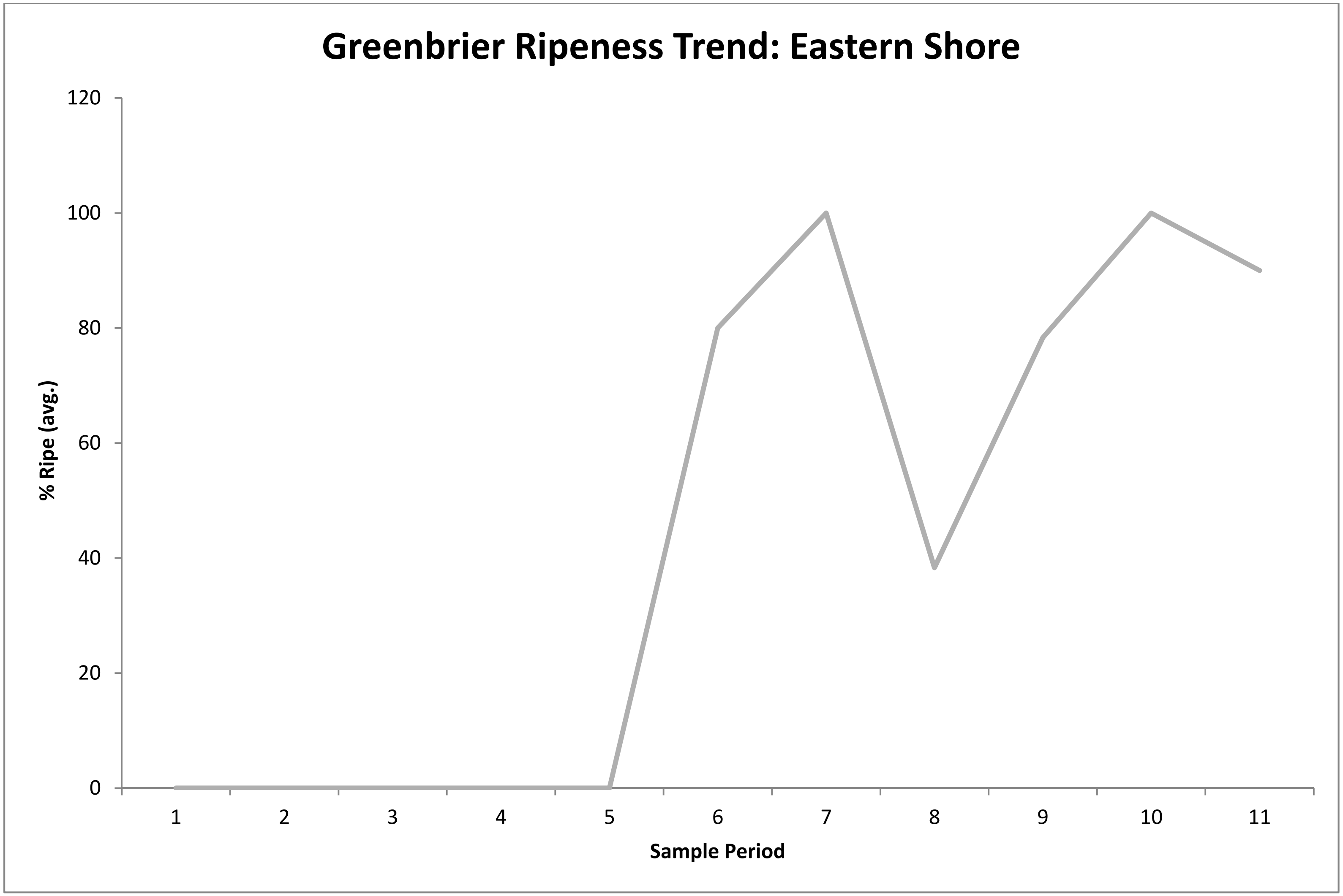


Figure 20: Ripeness trend for Greenbrier across all sampling periods for all Eastern Shore sites.

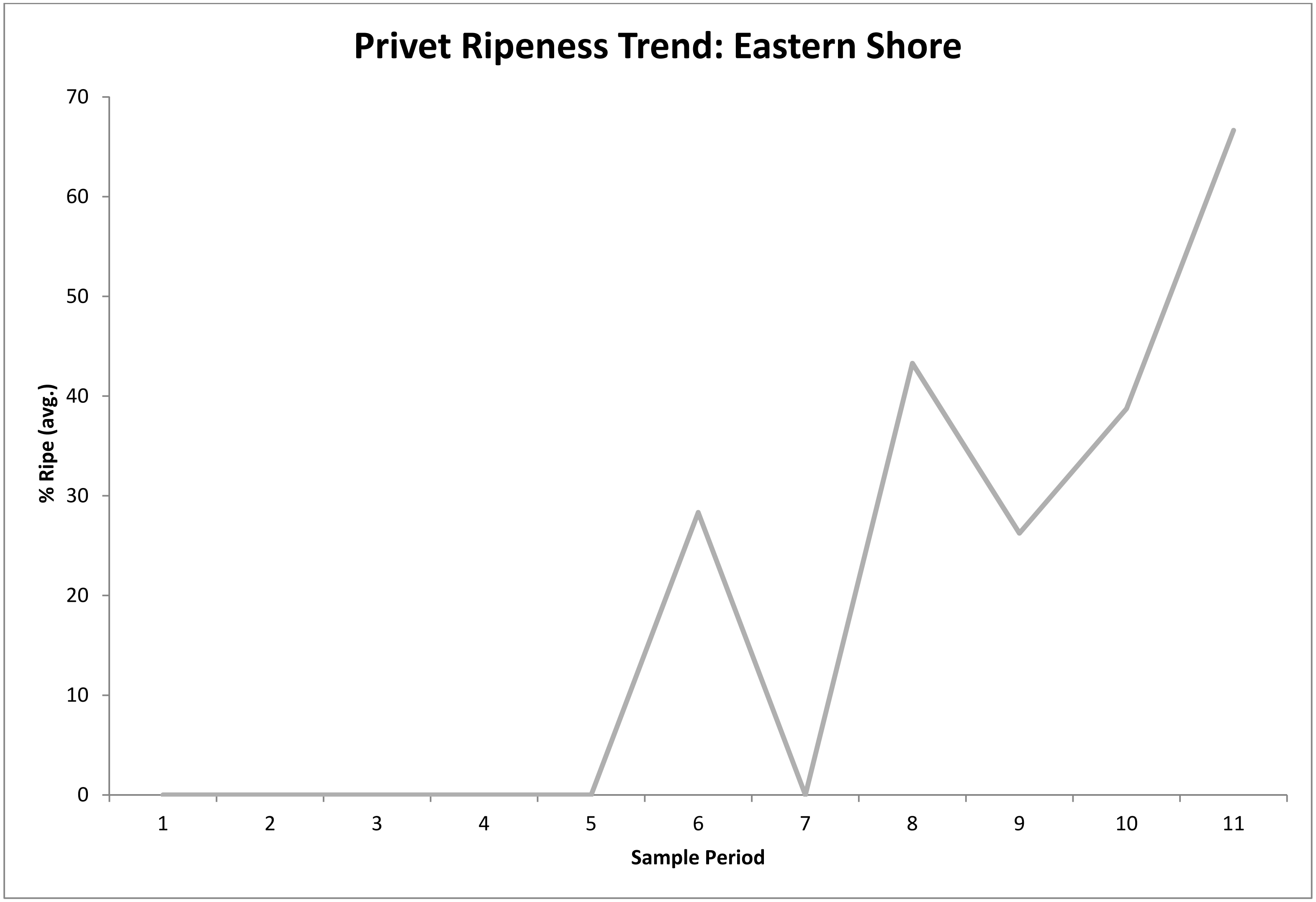


Figure 21: Ripeness trend for Privet across all sampling periods for all Eastern Shore sites.

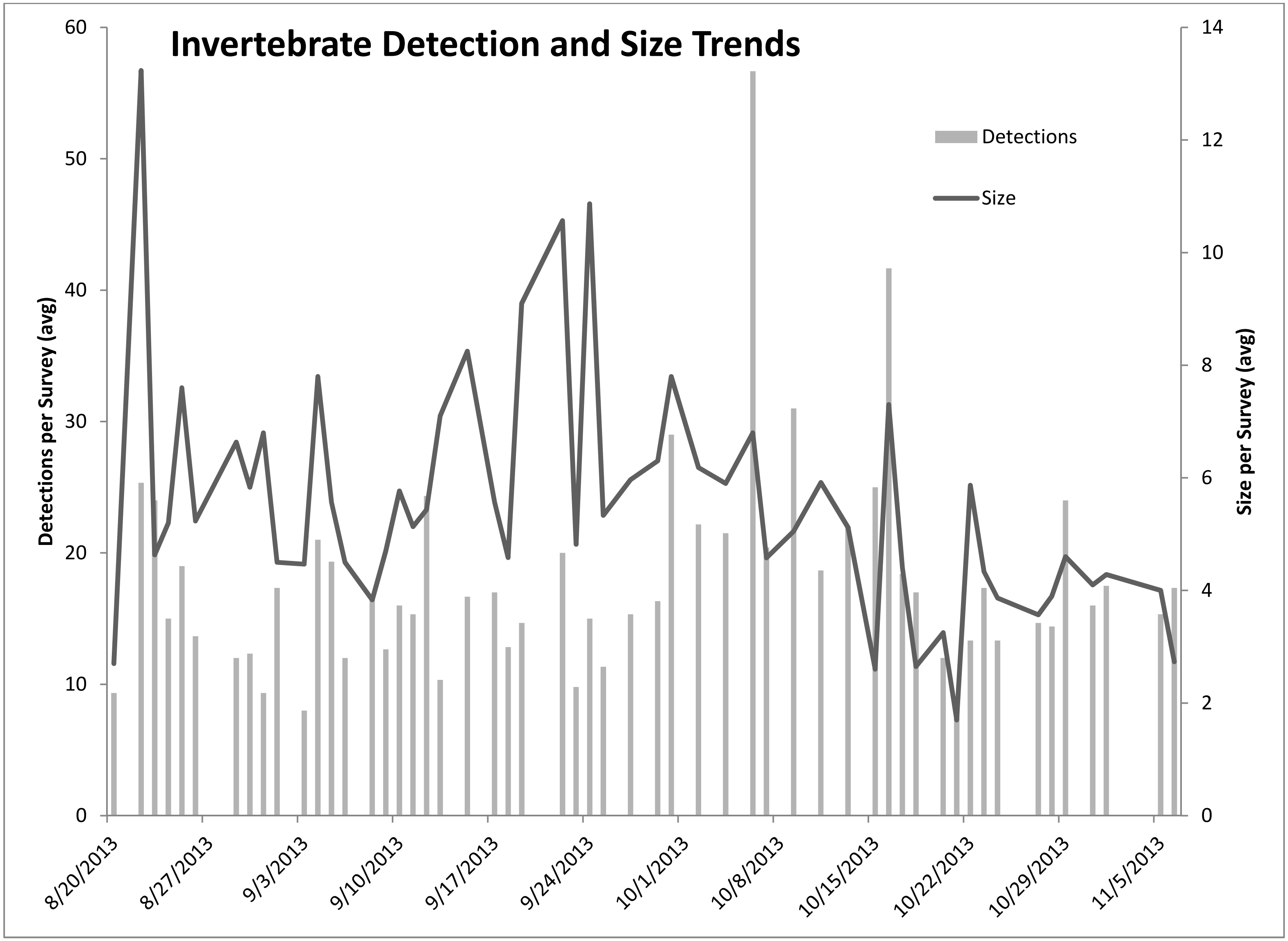


Figure 22: Seasonal trends for average invertebrate size and number of detections.

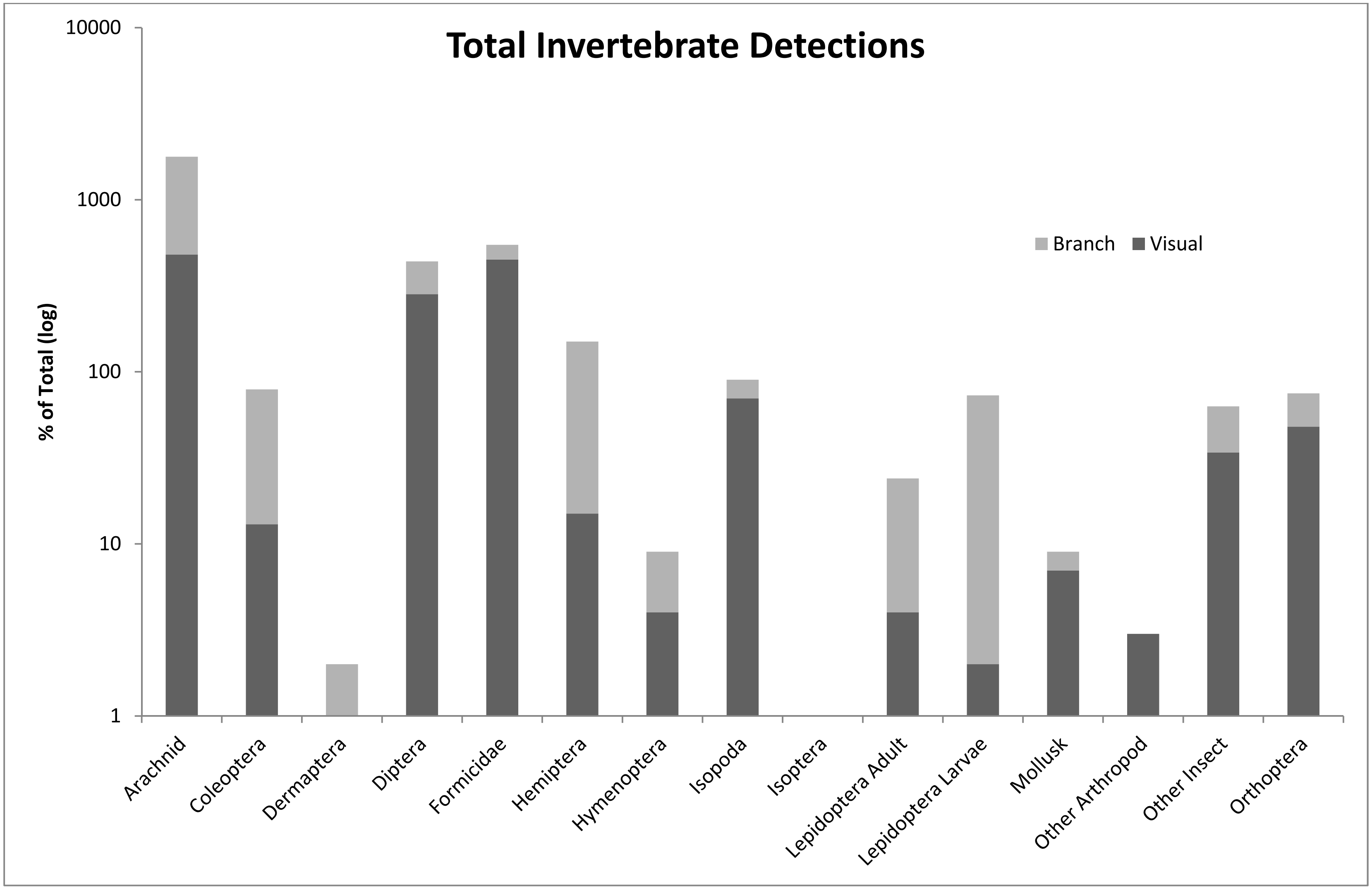


Figure 23: Summary of detections by Order, as well as means of collection (branch clipping or visual count).

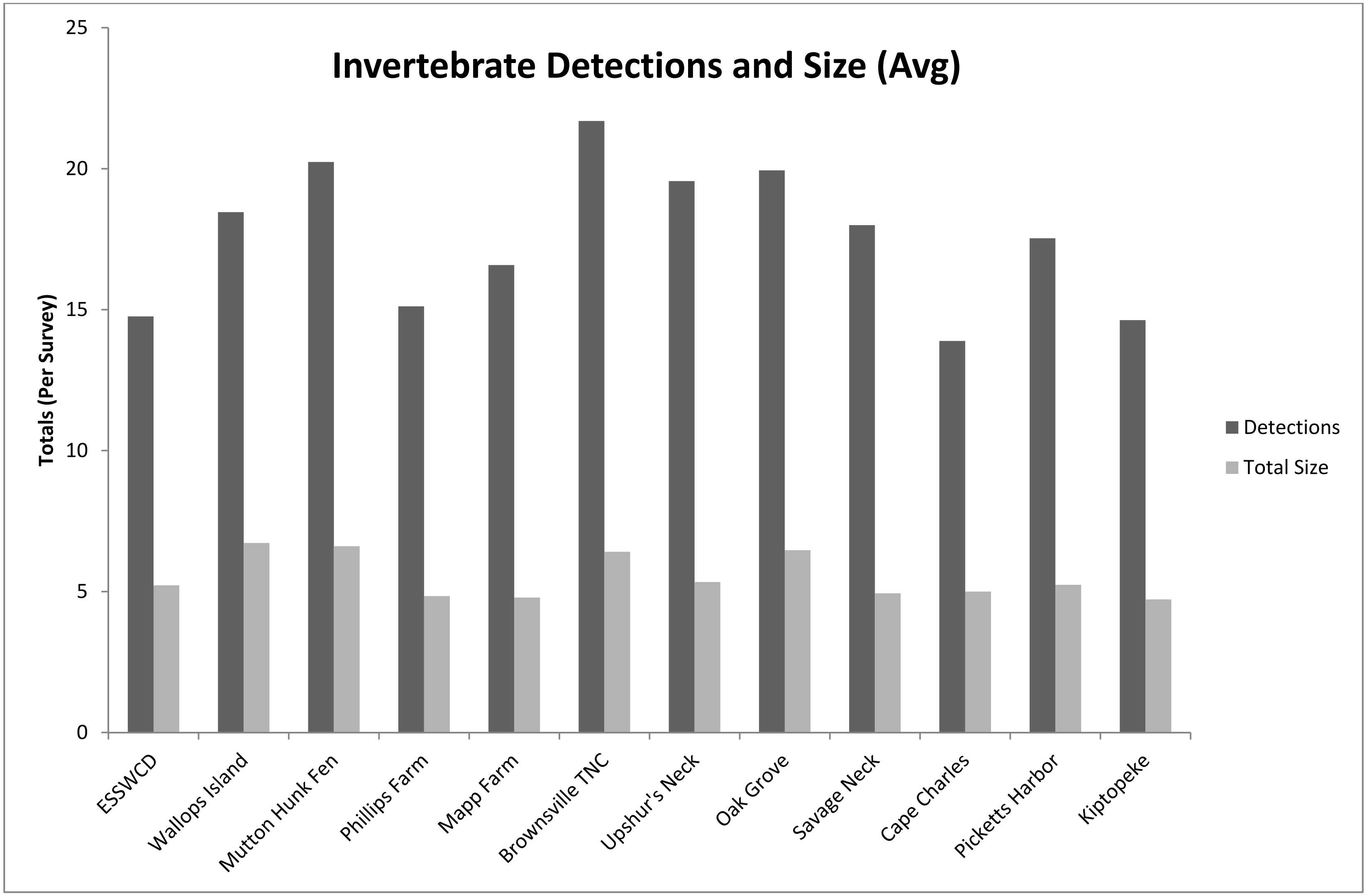


Figure 24: Trends in average invertebrate detections, as well as total size, for each site.

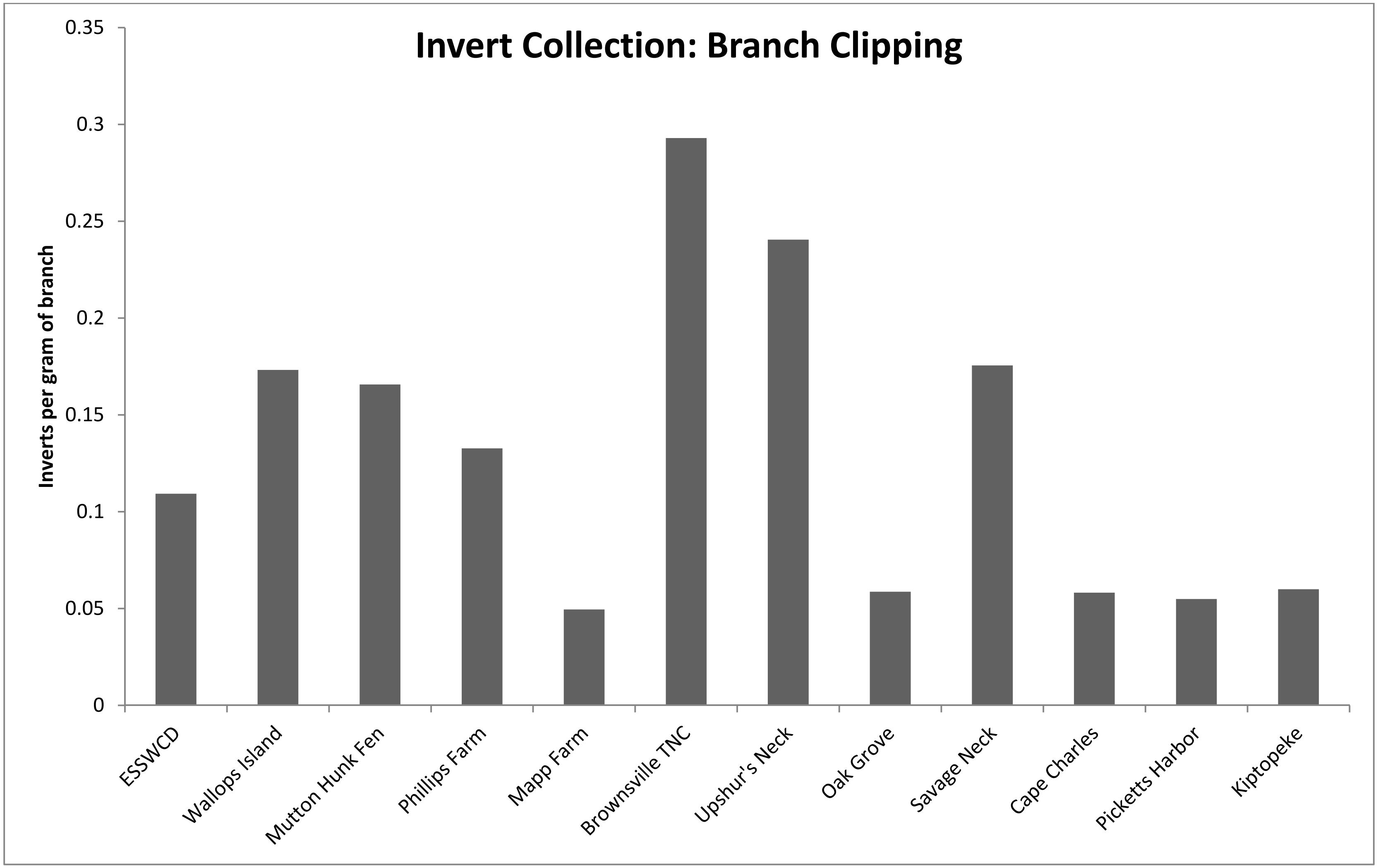


Figure 25: Invertebrate detections for all Eastern Shore sites, obtained via branch clippings.

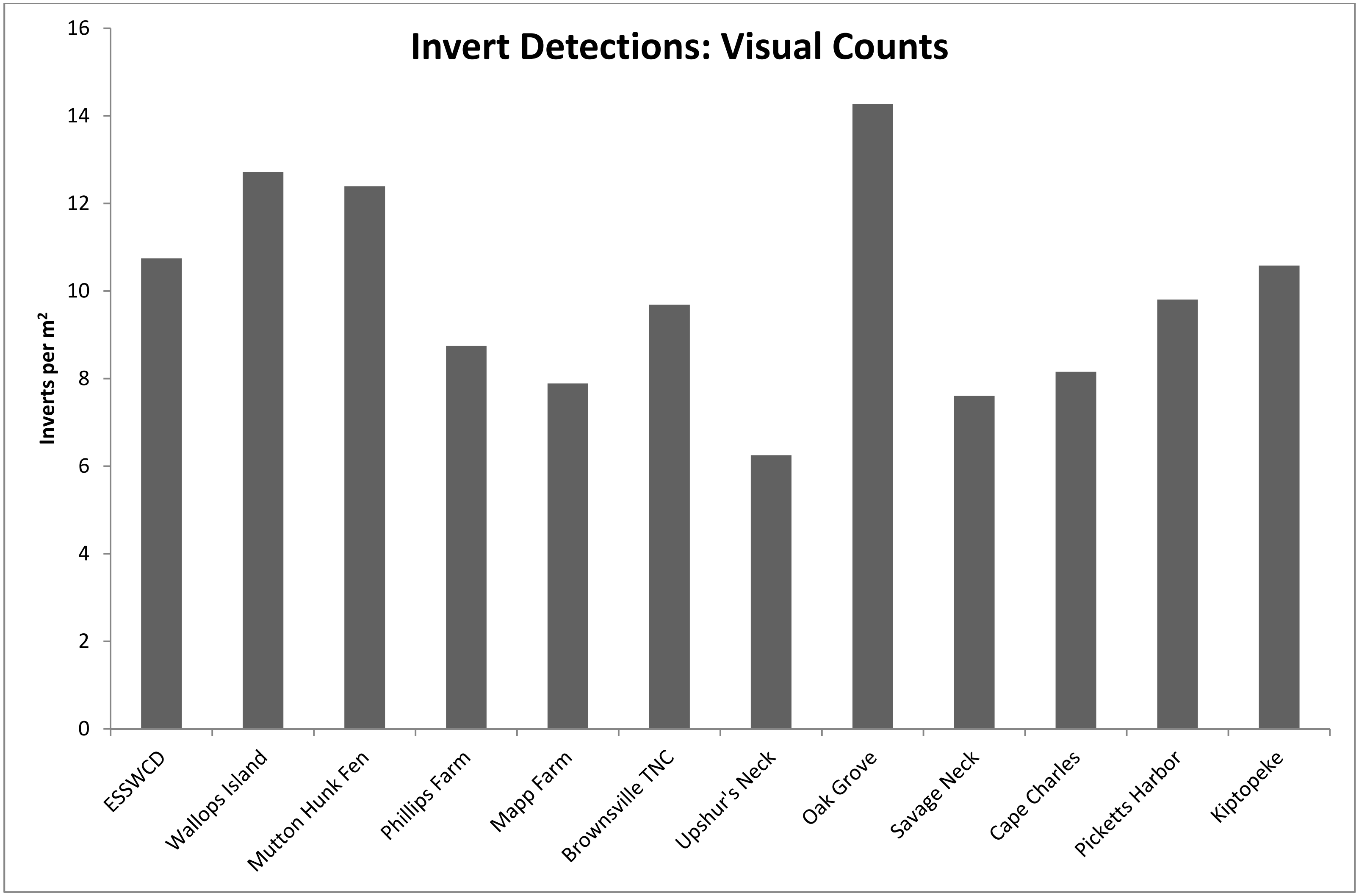


Figure 26: Invertebrate detections for all Eastern Shore sites, obtained via ground plot visual counts.

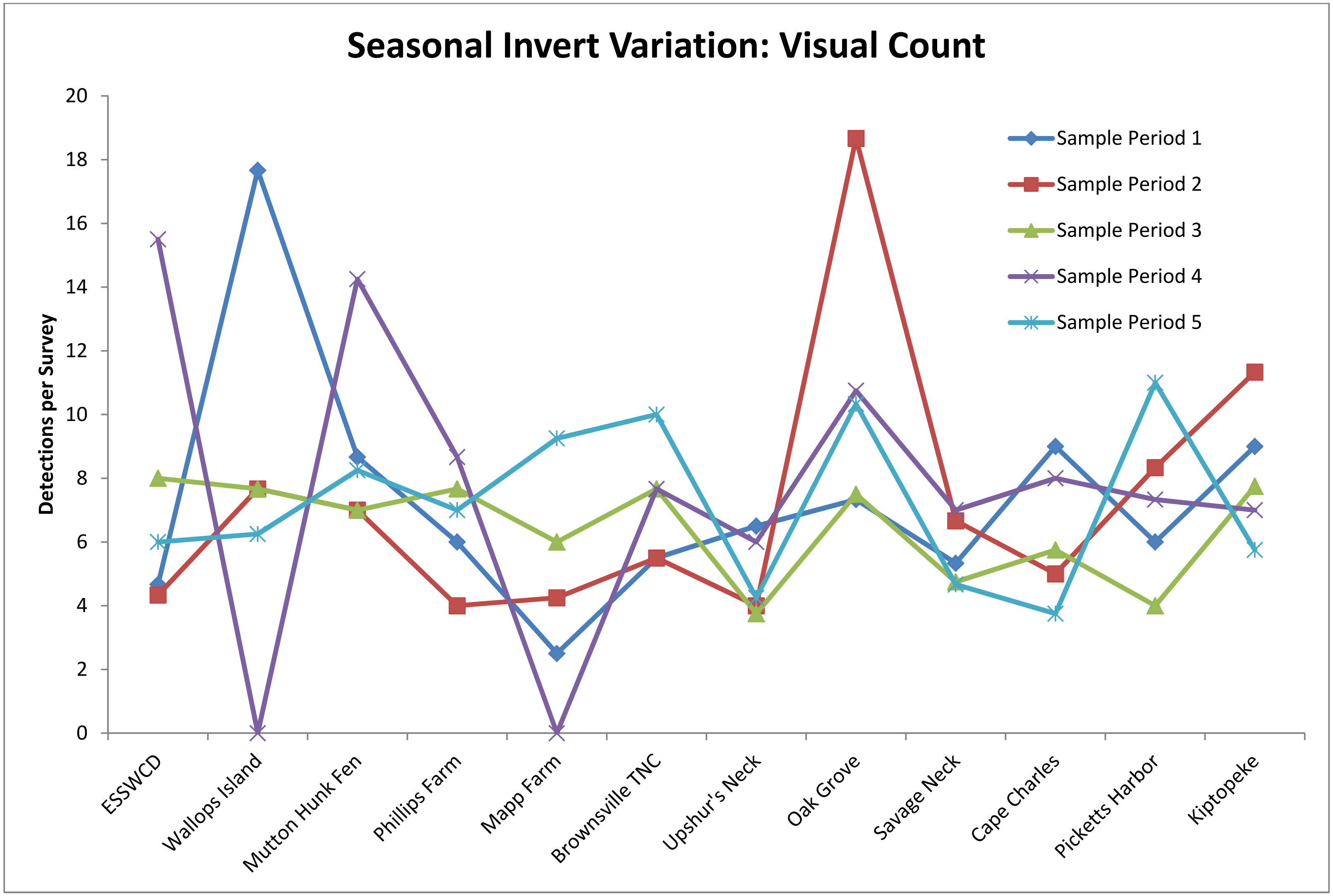


Figure 27: Invertebrate visual count detection trends for all Eastern Shore sites, highlighting that there was no significant decline in invertebrates. Note the decline to zero for invertebrates at Wallops Flight Facility and Mapp Farm during sample period 4 is due the absence of surveying effort.

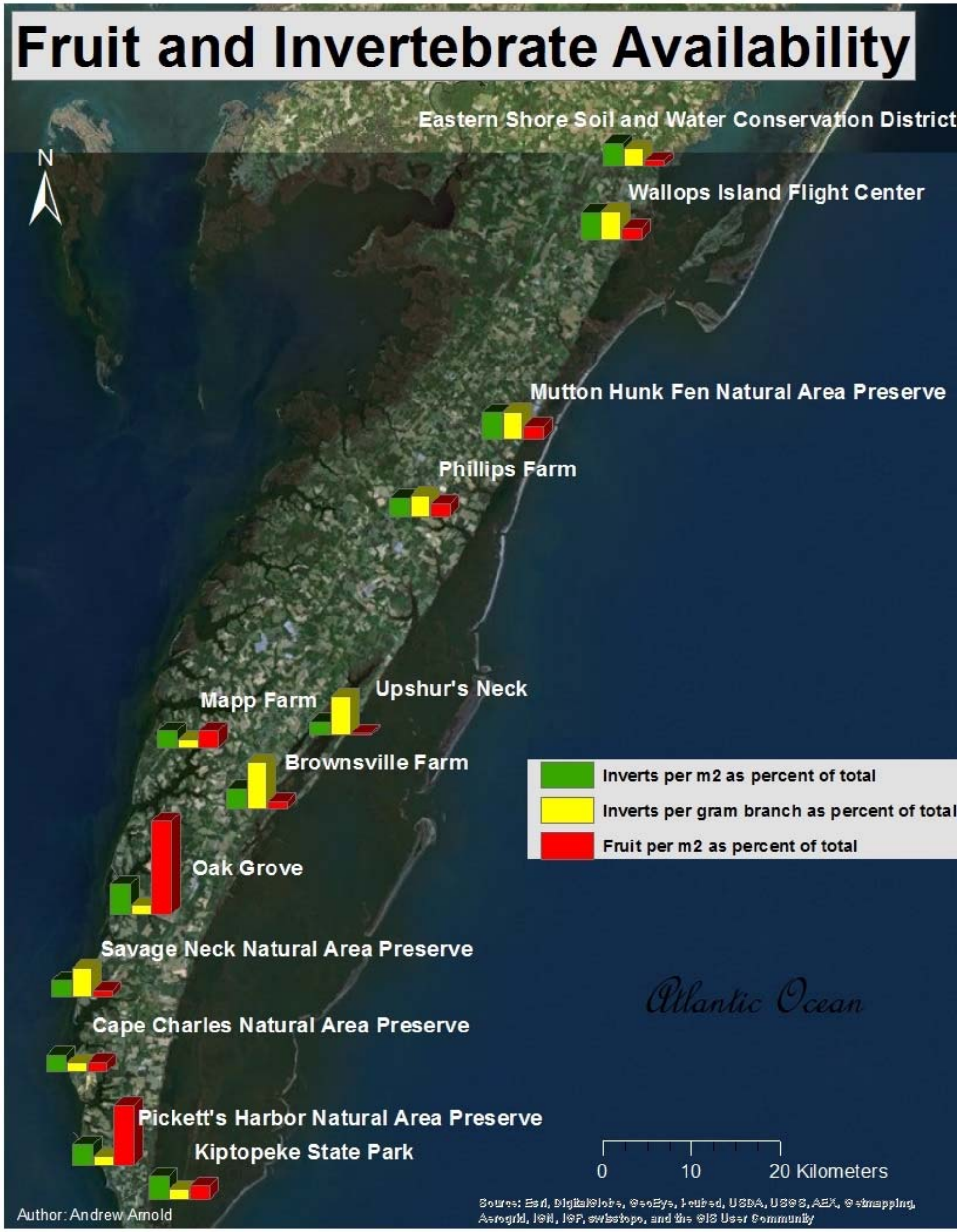


Figure 28: Fruit and Invertebrate averages for each site show great variation in overall seasonal availability.

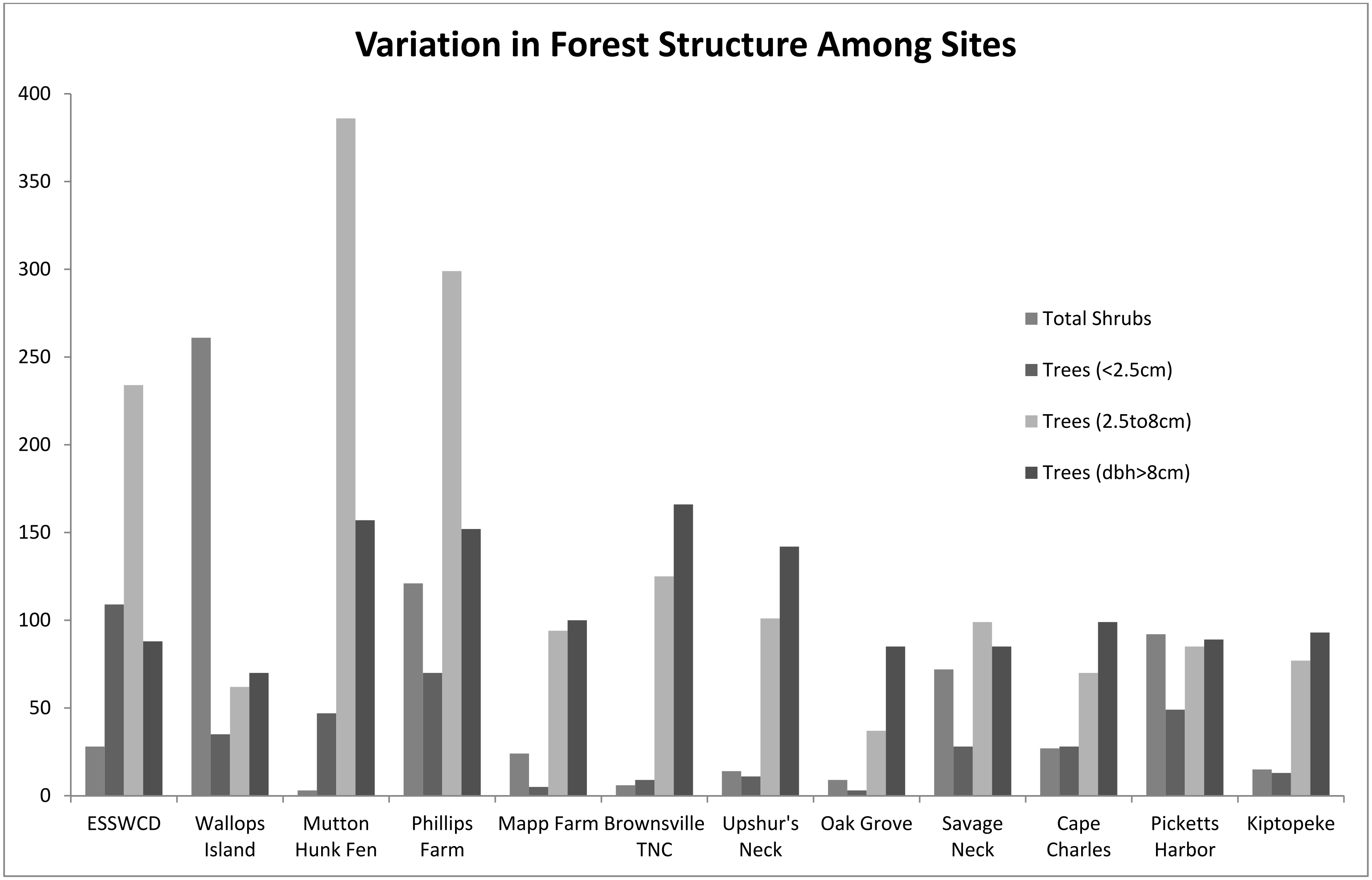


Figure 29: Variation in forest structure between each Eastern Shore survey location.

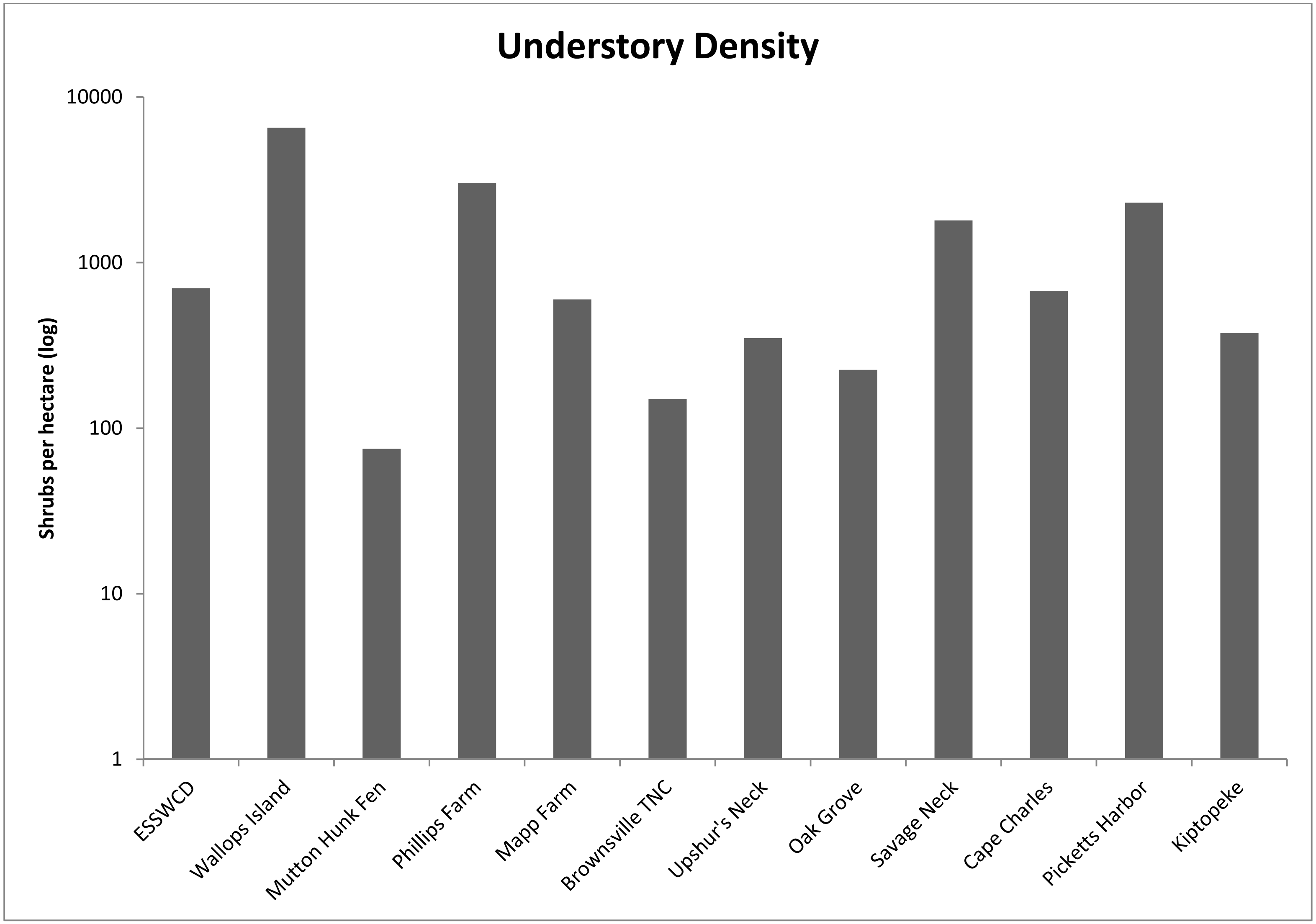


Figure 30: Variation in understory shrub density between each Eastern Shore survey location.

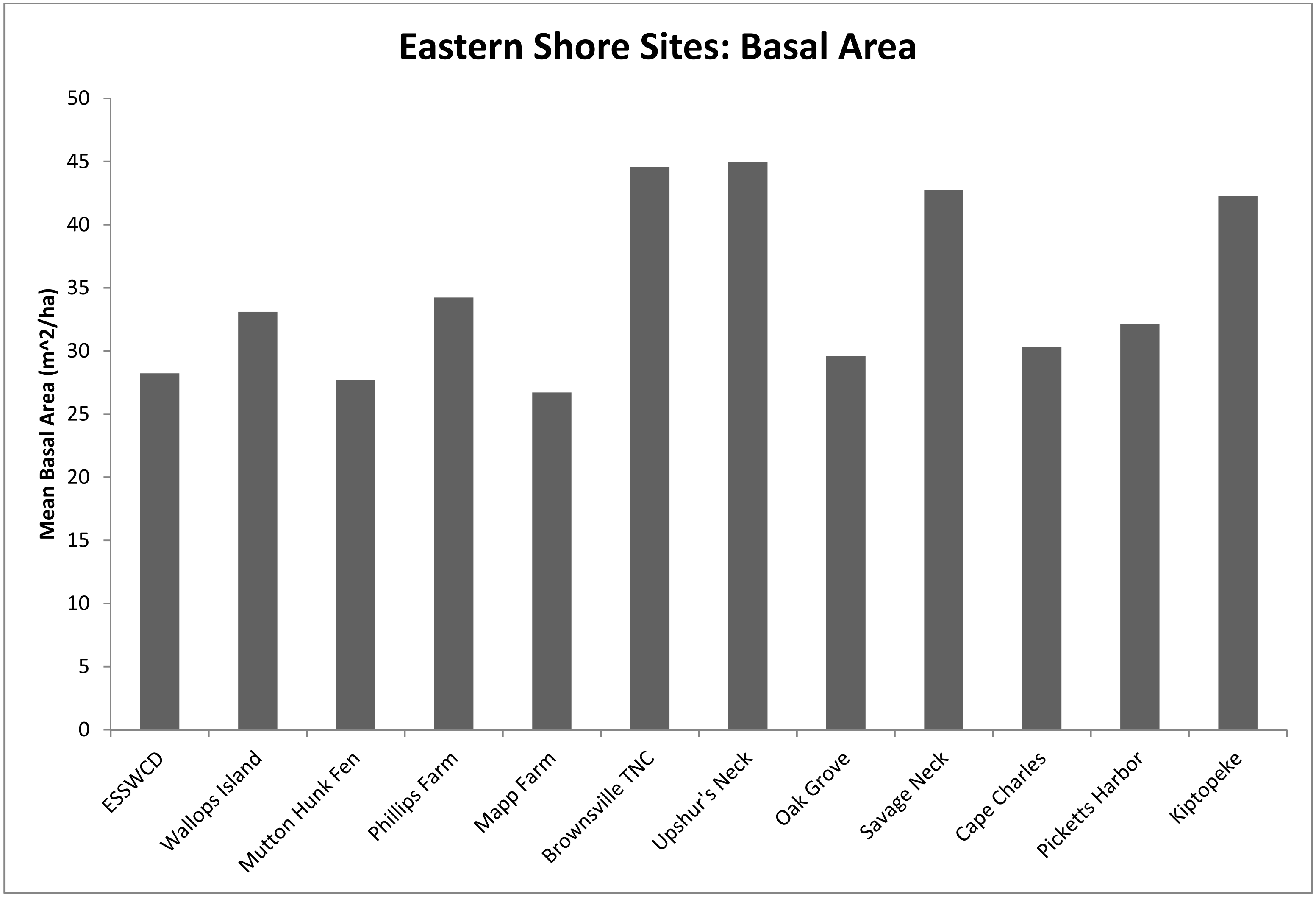


Figure 31: Mean basal area for each Eastern Shore forested survey location.

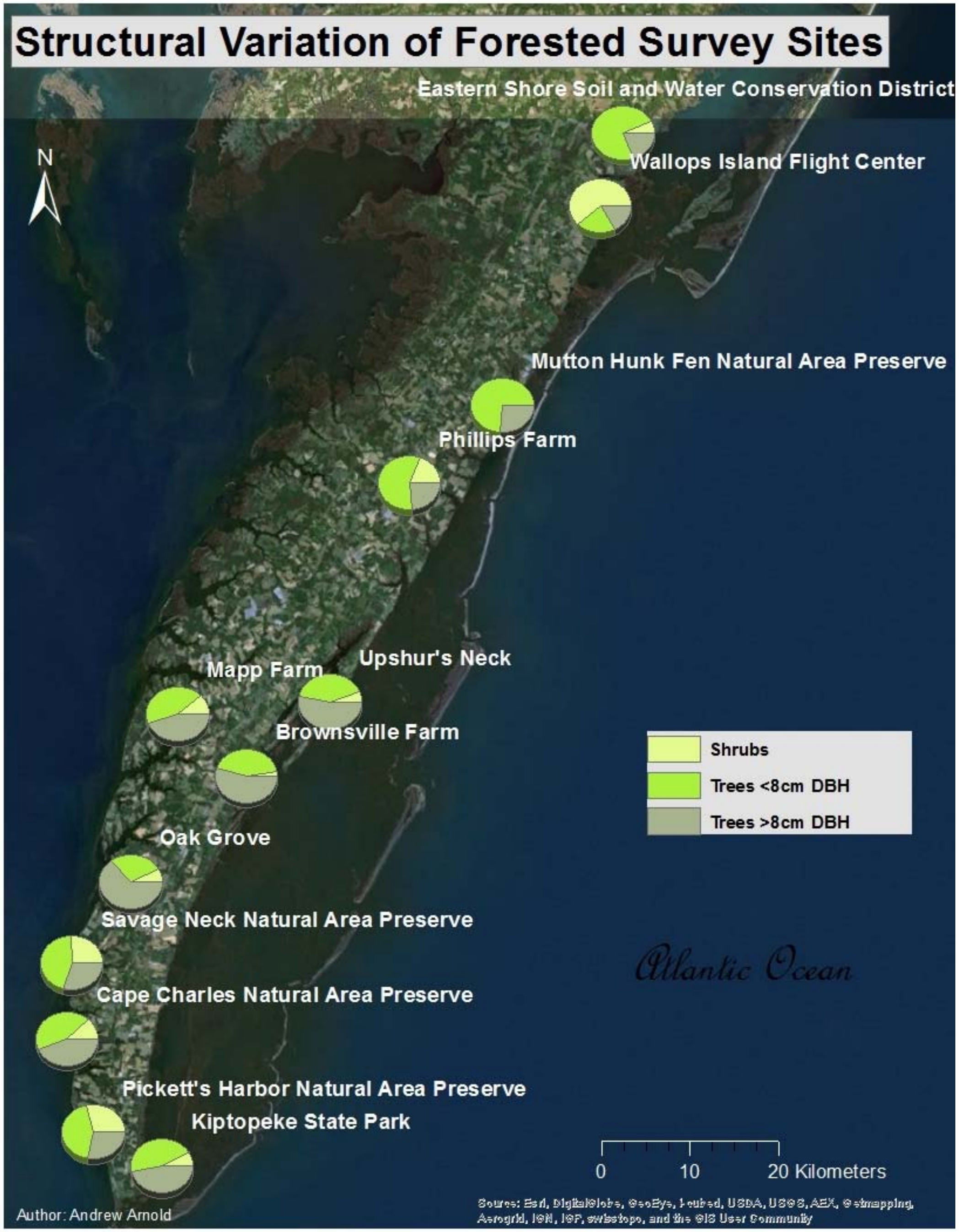


Figure 32: Variation in proportion of shrubs, small trees, and large trees between sites.

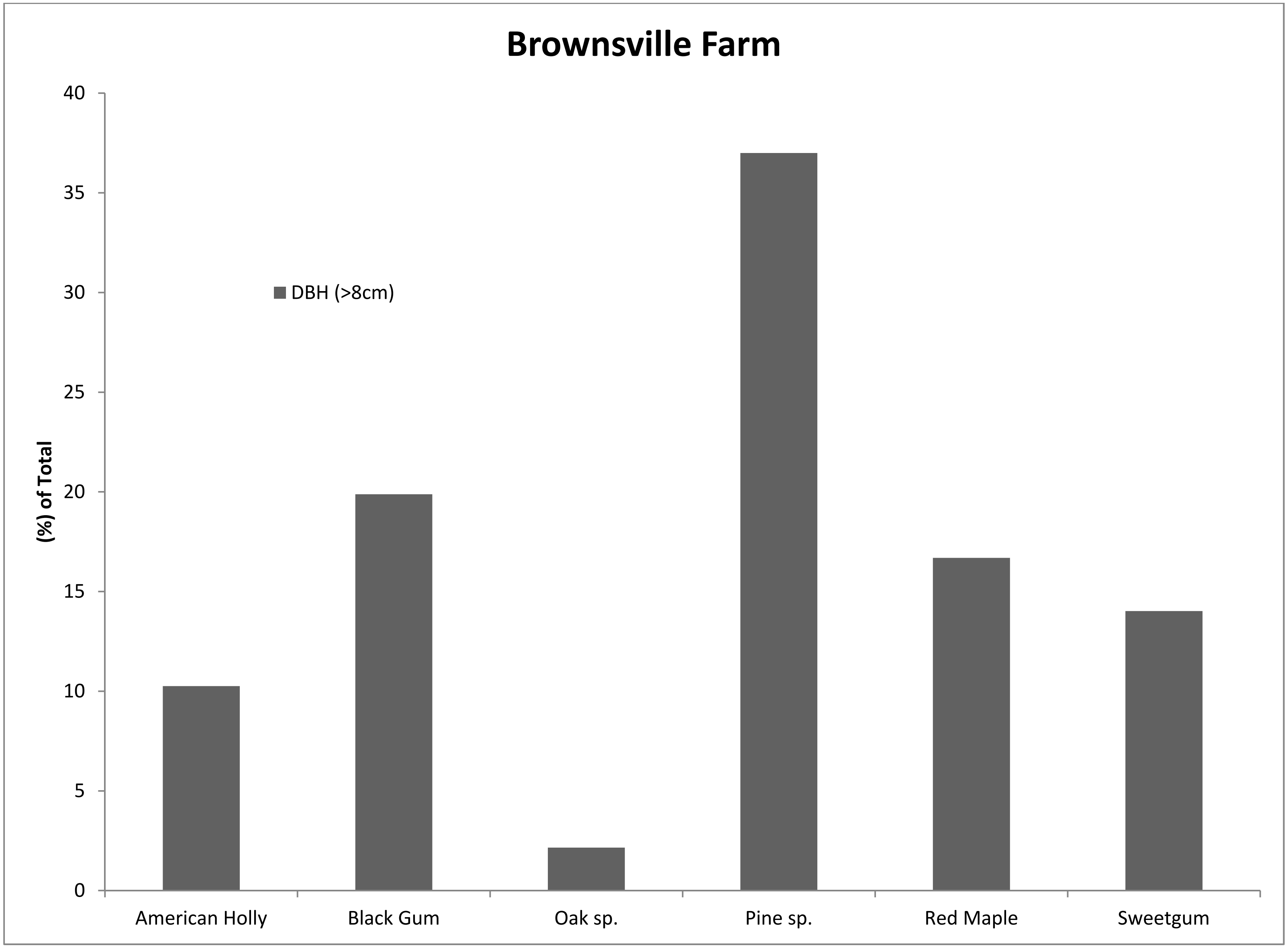


Figure 33: Percentage of trees (DBH > 8cm) at Brownsville Farm.

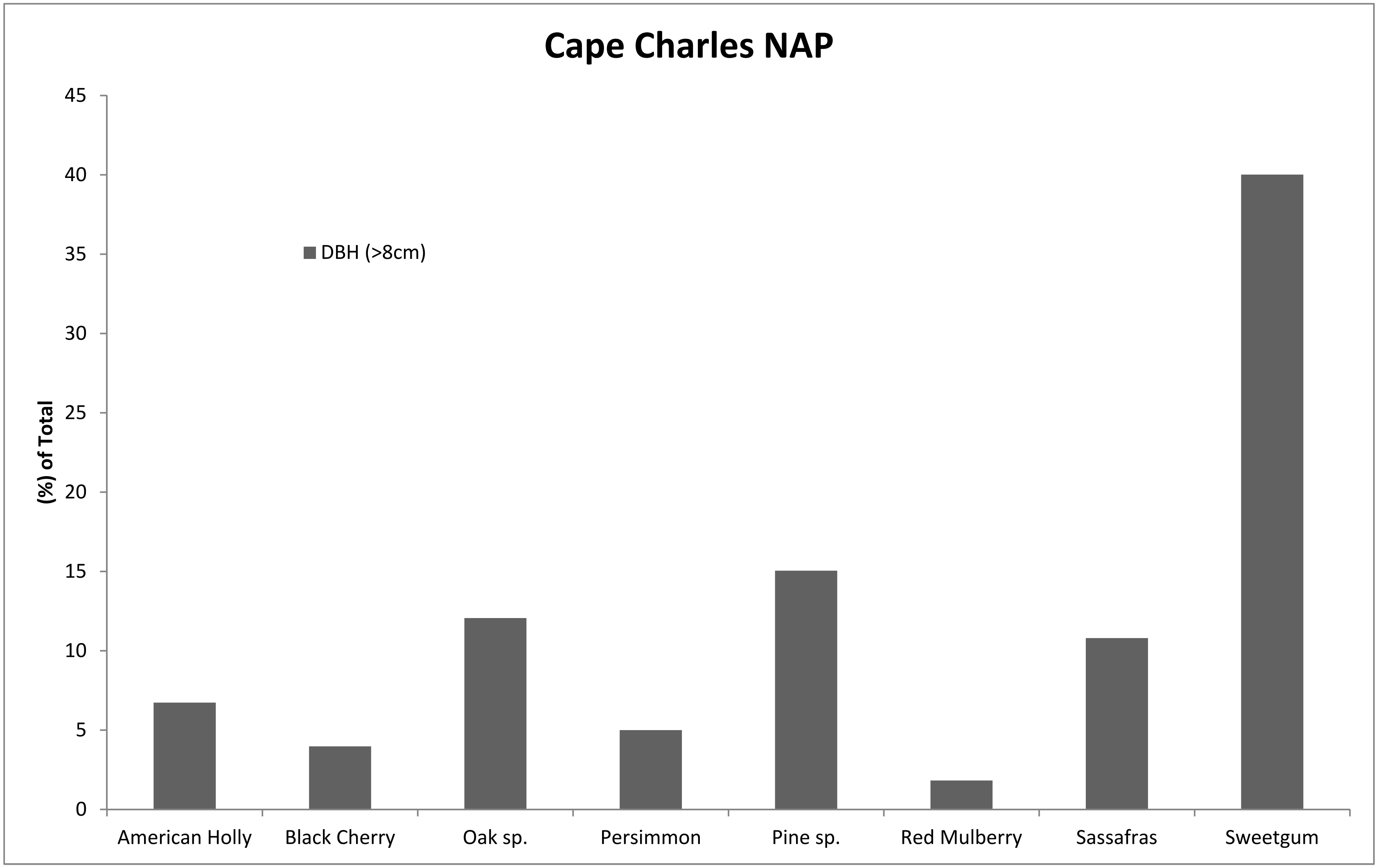


Figure 34: Percentage of trees (DBH > 8cm) at Cape Charles NAP.

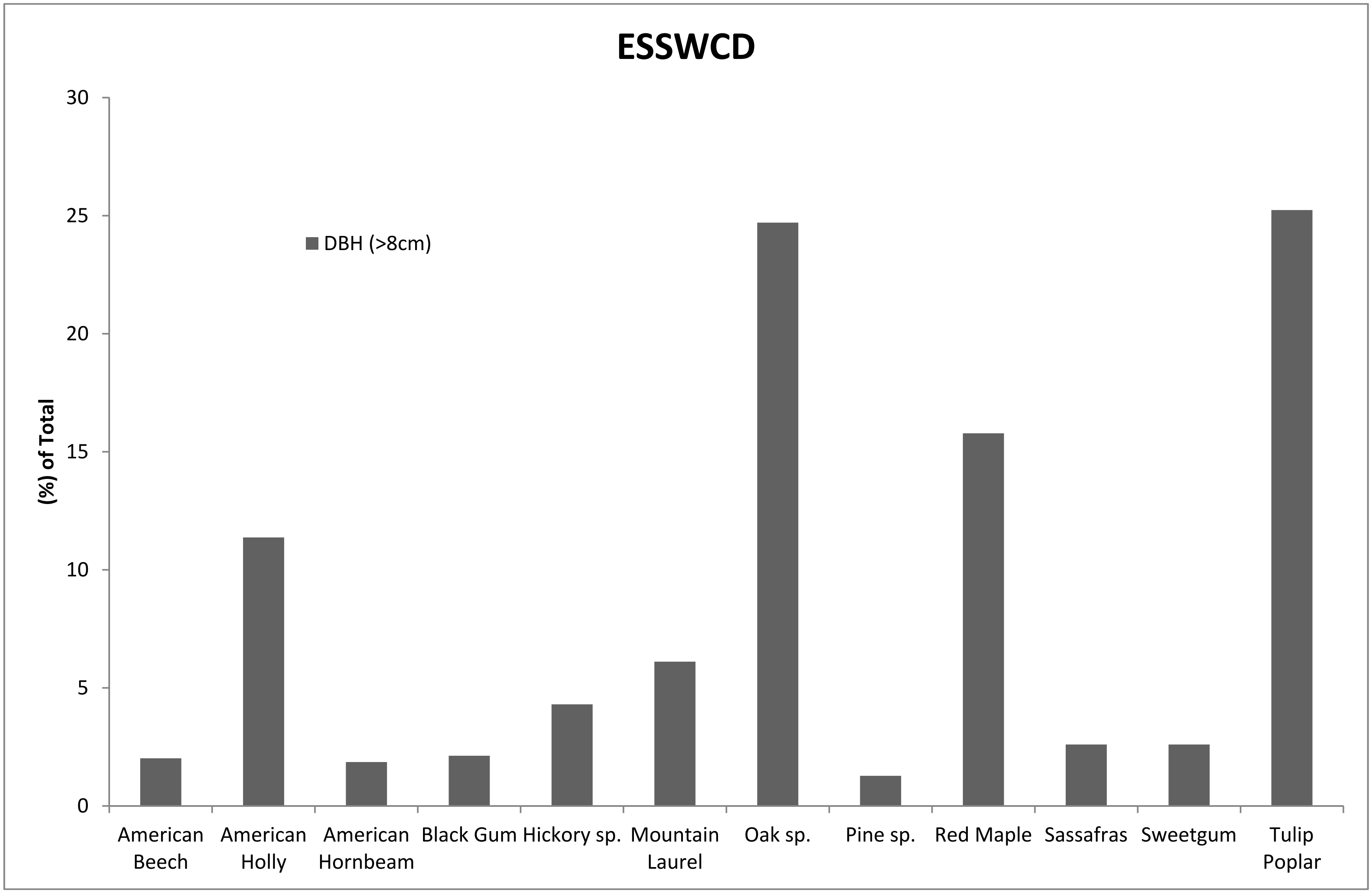


Figure 35: Percentage of trees (DBH > 8cm) at Eastern Shore Soil & Water Conservation District.

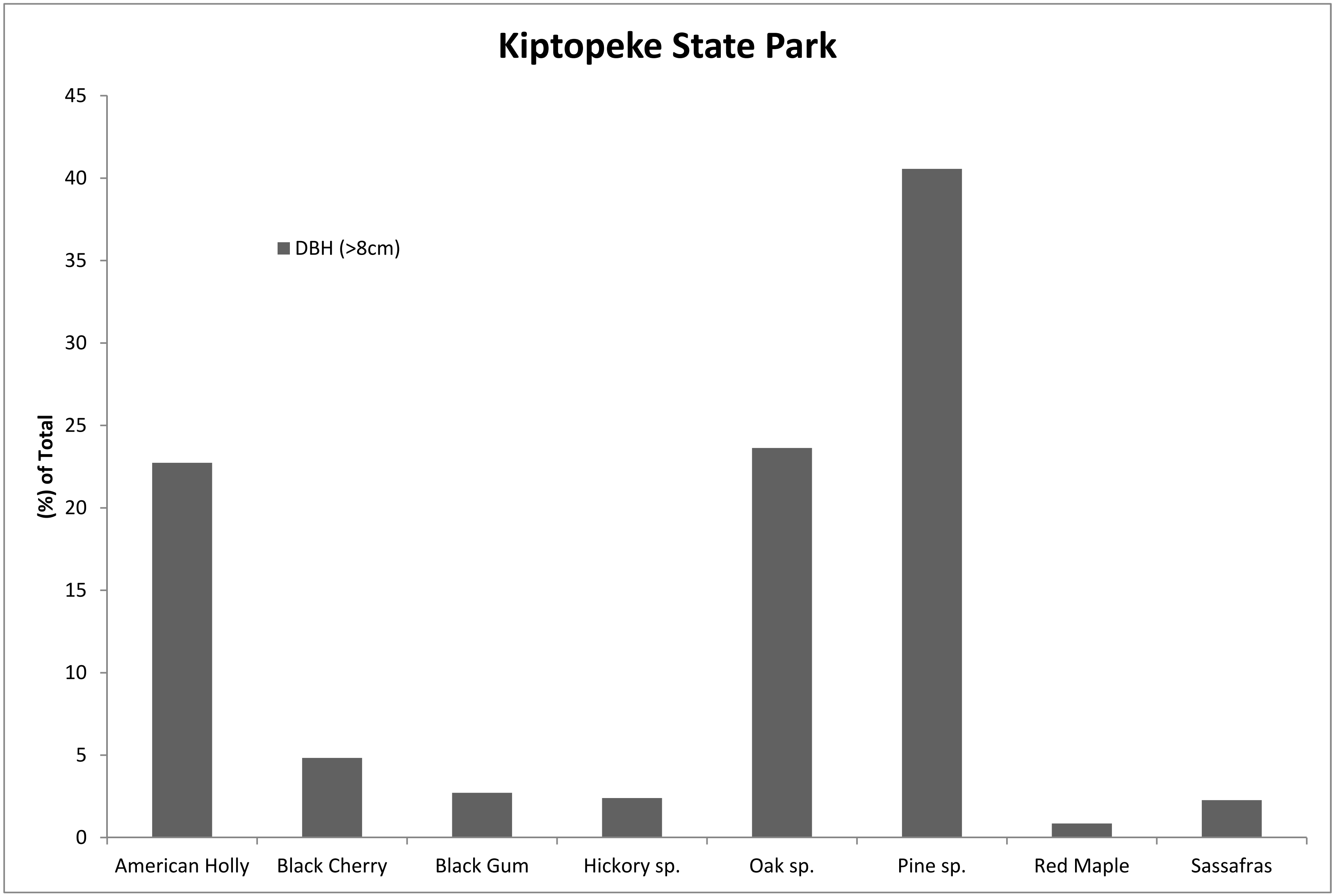


Figure 36: Percentage of trees (DBH > 8cm) at Kiptopeke State Park (Parsons Tract).

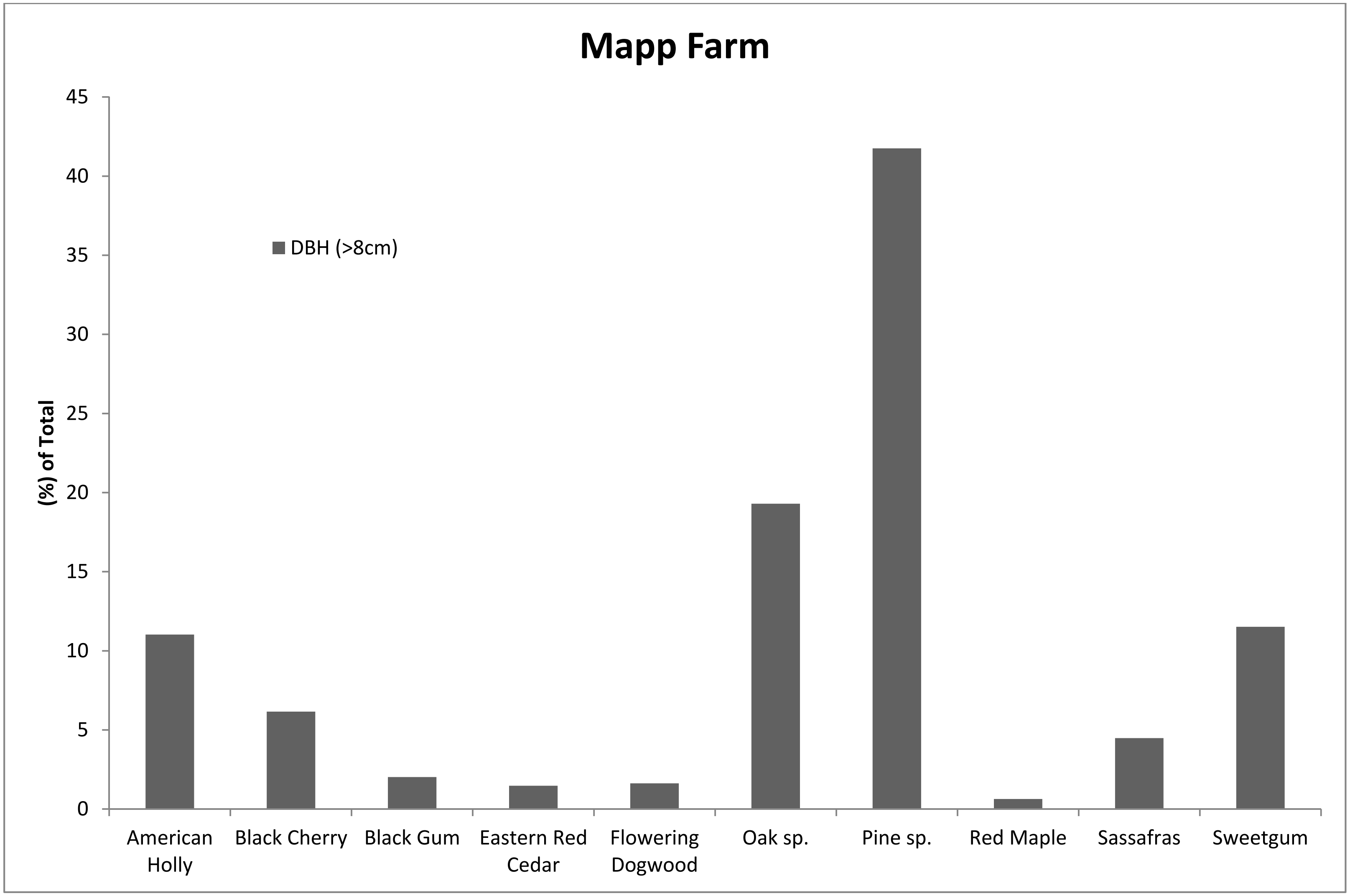


Figure 37: Percentage of trees (DBH > 8cm) at Mapp Farm.

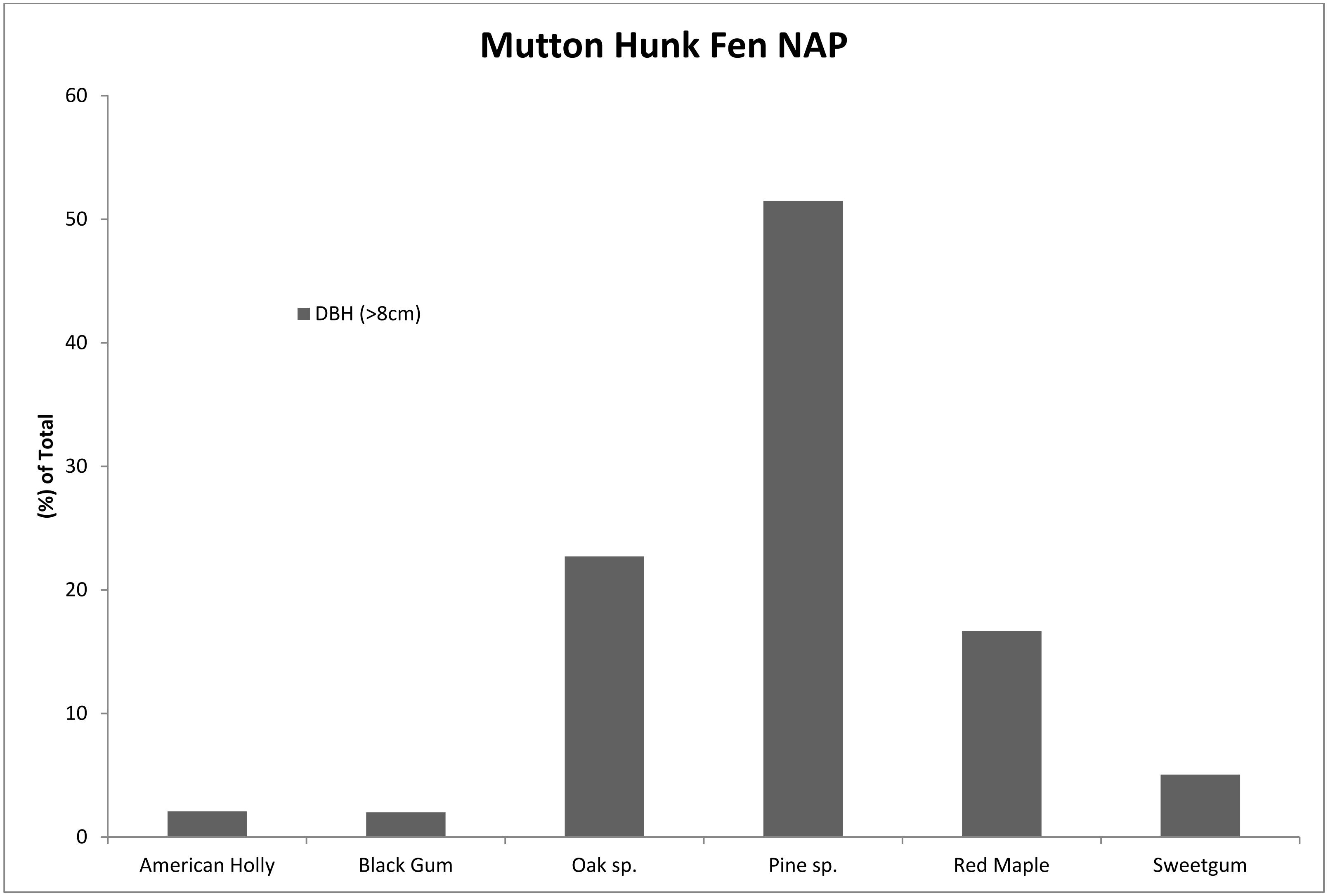


Figure 38: Percentage of trees (DBH > 8cm) at Mutton Hunk Fen NAP.

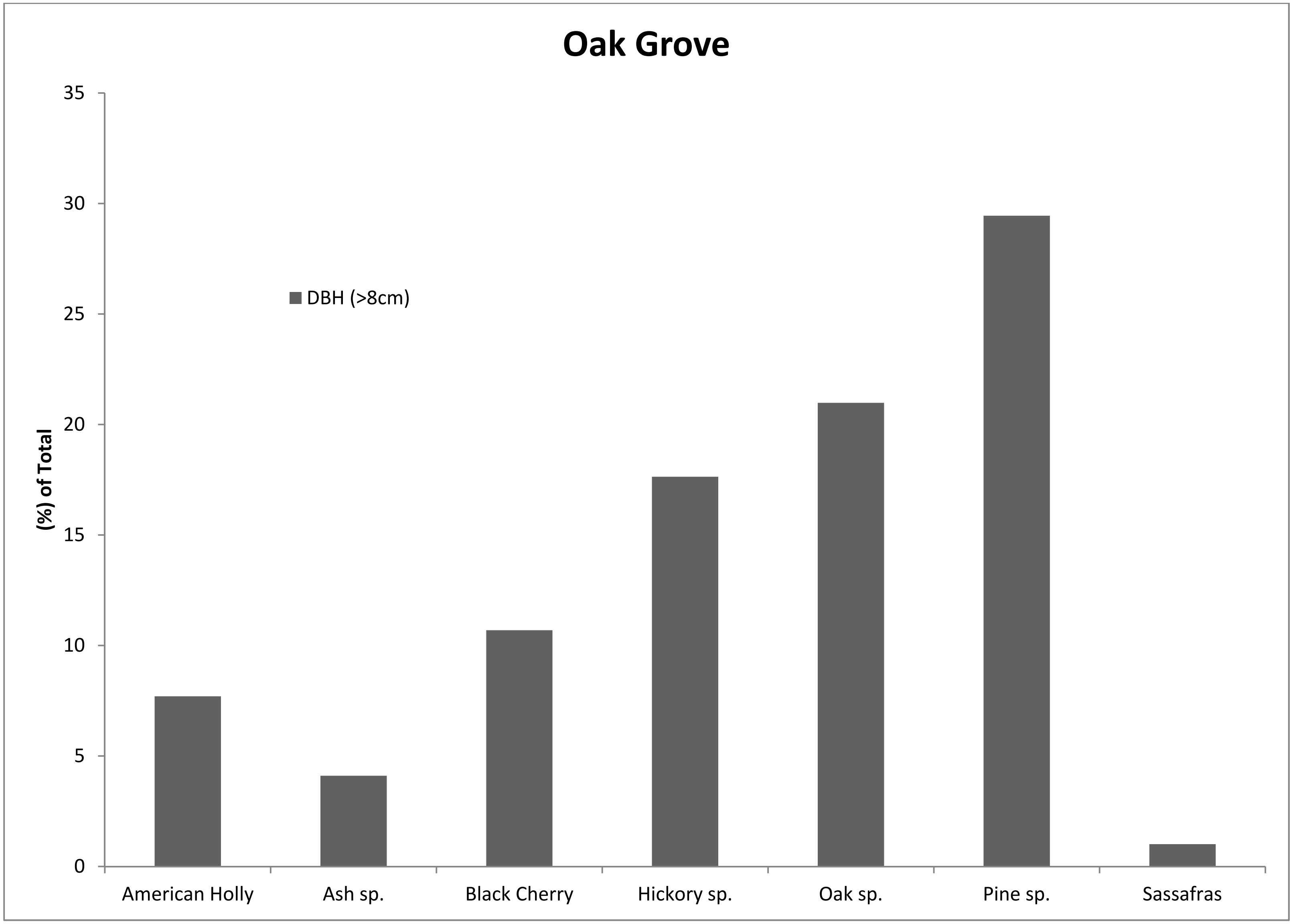


Figure 39: Percentage of trees (DBH > 8cm) at Oak Grove.

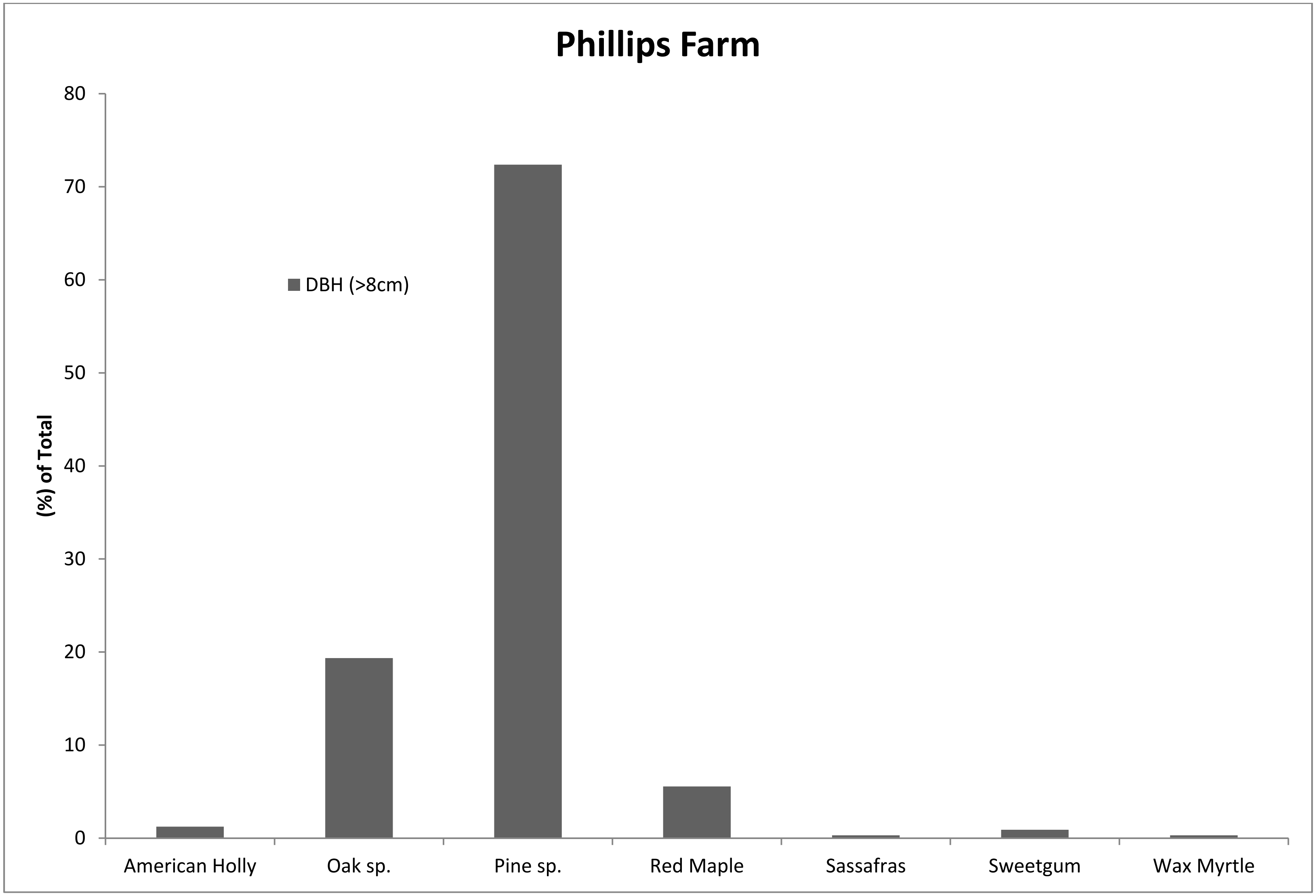


Figure 40: Percentage of trees (DBH > 8cm) at Phillips Farm.

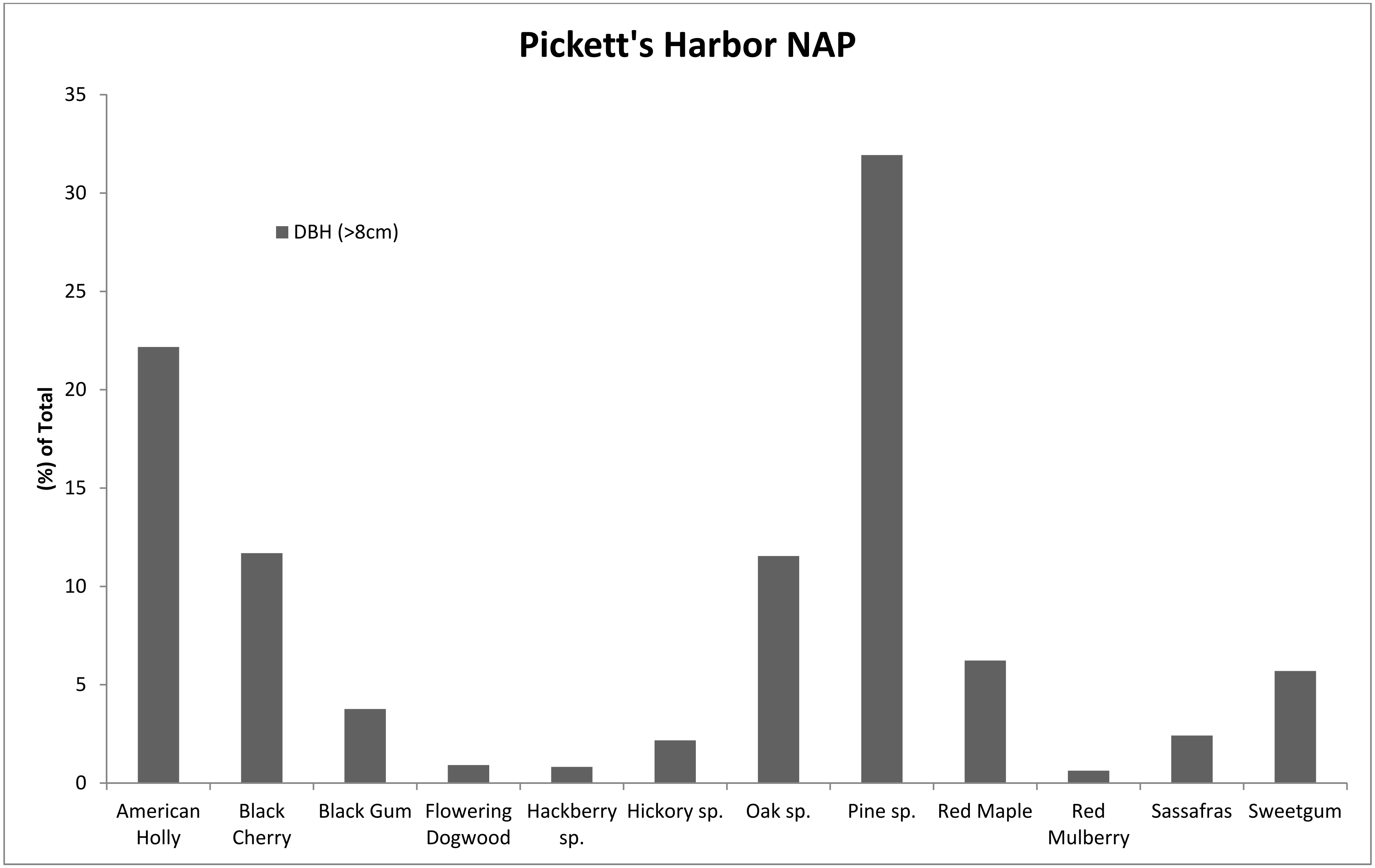


Figure 41: Percentage of trees (DBH > 8cm) at Pickett's Harbor NAP.

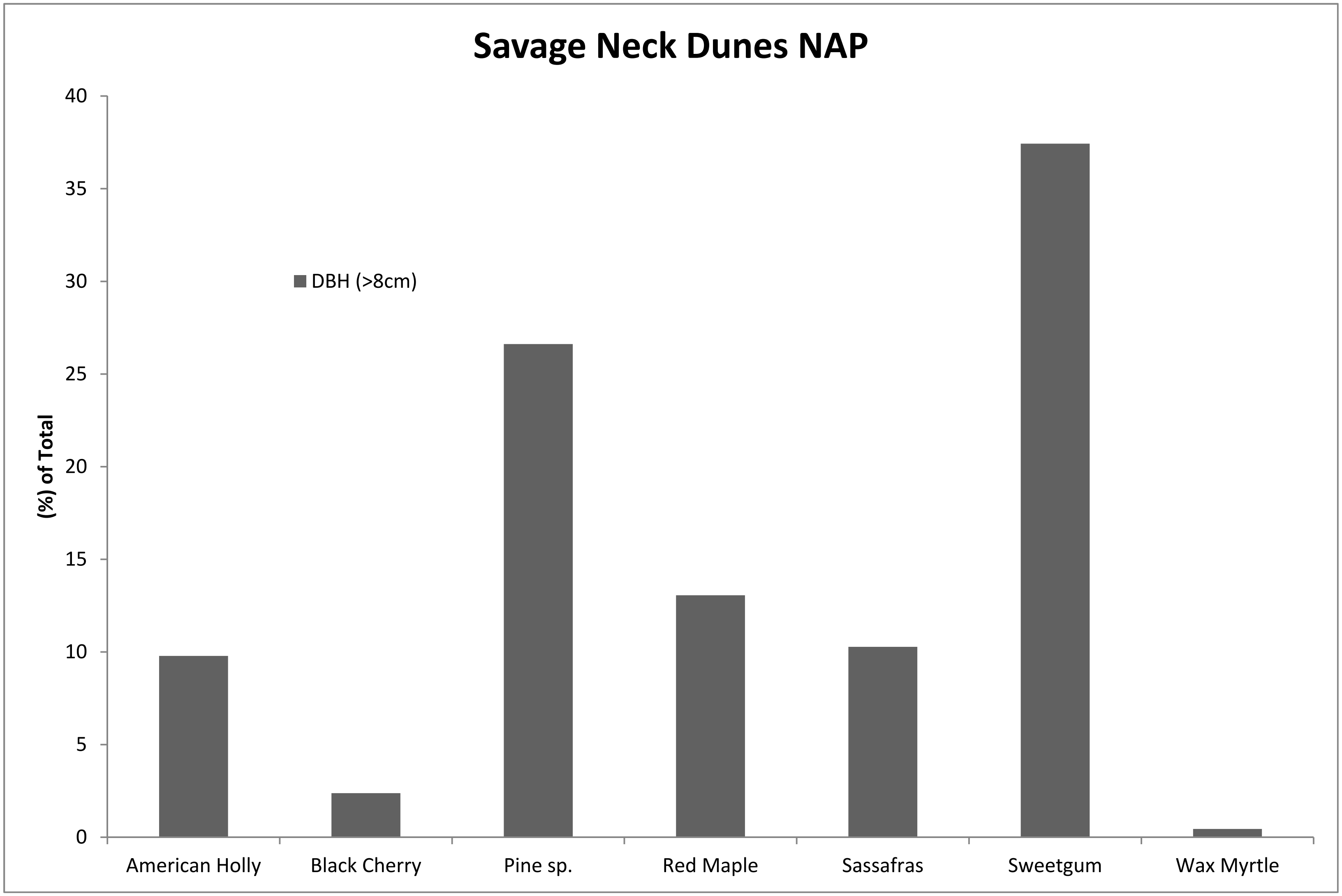


Figure 42: Percentage of trees (DBH > 8cm) at Savage Neck Dunes NAP.

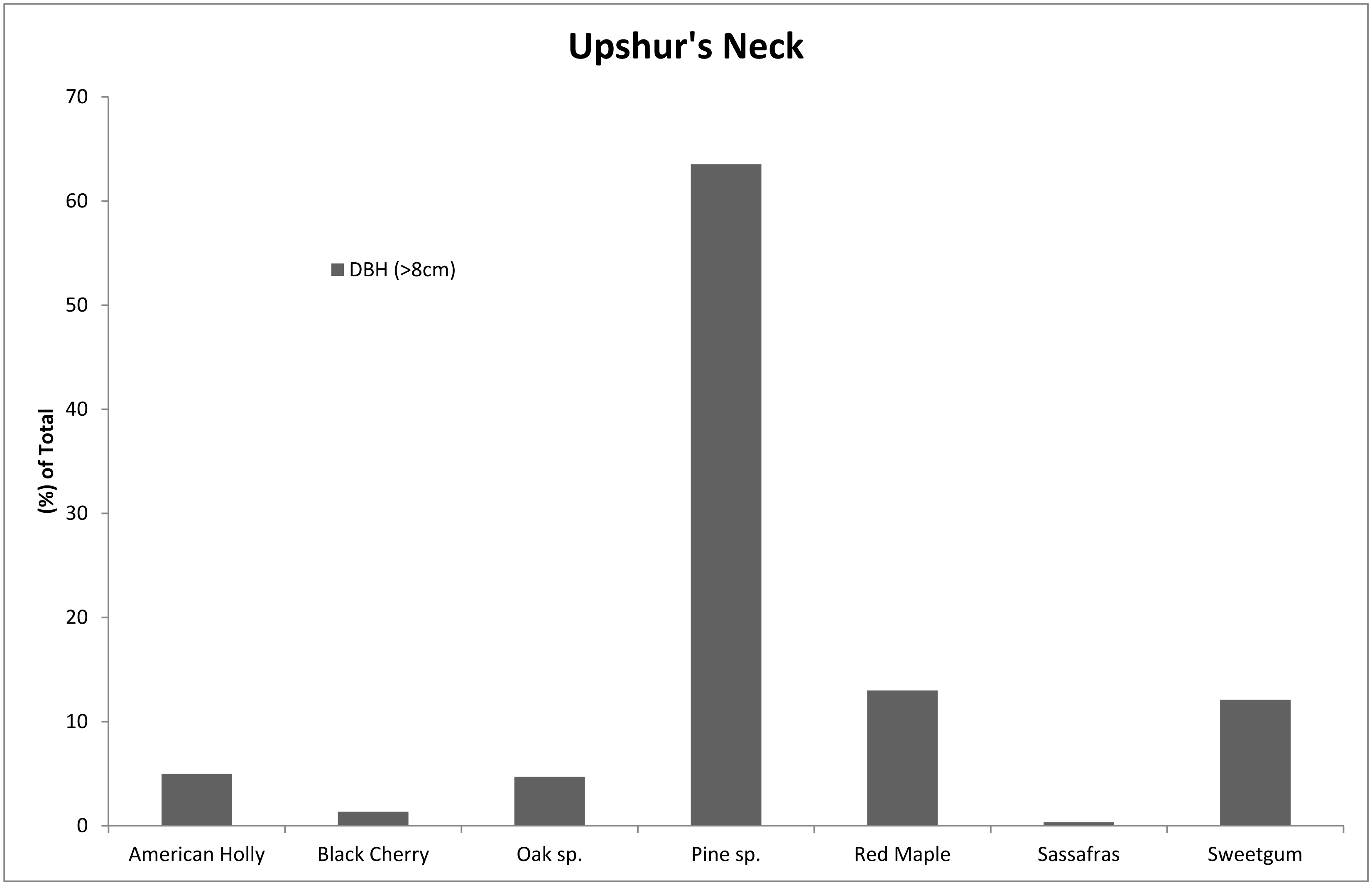


Figure 43: Percentage of trees (DBH > 8cm) at Upshur's Neck.

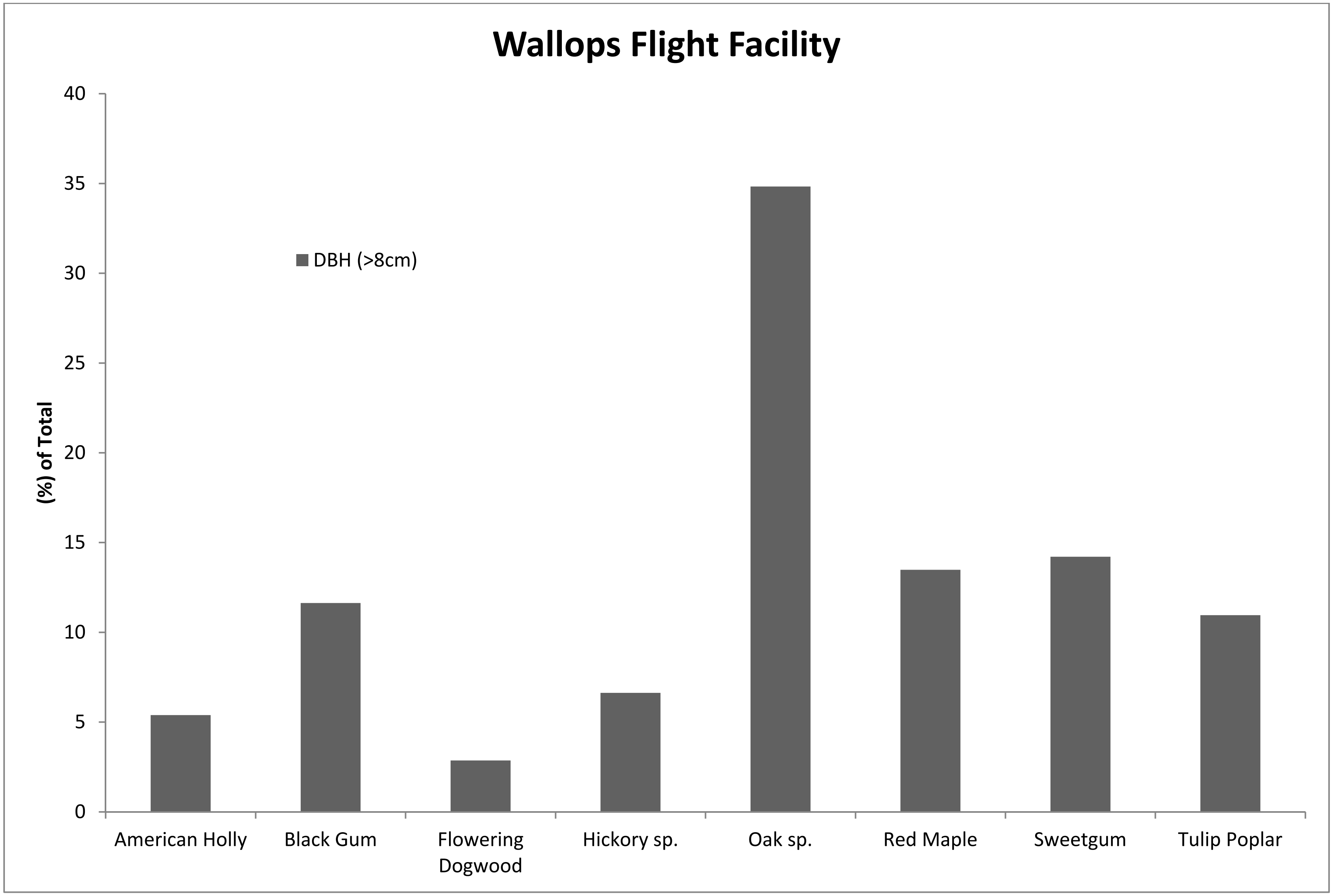


Figure 44: Percentage of trees (DBH > 8cm) at Wallops Island Flight Facility.

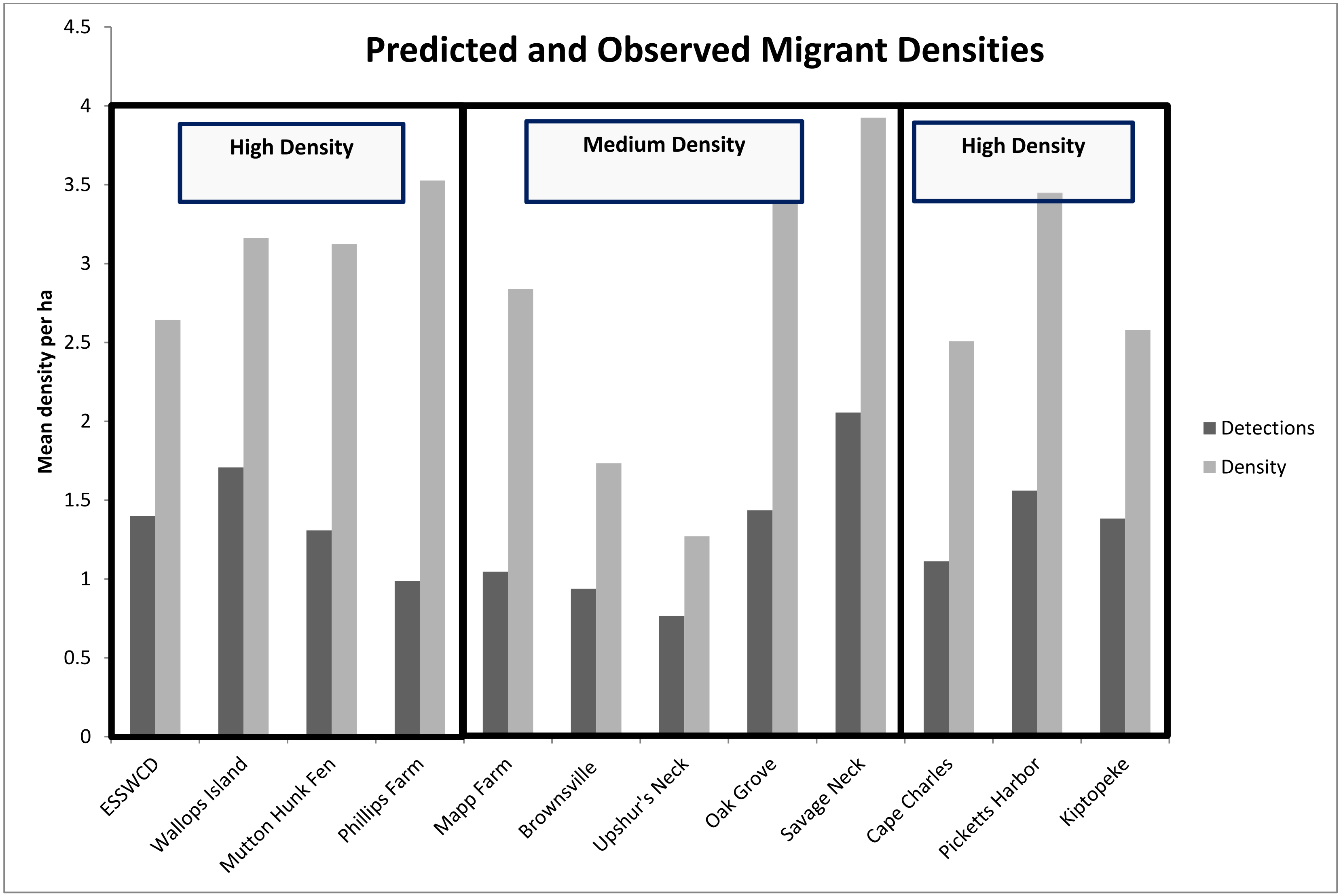


Figure 45: Predicted (grey-shaded boxes) and observed migrant densities for each site.

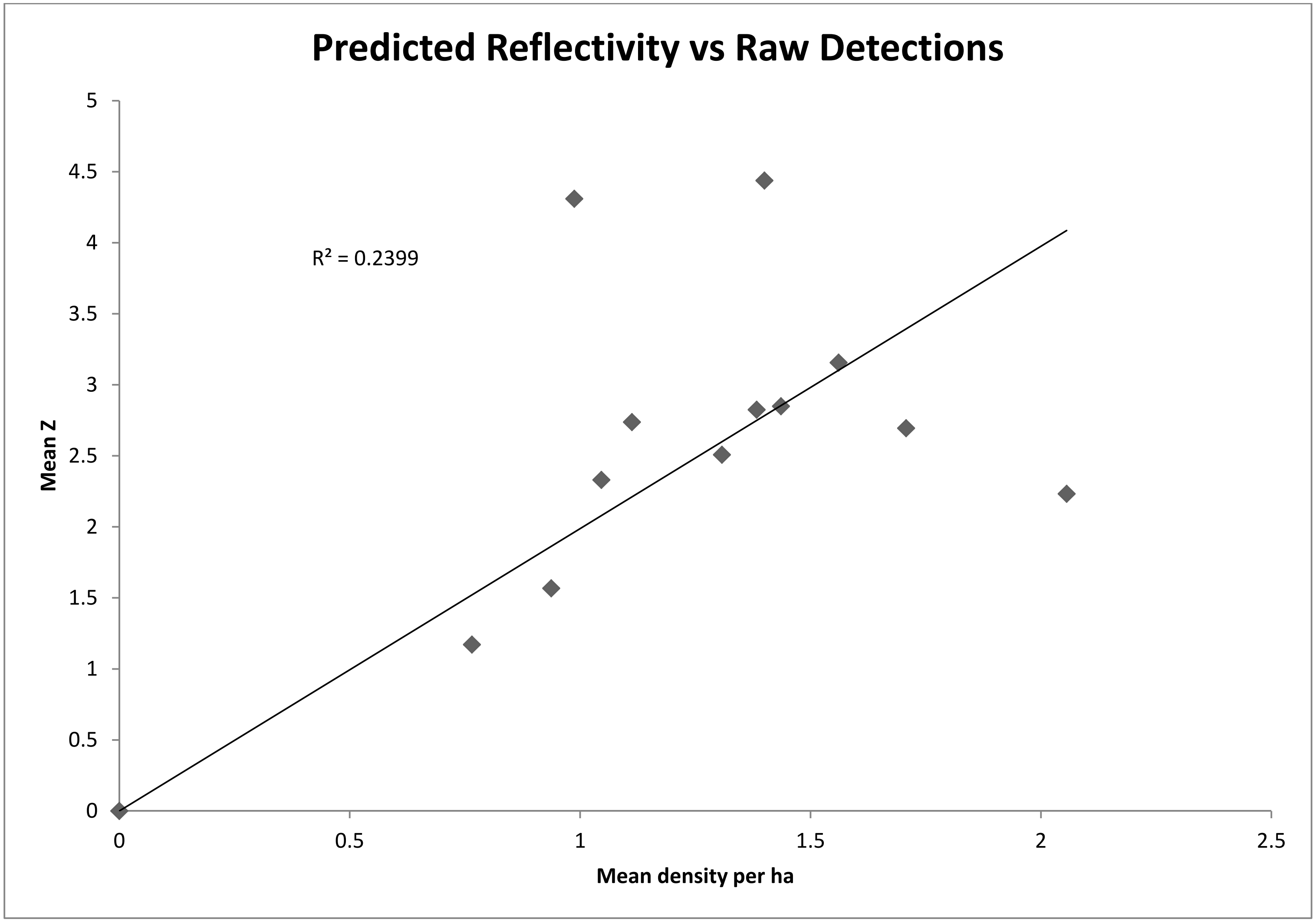


Figure 47: Comparison of unadjusted (raw) migrant density for each site with mean reflectivity value from predictive model shows a weak correlation (R^2 = 0.2399).

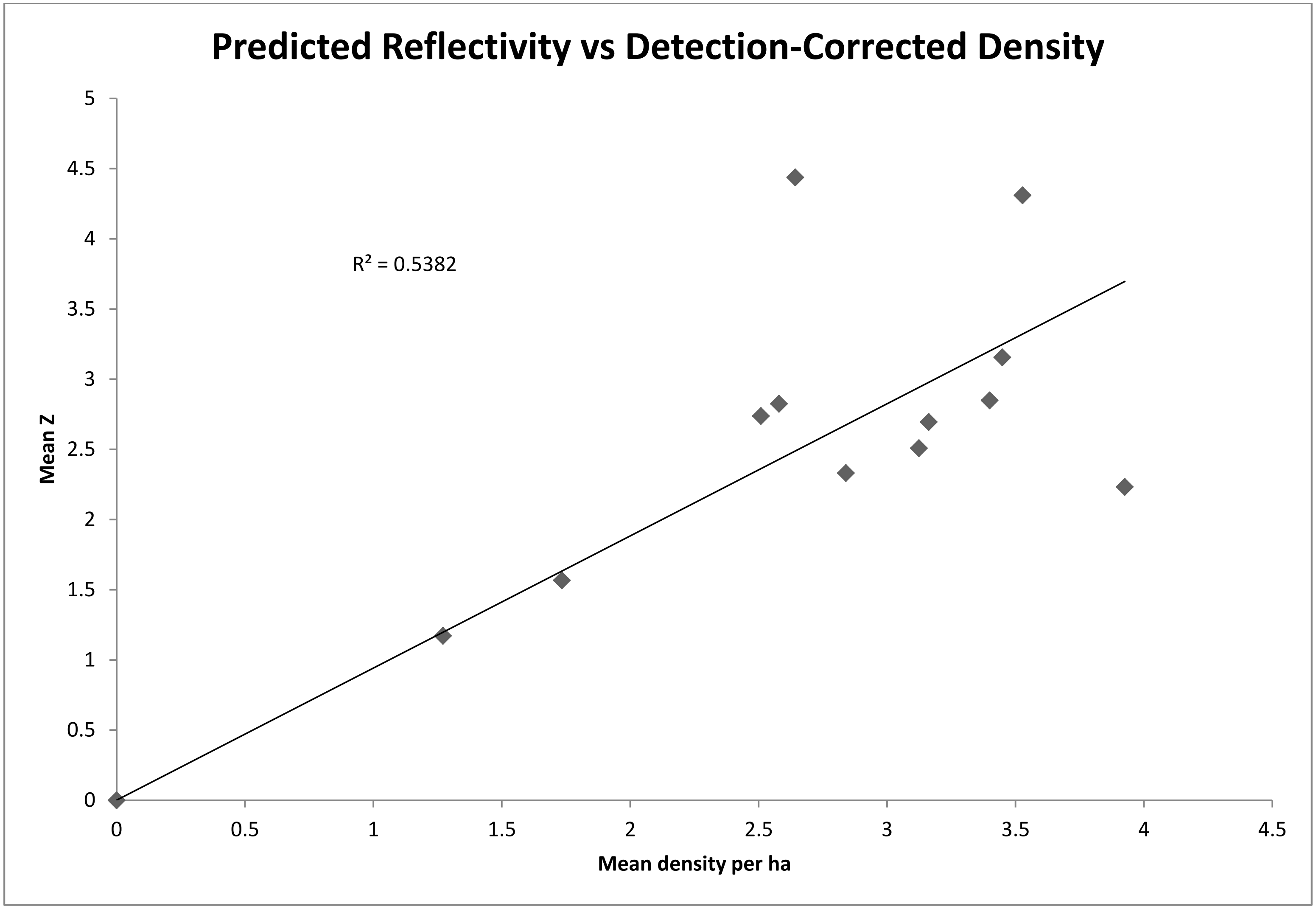


Figure 48: Comparison of detection-corrected migrant density for each site with mean reflectivity value from predictive model shows a much stronger correlation ($R^2 = 0.5382$) than when using unadjusted (raw) detection values.

Appendix B: Bird detections by site

Species Common Name	Brownsville Farm	Cape Charles NAP	Kiptopeke State Park	Mapp Farm	Mutton Hunk Fen NAP	Oak Grove	Phillips Farm	Pickett's Harbor NAP	ESSWCD	Upshur's Neck	Savage Neck Dunes NAP	Wallops Flight Facility	Species Totals
(Eastern) Tufted Titmouse	14	5	43	18	22	46	35	28	29	24	21	28	**313**
Acadian Flycatcher	4				4	1	2	1	23	1	5		**41**
American Crow	50	10	13	29	55	23	37	37	24	25	21	21	**345**
American Goldfinch	17	6	4	5	10	8	3	20	4	6	11	3	**97**
American Kestrel								3					**3**
American Redstart		9	12	2	8	36		15	3	3	8	7	**103**
American Robin	11	15	2	3	1	1	2	4		7	2	20	**68**
Bald Eagle								1		2	1		**4**
Bay-breasted Warbler					1								**1**
Belted Kingfisher		1				4							**5**
Black Vulture			2			1							**3**
Black-and-white Warbler		3	5	1	6	2	1	3			4		**25**
Blackpoll Warbler	2	1	3				6	1			2		**15**
Black-throated Blue Warbler		1	2		2	5		2			5		**17**
Blue Grosbeak	1	1	1	1		1		2			1		**8**
Blue Jay	2	24	43	9	4	29	9	59	8	5	8	14	**214**
Blue-gray Gnatcatcher	1								4			1	**6**
Blue-headed Vireo		1											**1**
Brown Creeper		2		2		1	3	2		2	6		**18**
Brown Thrasher		3				8		5					**16**
Brown-headed Cowbird							2	7					**9**
Brown-headed Nuthatch		2											**2**
Canada Goose	6				17	63		10	4	1		8	**109**
Canada Warbler							1				1		**2**
Carolina Chickadee	22	13	29	15	19	31	41	24	27	10	27	41	**299**
Carolina Wren	30	69	55	51	24	92	43	85	32	30	68	59	**638**
Cedar Waxwing			2		2						4		**8**
Chimney Swift											1		**1**
Chipping Sparrow						1							**1**
Common Grackle	3	3	7	5		30	3	20	1	5	1		**78**
Common Yellowthroat								1					**1**
Cooper's Hawk		1						1					**2**
Double-crested Cormorant											25		**25**
Downy Woodpecker	8	4	6	5	5	15	7	6	12	6	15	14	**103**
Eastern Bluebird		2	1	3	3	4		3		1		7	**24**
Eastern Phoebe	1		1				1						**3**
Eastern Screech-Owl	1			1			1		1	2			**6**
Eastern Towhee	2	1	3	2	1	5	2	9				1	**26**
Eastern Wood-Pewee		1	1			5		5	4	1	3	8	**28**
Fish Crow	1	4		2		1				1		1	**10**

Golden-crowned Kinglet	7	5	8	14	41	6	19	2	20	12	22	24	**180**
Golden-winged Warbler												1	**1**
Gray Catbird	1	9	1	2	1	5		10			5	1	**35**
Great Blue Heron						2		16					**18**
Great Crested Flycatcher		2				2		1		1	2	1	**9**
Great Horned Owl	1		1		1		2				2		**7**
Hairy Woodpecker	4	1	1	2	3	1	1	1		3	5	3	**25**
Hermit Thrush	1	2	3		7		4	3	6	1	1	4	**32**
Herring Gull		3											**3**
Hooded Warbler									1				**1**
House Wren		1											**1**
Indigo Bunting						4		3			2		**9**
Kentucky Warbler						1							**1**
Killdeer		1			1	1							**3**
Laughing Gull		3				2				1			**6**
Least Flycatcher						1					1		**2**
Magnolia Warbler			2					1				1	**4**
Mourning Dove	3	3	4	4	2	8	4	1		1	7		**37**
Northern (Baltimore) Oriole			1		1							1	**3**
Northern (Yellow-shafted) Flicker	13	13	16	9	13	15	5	24	14	7	17	10	**156**
Northern Cardinal	20	65	42	56	18	96	23	55	23	6	56	22	**482**
Northern Mockingbird		1											**1**
Northern Parula		2						1	1		1	7	**12**
Northern Waterthrush			1										**1**
Osprey	1	5											**6**
Ovenbird	1					2		2	2		6	2	**15**
Pileated Woodpecker	10	2	4	5	8	4	4	4	8	6	12	9	**76**
Pine Warbler	14		6	1	4	5	12	3	1	3	6	5	**60**
Purple Martin		2						1			1		**4**
Red-bellied Woodpecker	13	2	25	7	5	29	7	37	9	6	10	20	**170**
Red-eyed Vireo	5	3	10		8	1	7		25	1	3	10	**73**
Red-headed Woodpecker		1	19			6							**26**
Red-shouldered Hawk	1							1					**2**
Red-tailed Hawk	1					2						4	**7**
Red-winged Blackbird			4								3	3	**10**
Rock Dove			7					111					**118**
Rose-breated Grosbeak			1								2		**3**
Ruby-crowned Kinglet		1	4			4	2				3		**14**
Ruby-throated Hummingbird		1	1										**2**
Scarlet Tanager							1			1			**2**
Sharp-shinned Hawk		1		2				2					**5**
Song Sparrow		1		1									**2**
Summer	2	6	4	3	1		1	5	4	1	6	6	**39**

Tanager														
Swainson's Thrush								1					**1**	
Tree Swallow			16			2						2	**20**	
Turkey Vulture	2	1	3		3	2	3	1	3	3	2		**23**	
unidentified Accipiter	1				1			1					**3**	
unidentified Catharus											2		**2**	
unidentified Crow		1											**1**	
unidentified Empidonax								1	1		4		**6**	
unidentified woodpecker (drum)	3	1	3	2	1	4	1	1	5	3	2	1	**27**	
Unknown bird	30	9	21	14	12	17	14	20	13	23	20	9	**202**	
Unknown Blackbird	2			1				1			3	3	**10**	
Unknown Gull		6	3				2			1			**12**	
Unknown hawk			1	1								1	**3**	
Unknown Warbler	5	5	4	1	2	4	4	7	3	4	5	5	**49**	
Veery								2			4		**6**	
Whip-poor-will				1									**1**	
White-breasted Nuthatch				1				1				3	**5**	
White-eyed Vireo			1	1		1	2	4			1		**10**	
White-throated Sparrow		2		7		3		2				2	**16**	
Wild Turkey	2			8			7	1		7	1		**26**	
Winter Wren	1		1	1		1		1			4	4	**13**	
Wood Duck	1							6					**7**	
Wood Thrush									8			1	**9**	
Worm-eating Warbler	1	1	2	1	1		2		1	1	2	1	**13**	
Yellow-bellied Sapsucker					2	3		1			1		**7**	
Yellow-billed Cuckoo			2	1	4	6	2	6	7	3	3	1	**35**	
Yellow-rumped (Myrtle) Warbler	20	17	16	22	18	8	9	19	4	13	48	12	**206**	
Yellow-throated Vireo								1					**1**	
Yellow-throated Warbler			1			1							**2**	
Site Totals	**342**	**361**	**474**	**322**	**342**	**662**	**337**	**715**	**335**	**240**	**515**	**412**		