Urban Ecosystems
https://doi.org/10.1007/s11252-020-01009-y

# Effect of legacy on hydric forest structure in a subtropical urban watershed

John J. Lagrosa IV[1] · Michael G. Andreu[2] · Melissa H. Friedman[3] · Wayne C. Zipperer[4] · Robert J. Northrop[5]



## Abstract

Hydric forest communities within the Tampa Bay Watershed were inventoried to assess the effect of urbanization on these systems. Based on aerial photography and site visits, 85 hydric plots were assigned a legacy class—remnant (forest, pre-1948), emergent (forest, post 1948), and managed (actively managed grass on plot). On each plot, diameter at breast height (dbh) and canopy width and species were recorded for trees ≥2.5 cm dbh. A hierarchical agglomerative cluster analysis identified community types within a legacy class and one-way AOV ($\alpha = .05$) was used to compare structural features within and among legacy classes. Remnant plots (43 plots) were composed of six, natural community types as recognized by the Florida Natural Areas Inventory and no novel communities. Emergent plots (23 plots) were composed of four natural community types and one novel community. Managed plots (19 plots) contained only novel communities. Remnants had the highest species richness (41 species) and only one non-native species. Managed had the lowest species richness (33 species) but highest richness of non-native species (17). Remnant and emergent plots had similar densities for trees ≤32 cm dbh, (803 and 820 stems/ha, respectively), whereas managed plots had only 119 stems/ha. For trees >32 cm dbh, remnant plots had a significantly higher density (196 stems/ha) than emergent (99 stems/ha) and managed (40 stems/ha). These results suggest that legacy did not play a key role in differentiating between emergent and remnant plots but did play a key role in identifying managed plots.

**Keywords** Urban subtropical · Forest legacy · Forest community · Forest structure · Importance value

## Introduction

Forested wetlands play a critical role in urban and urbanizing landscapes by providing a number of ecosystem services such as recreational opportunities, wildlife habitat, biodiversity, flood storage, pollutant and sediment storage and denitrification (Faulkner 2004; Messina and Conner 1998). Forested wetlands are especially vulnerable to urban land-use changes, which alter hydrologic pathways, load nutrients, clear or disturb site conditions, and introduce non-native species. These changes can alter biodiversity by changing species composition and abundance (Baldwin 2011). For instance, Ehrenfeld (2008) examined non-native species composition, soil characteristics, and adjacent land-use of 21 deciduous forested wetlands in northern New Jersey, USA, and observed that distance from urban land-use only partially explained species composition. Overall, non-native species responded individually to human and environmental factors. Even forest wetland size did not play an important role in determining abundance of non-native species in these forested wetlands (Ehrenfeld 2008).

Faulkner's (2004) review of the literature on forested wetlands identified that hydrologic changes from habitat fragmentation led to a reduction in native species and an increase in the abundance of non-native species. He also reported that continued anthropogenic disturbances such as urbanization and agriculture lowered the similarity of a forested wetland to a natural site, primarily because of altered hydrologic processes. Alongside hydrologic changes were corresponding biogeochemical changes. For instance, denitrification rates decreased

✉ Wayne C. Zipperer
wayne.zipperer@usda.gov

1 Center for Urban Environmental Research and Education, University of Maryland Baltimore County, 1000 Hilltop Circle, TRC 102, Baltimore, MD 21250, USA

2 School of Forest Resources & Conservation, University of Florida, Newins-Ziegler Hall, P.O. Box 110410, Gainesville, FL 32611-0410, USA

3 Center for Landscape Conservation and Ecology, University of Florida, P.O. Box 110675, Gainesville, FL 32611-0675, USA

4 Southern Research Station, USDA Forest Service, 2306 Mowry Rd., P.O. Box 110806, Gainesville, FL 32611, USA

5 Hillsborough County Cooperative Extension Service, University of Florida, 5339 County Road 579, Seffner, FL 33584, USA

Published online: 10 June 2020

with increased urbanization but potential remained unchanged regardless of the extent of urbanization (Groffman et al. 2003). Forested wetlands were also sinks for heavy metals because of storm runoff and sedimentation (Faulkner 2004).

Even though urban forested wetlands are highly disturbed, they are generally hotspots for biodiversity because of the occurrence of native and non-native species (Baldwin 2011). For instance, Muratet et al. (2008) report 23 habitat types and abundance of rare native species for wetlands in the Hauts-de-Siene district adjacent to Paris, France. Nonetheless, high biodiversity often results from a high number of non-native species. In forested wetlands in New Jersey, Ehrenfeld (2008) repeatedly observed the following invasive species: *Lonicera tatarica*, *L. japonica*, *Celastrus orbiculatus*, *Rosa multifolia*, and *Microstegium vimineum*.

Another factor that may influence species composition is site legacy. During the 1930s and 40s, many forested wetlands in South were drained and cleared for agricultural purposes. With the cessation of agricultural activities and drainage practices, sites reverted back to forested conditions. Although analyses of forested wetlands after agricultural cessation have not been conducted, an analysis of upland sites showed that a suite of native and non-native species dominated reforested sites forming novel communities (Zipperer 2002).

The majority of work on forested wetlands has been conducted for temperate regions. In this study, we describe species composition and structure of forested wetlands in a sub-basin of the Tampa Bay Watershed, a sub-tropical urbanizing region. Analyses are based on site legacy and management and comparisons are done at the community level to identify nuances in species structure and composition.

## Methods

### Study area

The study was conducted within an 800 km$^2$ boundary determined by a series of sub-basin boundaries adjacent to the city of Tampa, Florida in the southeastern United States. This area was contained within the greater Tampa Bay Watershed (TBW) located in the west-central portion of Florida along the Gulf of Mexico. The TBW spans 16,600 km$^2$ with a drainage basin of 5700 km$^2$ (USGS 2010). It is the largest estuary in the state with approximately 100 tributaries, 4 rivers, and 40 brackish streams. The TBW has a humid subtropical climate with a mean annual temperature of 23.3 °C. Winters are short, dry, and mild with roughly 1–2 freezes per year. Most rain occurs during summer months ranging from late April to October. Mean annual precipitation is 127 cm.

The watershed is home to over 3 million people (FDEP 2011). Population centers include the cities of Tampa, St. Petersburg, and Clearwater. As an important urban center of Florida, the TBW contains productive agricultural lands, phosphate mining, power generation, tourism, recreation, and other industries. These activities have led to significant environmental degradation and land-use change (Xian et al. 2007).

### Sampling procedure

The study area was divided into a grid of 1.77 km$^2$ hexagons with a random sample point selected in each. A total of 500 plots, each 400 m$^2$, were inventoried for a regional analysis. Of these, 85 were identified as hydric, e.g. within 15 m of a hydric feature such as a stream, river, lake, or wetland. On each plot, tree and shrub strata were evaluated. For the tree stratum, species, diameter at breast height (DBH) and canopy cover were collected for all individuals whose diameters were greater than or equal to 2.5 cm. Canopy cover was determined by measuring the width in two directions, north-south and east-west, and then averaged to determine area. For the shrub stratum, percent cover and species were recorded for all woody stems less than 2.5 cm DBH but greater than or equal to 30 cm in height. For this paper, only tree stratum data were used in the analyses.

Patch size and plot location were recorded for each plot. Patch size was also classified into one of three categories– $<$ 1 ha, 1–5 ha, and $>$ 5 ha. Plot location was classified as being within 30 m of the forest edge or $\geq$ 30 m from the edge. Category of patch size and distance from edge were based on (Levenson 1981). Plots within 30 m of the edge were defined as an edge plot, whereas plots $\geq$30 m from the edge were defined as an interior plot. Levenson (1981) and Ranney et al. (1981) showed that 30 m was the relative demarcation for edge and interior species. Finally, each sample plot was assigned a drainage class based on soil survey data for Hillsborough (USDA/NRCS 2006) and Pasco (USDA/NRCS 2007) Counties. Drainage classes were chosen because they are directly related to the frequency and duration of hydroperiods (USDA/NRCS 2009). Classes were the following: excessively drained-1; well-drained-2; moderately well-drained-3; somewhat poorly drained-4; poorly drained-5; very poorly drained-6, water-7 and urban-8.

Species were identified to specific epithet when possible; otherwise down to genera using nomenclature established in the PLANTS Database developed by the Natural Resources Conservation Service, an agency of the United States Department of Agriculture (USDA, NRCS 2014). Each tree species was classified as native or non-native according to the Florida Exotic Pest Plant Council (FLEPPC 2011) and the Atlas of Florida Vascular Plants database (Wunderlin and Hansen 2008). Trees which were only identified to genera were given a nativity of unknown.

## Legacy classification

Plots were classified into three categories: remnant forest, emergent forest and managed (Fig. 1). Anthropogenic disturbance was used to differentiate the forest groups from the managed group. If a plot contained actively mechanically maintained grass it was classified as managed since this activity interferes with natural forest dynamics (Zipperer et al. 1997). Based on the oldest available aerial photographs (1948–1952), a plot was classified as remnant if it was forested in both 1948 and 2007 and emergent if little or no forest cover occurred in 1948 but was forested in 2007. It was possible, however, that a forest patch, classified as remnant, was cleared, converted to another land cover, and then allowed to revert back to a forest during the 60-year interval between 1948 and 2007. The diameter distributions indicated that this land –clearing scenario was unlikely.

## Community type classification

In a previous publication (Friedman et al. 2015), we classified each legacy class using a hierarchical agglomerative cluster analysis, based on species importance values (IV), with a Sorensen distance measure (McCune and Grace 2002). IV was calculated for each species by plot as [(relative density + relative crown cover + relative basal area)/3] (Curtis and McIntosh 1951). Clusters were assigned community types based on native Florida community characteristics according to the Florida Natural Areas Inventory (FNAI 2010). If a community was not characterized by the descriptions provided in FNAI, they were considered novel and labeled according to the species with the highest importance values within that community (Friedman et al. 2015).

## Statistical analyses

Means (± standard error) were calculated for density basal area, canopy cover, DBH and patch size by community type within a legacy class and by species within a community type. In addition, density was divided among five DBH classes: 2.54–16.0, 16.1–32.0, 32.1–48.0, 48.1–64.0, and >= 64.1 cm. Mean density by DBH class was calculated by community type within a legacy class and by species within a community type. Analysis of Variance (AOV) was used to compare mean values of communities within and among legacy classes (remnant, emergent, and managed). The Tukey-Kramer method ($\alpha = .05$) for unequal sample sizes was used to identify differences among means (Lau 2011). The

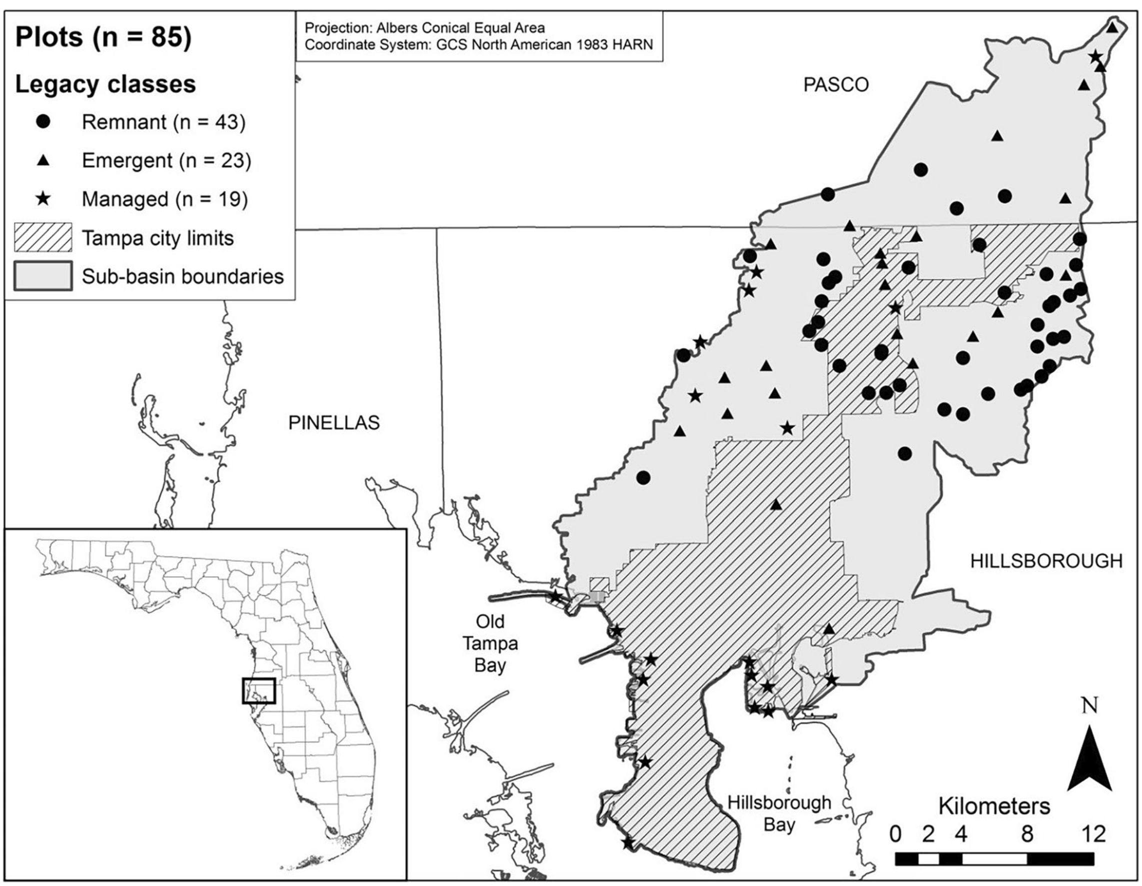


**Fig. 1** Legacy classes of the sample plots in Hillsborough and Pasco Counties, Florida used in this study

Student's t test for samples with unequal variances was used to evaluate differences between legacy classes within the same community type (Welch 1947). A chi-square analysis was used to evaluate categories of patch size and plot location ($\alpha = 0.05$).

## Results

### Legacy structure

Of the 85 sampled plots, 43 were classified as remnant, 23 emergent, and 19 managed. AOV showed that the three legacy classes differed structurally for basal area ($p < 0.01$), crown cover ($p < 0.01$), total density ($p < 0.01$), and all five densities by DBH class (Table 1). Legacy classes did not differ by mean DBH. Remnant differed from emergent plots for basal area ($p < 0.01$) and tree cover ($p = 0.01$) but not total density. Managed plots were different from both remnant and emergent for basal area, crown cover, and total density ($p < 0.01$).

Remnant and emergent plots had similar densities for trees ≤32 cm DBH, (803 and 820 stems/ha, respectively), whereas managed plots had only 119 stems/ha (Fig. 2). For trees >32 cm DBH, remnant plots had a significantly higher density (196 stems/ha) than emergent (99 stems/ha) and managed (40 stems/ha) (Table 1).

Remnant plots occurred primarily on patches in the large size category ($p < 0.001$) and at greater distances from the edge ($p < 0.001$). In contrast, managed plots occurred on patches in the smaller size category and were closer to the edged. Hydrologically, 83% of the remnant plots occurred in drainage class 5 (poorly drained). For emergent plots, plots predominately occurred in drainage classes 4 (somewhat poorly drained) and 5, 52 and 39% respectively. For managed plots, plots predominately occurred in classes 3 (moderately well-drained) (30%), 4 (40%) and 5 (15). Managed had the only plot classified as urban.

### Legacy composition

Remnant had the highest number of species at 41 (35 native, 3 non-native and 3 unknown) followed by emergent (30 native, 3 non-native and 1 unknown) and then managed (15 native, 17 non-native and 1 unknown) (Fig. 3). Although the total number of species for emergent and managed plots differed by only one, 88% of species found on emergent plots were native, compared to only 45.5% on managed.

The top five species in remnant plots by importance value (IV) were *Taxodium distichum*, *Quercus laurifolia*, *T. ascendens*, *Sabal palmetto*, and *Acer rubrum*. *Q. laurifolia* was the most dominant species in emergent plots followed by *T. ascendens*, both of which were among the top species in remnant plots (Table 2, See Appendix Table 7 for

**Table 1** Mean DBH (±standard error), basal area, crown cover, density, DBH claesses, and species richness for trees on hydric plots in Tampa Bay Watershed sub-basins adjacent to the city of Tampa, FL as classified as remnant, emergent and managed (see text)

| | Remnant $n = 43$ | Emergent $n = 23$ | Managed $n = 19$ | F-statistic | $p$ value |
|---|---|---|---|---|---|
| DBH (cm) | 23.3 (1.28) | 21.7 (3.48) | 27.7 (3.92) | 1.15 | 0.32 |
| Basal Area (m$^2$/ha) | 49.1 (3.4) | 27.6$^a$ (5.5) | 7.7$^b$ (2.0) | 25.90 | 0.01 |
| Crown Cover (m$^2$/ha) | 22,965.3 (1876.0) | 14,895.8$^a$ (2225.1) | 3593.2$^b$ (1079.6) | 21.56 | 0.01 |
| Density (stems/ ha) | 998.8 (89.5) | 918.8 (184.8) | 157.9$^a$ (40.5) | 12.27 | 0.01 |
| DBH Class (stems/ha) | | | | | |
| 2.54–16.0 cm | 520.1 (75.4) | 567.2 (141.1) | 90.6$^a$ (32.4) | 5.72 | 0.01 |
| 16.1–32.0 cm | 282.7 (27.3) | 252.7 (55.5) | 27.5$^a$ (10.9) | 12.25 | 0.01 |
| 32.1 - 48.0 cm | 129.3 (14.3) | 65.1 (16.6) | 27.5$^a$ (6.6) | 11.78 | 0.01 |
| 48.1 - 64.0 cm | 36.2 (5.8) | 17.9$^a$ (7.3) | 6.9$^b$ (3.4) | 5.62 | 0.01 |
| > = 64.1 cm | 30.5 (4.9) | 15.7$^a$ (9.1) | 5.5$^b$ (3.2) | 4.06 | 0.02 |
| Mean Patch Size (ha) | 66.5 (6.2) | 24.3 (8.0)$^a$ | 12.7 (6.9)$^b$ | | |
| Number of Species | | | | | |
| Total | 41 | 39 | 36 | | |
| Native | 36 | 34 | 14 | | |
| Non-native | 3 | 4 | 21 | | |
| Invasive | 1 | 4 | 6 | | |
| Unknown | 2 | 1 | 1 | | |

Lower-case letters denote significantly different means

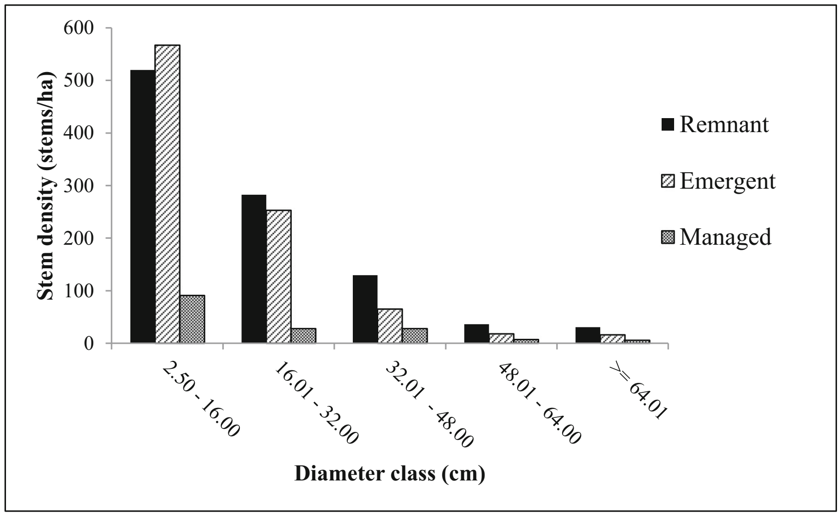


**Fig. 2** Diameter distribution of trees in remnant, emergent and managed plots in Tampa Bay Watershed sub-basins adjacent to the city of Tampa

complete list). The third most dominant species in emergent plots was the category I invasive *Melaleuca quinquenervia* (FLEPPC 2011), the only non-native in the top five for any of the three legacy classes. Managed plots were dominated by four oak species (*Q. virginiana*, *Q. hemisphaerica*, *Q. nigra*, and *Q. laurifolia*) in the top five as well as *Sabal palmetto* ranking third. *Schinus terebinthifolius* (Brazilian pepper), a category I invasive (FLEPPC 2011), ranked seventh on managed plots compared to twenty-fifth on emergent. It did not occur on any of the remnant plots. Of the total number of species across all legacy classes, 17 were unique to remnant plots, 10 unique to emergent plots and 20 unique to managed plots.

Two pine species were found on emergent plots (*Pinus elliottii* [12th in importance] and *P. palustris* [26th]). Only *P. elliottii* (33rd) was found on remnant plots while no pines were found on managed. As mentioned, the other major conifer was cypress, which was highly dominant on both remnant (*T. distichum* [1st], *T. ascendens* [3rd]) and emergent (*T. distichum* [7th], *T. ascendens* [2nd]) plots. Only *T. ascendens* (9th) was found on managed plots.

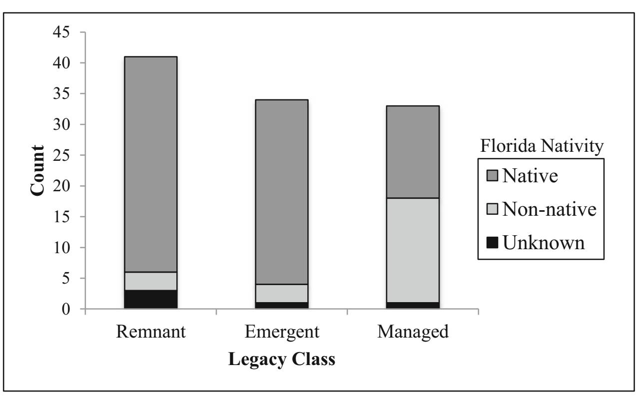


**Fig. 3** Species richness by Florida nativity status for remnant, emergent, and managed plots in Tampa Bay sub-basins adjacent to the city of Tampa

## Cluster analyses

Cluster analyses showed that remnant plots were grouped into six distinct, native community types (FNAI 2010): *T. ascendens* (TAAS) basin swamp, *Nyssa sylvatica* (NYSY) basin swamp, bottomland, hydric hammock, alluvial, and floodplain (Friedman 2011). Emergent plots were grouped into five communities: four of which were native to Florida (FNAI 2010) while one was novel. The four natural

**Table 2** Importance values for dominant species in remnant, emergent, and managed hydric plots in Tampa Bay Watershed sub-basins adjacent to the city of Tampa, FL based on relative density, relative basal area and relative cover. (See text for calculation)

| Species | Remnant | Emergent | Managed |
|---|---|---|---|
| *Acer rubrum* | 7.49 | – | 4.18 |
| *Carpinus caroliniana* | 5.79 | – | – |
| *Fraxinus caroliniana* | 3.50 | – | – |
| *Liquidambar styraciflua* | 6.48 | – | – |
| *Magnolia virginiana* | – | 3.95 | – |
| *Mangifera indica* | – | – | 2.14 |
| *Melaleuca quinquenervia* | – | 11.82 | – |
| *Morella cerifera* | – | 5.55 | – |
| *Nyssa sylvatica* | 6.47 | 4.63 | – |
| *Persea borbonia* | – | 4.25 | 3.51 |
| *Quercus hemisphaerica* | – | – | 13.25 |
| *Quercus laurifolia* | 13.01 | 15.68 | 7.45 |
| *Quercus nigra* | – | 5.59 | 7.54 |
| *Quercus virginiana* | – | 5.53 | 21.15 |
| *Sabal palmetto* | 9.14 | – | 11.01 |
| *Schinus terebinthifolius* | – | – | 3.95 |
| *Taxodium ascendens* | 11.79 | 11.97 | 3.03 |
| *Taxodium distichum* | 13.09 | 5.49 | – |
| *Ulmus americana* | 4.60 | – | – |

communities were TAAS basin swamp, bottomland, hydric hammock, and mesic hammock. The one novel community was labeled *Melaleuca*, due to the prevalence of *M. quinquenervia*. Managed plots consisted of six novel communities, none of which were recognized by FNAI (2010). Communities were labeled according to the dominant species: Oak/Maple, Redbay/Wax myrtle, Sabal/Fig, Live oak/Sabal, Oak/Cypress and Brazilian Pepper (please see Friedman et al. 2014 for detailed community results).

### Community structure by legacy class

AOV of remnant communities showed that TAAS basin swamp differed from floodplain for mean DBH ($p = 0.04$) and NYSY basin swamp differed from alluvial ($p = 0.02$) for mean tree cover. Otherwise remnant communities were not statistically different from one another (Table 3). For DBH classes, the alluvial remnant community differed from hydric hammock for the 16.1–32.0 cm class ($p = 0.04$) and from TAAS basin swamp ($p = 0.04$), bottomland ($p = 0.02$), and hydric hammock ($p = 0.02$) for the > = 64.1 cm class.

For emergent community types, the primary difference was observed in the 48.1–64.0 cm class (Table 4). The novel *Melaleuca* community differed from bottomland ($p = 0.01$), hydric hammock ($p = 0.01$), and mesic hammock ($p = 0.02$). *Melaleuca* also differed from TAAS basin swamp ($p = 0.03$), bottomland ($p = 0.02$), and mesic hammock ($p = 0.03$) for the > = 64.1 DBH class.

The six managed communities were not statistically different for measured variables (Table 5). The highest tree density on a plot across all managed communities was 38 as compared to 100–400 stems per plot for remnant and emergent classes. In addition, plots classified as managed had higher standard errors per mean for all measured variables than those observed for remnant and emergent classes.

Only three community types were shared between remnant and emergent plots *T. ascendens* basin swamp, bottomland, and hydric hammock. Since all managed types were novel, none were shared with the other two legacy classes. Of these, only remnant hydric hammock was significantly different from emergent hydric hammock for DBH ($p < 0.03$), basal area ($p < 0.04$), crown cover ($p < 0.01$), density ($p < 0.01$), densities of smaller tree classes: (2.5–16.0 cm, $p < 0.01$) and densities of mid-size trees (16.1–32.0 cm, $p < 0.01$) (Table 6).

## Discussion

Forest structure showed distinct differences between the three legacy classes. Remnant plots contained a higher number of species, higher stem density, larger trees, and greater basal area than either emergent or managed plots. Although remnant and emergent had similar values for total density (999 and 919 stems/ha respectively), stem density differed by diameter class. Remnant and emergent stands had similar densities for trees <= 32 cm DBH (803 and 820 stems/ha, respectively), but

**Table 3** AOV results for mean DBH (±standard error), mean basal area, mean crown cover, mean density, and species richness for trees in remnant communities on designated hydric plots in Tampa Bay Watershed sub-basins adjacent to the city of Tampa, FL

| | TAAS Basin Swamp<br>$n = 8$ | Bottomland<br>$n = 10$ | Hydric Hammock<br>$n = 8$ | Alluvial<br>$n = 5$ | NYSY Basin Swamp<br>$n = 2$ | Floodplain<br>$n = 10$ | F-statistic | p value |
|---|---|---|---|---|---|---|---|---|
| DBH (cm) | 19.1 (2.21) | 21.9 (2.69) | 18.5 (1.87) | 27.6 (4.54) | 23.0 (6.68) | 29.8 (2.26) | 3.09 | 0.02 |
| Basal Area ($m^2$/ha) | 44.5 (7.6) | 46.4 (6.3) | 44.3 (4.3) | 38.2 (13.4) | 53.7 (2.8) | 63.8 (8.1) | 1.38 | 0.25 |
| Crown Cover ($m^2$/ha) | 19,056.9 (4575.0) | 25,691.9 (3175.8) | 30,717.5 (3802.8) | 12,346.3 (5358.4) | 42,175.6 (3857.6) | 18,630.9 (2779.8) | 3.83 | 0.01 |
| Density (stems/ha) | 1309.7 (241.1) | 1042.8 (205.8) | 1207.7 (208.7) | 558.5 (205.9) | 1223.2 (457.2) | 714.1 (86.4) | 1.95 | 0.11 |
| DBH Class (stems/ha) | | | | | | | | |
| 2.54–16.0 cm | 750.6 (229.0) | 575.8 (188.5) | 691.9 (163.5) | 286.7 (130.9) | 642.5 (395.4) | 234.8 (43.8) | 1.58 | 0.19 |
| 16.1–32.0 cm | 373.8 (76.3) | 274.3 (50.8) | 383.0 (61.8) | 103.8 (25.2) | 321.2 (74.1) | 219.9 (47.2) | 2.60 | 0.04 |
| 32.1–48.0 cm | 169.5 (42.3) | 151.4 (14.4) | 105.9 (31.8) | 105.0 (56.5) | 185.3 (37.1) | 163.1 (29.3) | 0.73 | 0.61 |
| 48.1 - 64.0 cm | 74.1 (28.5) | 60.4 (15.5) | 29.7 (4.9) | 49.4 (0.0) | 37.1 (12.4) | 52.2 (10.5) | 0.79 | 0.57 |
| > = 64.1 cm | 24.7 (0.0) | 28.8 (4.1) | 28.8 (4.1) | 80.3 (21.1) | 74.1 (−) | 61.8 (9.3) | 4.84 | 0.01 |
| Number. of Species | | | | | | | | |
| Total | 24 | 20 | 22 | 9 | 9 | 15 | | |
| Native | 21 | 19 | 20 | 9 | 9 | 15 | | |
| Non-native | 0 | 1 | 2 | 0 | 0 | 0 | | |
| Unknown | 3 | 0 | 0 | 0 | 0 | 0 | | |

**Table 4** AOV results for mean DBH (±standard error), basal area, crown cover, density, and total species richness for trees in emergent communities on designated hydric plots in Tampa Bay Watershed sub-basins adjacent to the city of Tampa, FL

| | TAAS Basin Swamp *n* = 4 | Bottomland *n* = 9 | Hydric Hammock *n* = 2 | Mesic Hammock *n* = 4 | Melaleuca *n* = 4 | F-statistic | p value |
|---|---|---|---|---|---|---|---|
| DBH (cm) | 16.7 (1.92) | 24.4 (8.26) | 29.9 (2.21) | 15.7 (1.81) | 22.6 (4.54) | 0.37 | 0.83 |
| Basal Area ($m^2$/ha) | 34.7 (7.8) | 25.9 (7.5) | 20.5 (5.3) | 20.9 (5.3) | 36.8 (36.7) | 0.25 | 0.91 |
| Crown Cover ($m^2$/ha) | 15,463.9 (4298.4) | 16,204.8 (3967.8) | 10,219.2 (1041.3) | 18,635.4 (5010.6) | 8342.7 (7993.9) | 0.51 | 0.73 |
| Density (stems/ha) | 1618.6 (612.4) | 908.8 (268.7) | 234.8 (37.1) | 753.7 (169.6) | 691.9 (654.9) | 1.06 | 0.40 |
| DBH Class (stems/ha) | | | | | | | |
| 2.54–16.0 cm | 982.3 (516.1) | 685.7 (243.7) | 49.4 (0.0) | 500.4 (143.9) | 481.9 (457.2) | 0.68 | 0.62 |
| 16.1–32.0 cm | 586.9 (182.8) | 216.2 (60.1) | 74.1 (0.0) | 185.3 (49.9) | 197.7 (172.9) | 2.68 | 0.07 |
| 32.1–48.0 cm | 86.5 (37.1) | 148.3 (43.5) | 74.1 (24.7) | 65.9 (8.2) | 172.9 (−) | 0.99 | 0.47 |
| 48.1 - 64.0 cm | - (−) | 30.9 (6.2) | 37.1 (12.4) | 49.4 (−) | 148.3 (−) | 20.00 | < 0.01 |
| > = 64.1 cm | 24.7 (−) | 32.9 (8.2) | - (−) | 24.7 (−) | 197.7 (−) | 38.67 | 0.03 |
| Number of Species | | | | | | | |
| Total | 11 | 21 | 5 | 15 | 3 | | |
| Native | 11 | 20 | 4 | 14 | 0 | | |
| Non-native | 0 | 0 | 1 | 1 | 2 | | |
| Unknown | 0 | 1 | 0 | 0 | 1 | | |

they differed for trees >32 cm DBH (159 and 99 stems/ha, respectively). A different pattern was observed for remnant and emergent patches on upland sites in Syracuse, New York (Zipperer 2002). In Syracuse, remnant and emergent plots had similar densities for large trees and plot basal areas even though emergent plots were 30–40 years younger than remnants plots. The similarity of structure was attributed to faster growing shade-intolerant species on emergent plots, primarily *Acer negundro* and *A. platanoides*. In Tampa, emergent plots had similar species composition as remnant plots for respective community types, which were dominated by slower growing species. Given time and lack of further disturbances, emergent plots are projected to have a structure similar to remnant plots.

Managed plots differed significantly from both remnant and emergent plots for structure and composition. These differences may reflect hydrologic conditions and plot location. Managed plots had more species associated with drained to well-drained conditions. Likewise, managed plots had a higher frequency of sample plots within 30 m of the patch edge. Plots closer to the edge may be drier because of sun light and wind penetration (Matlack 1993).

Compositionally, remnant plots reflected a relatively intact native species structure similar to that predicted by the Florida Native Areas Inventory (FNAI 2010). Overall, the native species importance value (IV) was 98.8% (Appendix Table 7). Surprisingly, emergent plots had similar species compositions for their respective community types as predicted by FNAI (2010). Nevertheless, their non-native species IV was 13.8%, representing a potential increase in the effect of non-native species on stand dynamics as compared to remnant stands.

Managed plots had no FNAI reference compositions for comparison and had the highest non-native species IV of 21.6% (Appendix Table 7). Although managed plots were dominated by native species, the IV value for non-native species may reflect the consequences of both the unintentional spread of invasive species as well the intentional use of non-natives for landscaping purposes. Likewise, many of the species associated with managed plots were facultative-upland and upland species, indicating changes in hydrologic conditions. Another factor contributing to a higher preponderance on facultative upland and upland species on managed sites was our definition of hydric sites—15 m from bodies of water. Topographically, managed sites could have relatively higher elevations; hence, their use in urban development. It is also important to reiterate that this study only looked at stems with DBH >2.5 cm. Many of the invasive species in Florida are smaller shrubs and grasses (FLEPPC 2011) and would likely increase the IV of non-natives across all plots, especially managed.

Although site legacy was not recorded for Atlantic white cedar (*Chamaecyparis thyoides*) wetlands in the New Jersey Pinelands, Ehrenfeld and Schneider (1991) also reported similar patterns of species composition with hydrology alteration and urbanization. Their study examined four sites: control-wetlands isolated from engineered features; near-development sites near to or upstream of unpaved roads; developed sites- sites located within suburban development; and run-off- sites within suburban development and receiving direct storm water outflows. Sewage treatment on developed

**Table 5** AOV results for mean (±standard error), basal area, crown cover, density, and total species richness for trees in managed communities on designated hydric plots in Tampa Bay Watershed sub-basins adjacent to the city of Tampa, FL.

| | Oak/Maple *n* = 4 | Redbay/Wax myrtle *n* = 4 | Sabal/Fig *n* = 4 | Live oak/Sabal *n* = 3 | Oak/Cypress *n* = 2 | Brazilian Pepper *n* = 2 | F-statistic | p value |
|---|---|---|---|---|---|---|---|---|
| DBH (cm) | 27.9 (2.86) | 35.1 (15.59) | 25.9 (5.66) | 33.4 (9.92) | 16.7 (4.29) | 17.4 (6.50) | 0.48 | 0.79 |
| Basal Area ($m^2$/ha) | 15.7 (7.2) | 4.1 (2.6) | 5.8 (2.3) | 8.1 (4.0) | 8.0 (1.9) | 1.1 (0.7) | 1.16 | 0.38 |
| Crown Cover ($m^2$/ha) | 7348.6 (3209.8) | 824.6 (126.9) | 1264.8 (766.4) | 5127.7 (3375.6) | 5575.0 (3672.4) | 828.4 (−) | 1.44 | 0.28 |
| Density (stems/ha) | 222.4 (17.5) | 74.1 (30.3) | 107.1 (50.1) | 65.9 (29.7) | 469.5 (296.5) | 98.8 (74.1) | 3.02 | 0.06 |
| DBH Class (stems/ha) | | | | | | | | |
| 2.54–16.0 cm | 86.5 (31.1) | 98.8 (0.0) | 86.5 (12.4) | 24.7 (0.0) | 345.9 (247.1) | 172.9 (−) | 1.36 | 0.34 |
| 16.1–32.0 cm | 90.6 (8.4) | - (−) | - (−) | 49.4 (−) | 148.3 (−) | 24.7 (−) | 14.67 | 0.06 |
| 32.1–48.0 cm | 41.2 (8.2) | 37.1 (12.4) | 49.4 (24.7) | 24.7 (0.0) | 49.4 (24.7) | - (−) | 0.29 | 0.88 |
| 48.1 - 64.0 cm | 37.1 (12.4) | - (−) | - (−) | 24.7 (0.0) | - (−) | - (−) | 1.00 | 0.42 |
| > = 64.1 cm | 37.1 (12.4) | 24.7 (−) | - (−) | - (−) | - (−) | - (−) | 0.33 | 0.67 |
| Number of Species | | | | | | | | |
| Total | 18 | 6 | 7 | 4 | 8 | 2 | | |
| Native | 8 | 5 | 1 | 2 | 7 | 1 | | |
| Non-native | 9 | 1 | 6 | 2 | 1 | 1 | | |
| Unknown | 1 | 0 | 0 | 0 | 0 | 0 | | |

sites came from septic tanks. Across this gradient of development and nutrient loading, tree species richness did not vary significantly; however, structurally, the controlled and near-development sites had a significantly higher density of stems (≥ 25.0 cm DBH) than more suburban sites. Likewise, they observed that non-native species increased with suburbanization effects; a condition similar to what we observed on our managed sites. However, when they included saplings, shrubs, and herbaceous species, species richness increased with increased suburbanization. This pattern was also observed in other wetlands studies (see Baldwin 2011).

## Conclusion

Maintaining wet soils appear to be a driving force in the successional development of a site. Findings suggest that forest wetlands, previously cleared for agricultural use and then abandoned from agricultural usage, reverted back to assemblages similar to native forest wetland communities if their drainage classes remained wet (i.e.; poorly drained and very poorly drained). Sites with drier drainage classes (i.e.; somewhat poorly-drained, moderately well-drained and well-drained) developed new,

**Table 6** T-test results comparing community types present on both remnant and emergent on designated hydric plots in Tampa Bay Watershed sub-basins adjacent to the city of Tampa, FL

| | TAAS Basin Swamp t-statistic | p value | Bottomland t-statistic | p value | Hydric Hammock t-statistic | p value |
|---|---|---|---|---|---|---|
| DBH (cm) | −0.83 | 0.43 | 0.29 | 0.78 | 3.95 | 0.03 |
| Basal Area ($m^2$/ha) | −0.89 | 0.39 | −2.10 | 0.05 | −3.49 | 0.04 |
| Crown Cover ($m^2$/ha) | −0.57 | 0.58 | −1.87 | 0.08 | −5.20 | 0.00 |
| Total Density (stems/ha) | 0.47 | 0.66 | −0.39 | 0.70 | −4.59 | 0.00 |
| DBH Class (stems/ha) | | | | | | |
| 2.54–16.0 cm | 0.41 | 0.70 | 0.36 | 0.73 | −3.93 | < 0.01 |
| 16.1–32.0 cm | 1.08 | 0.34 | −0.74 | 0.47 | −5.00 | < 0.01 |
| 32.1–48.0 cm | −1.48 | 0.21 | −0.07 | 0.95 | −0.79 | 0.47 |
| 48.1 - 64.0 cm | – | – | −1.77 | 0.11 | 0.56 | 0.66 |
| > = 64.1 cm | – | – | 0.45 | 0.68 | – | – |

novel assemblages consisting of native and non-native species. Likewise, remnant and emergent legacy classes were similar compositionally and structurally with the except of the largest diameter class. Even though emergent forest patches had more non-native species, their importance to community structure and composition was minimal. Native species dominanted community assemblages in both remnant and emergent legacy classes.

## Appendix 1

**Table 7** Importance values (IV), from largest to smallest, for species in remnant, emergent, and managed hydric plots in Tampa Bay Watershed subbasins adjacent to the city of Tampa, FL

| | Remnant | | Emergent | | Managed | |
|---|---|---|---|---|---|---|
| Rank | Species | IV | Species | IV | Species | IV |
| 1. | *Taxodium distichum* | 13.09 | *Quercus laurifolia* | 15.68 | *Quercus virginiana* | 21.15 |
| 2. | *Quercus laurifolia* | 13.01 | *Taxodium ascendens* | 11.97 | *Quercus hemisphaerica* | 13.25 |
| 3. | *Taxodium ascendens* | 11.79 | *Melaleuca quinquenervia* | 11.82 | *Sabal palmetto* | 11.01 |
| 4. | *Sabal palmetto* | 9.14 | *Quercus nigra* | 5.59 | *Quercus nigra* | 7.54 |
| 5. | *Acer rubrum* | 7.49 | *Morella cerifera* | 5.55 | *Quercus laurifolia* | 7.45 |
| 6. | *Liquidambar styraciflua* | 6.48 | *Quercus virginiana* | 5.53 | *Acer rubrum* | 4.18 |
| 7. | *Nyssa sylvatica* | 6.47 | *Taxodium distichum* | 5.49 | *Schinus terebinthifolius* | 3.95 |
| 8. | *Carpinus caroliniana* | 5.79 | *Nyssa sylvatica* | 4.63 | *Persea borbonia* | 3.51 |
| 9. | *Ulmus americana* | 4.60 | *Persea borbonia* | 4.25 | *Taxodium ascendens* | 3.03 |
| 10 | *Fraxinus caroliniana* | 3.50 | *Magnolia virginiana* | 3.95 | *Mangifera indica* | 2.14 |
| 11. | *Quercus nigra* | 2.52 | *Ilex cassine* | 3.54 | *Morella cerifera* | 2.02 |
| 12. | *Carya glabra* | 2.32 | *Pinus elliottii* | 3.20 | *Citrus sinensis* | 1.87 |
| 13. | *Quercus virginiana* | 1.71 | *Sabal palmetto* | 3.01 | *Salix caroliniana* | 1.56 |
| 14. | *Ilex cassine* | 1.67 | *Quercus hemisphaerica* | 2.55 | *Persea* sp. | 1.55 |
| 15. | *Quercus hemisphaerica* | 1.54 | *Liquidambar styraciflua* | 2.13 | *Ilex cassine* | 1.52 |
| 16. | *Magnolia virginiana* | 1.53 | *Salix* sp. | 1.50 | *Washingtonia robusta* | 1.42 |
| 17. | *Celtis laevigata* | 1.05 | *Acer rubrum* | 1.40 | *Roystonea elata* | 1.33 |
| 18. | *Morella cerifera* | 0.99 | *Ulmus americana* | 1.38 | *Musa* sp. | 1.28 |
| 19. | *Peltophorum pterocarpum* | 0.81 | *Nyssa sylvatica var. biflora* | 1.27 | *Leucaena leucocephala* | 1.23 |
| 20. | *Persea borbonia* | 0.75 | *Quercus geminata* | 1.15 | *Syagrus romanzoffiana* | 1.12 |
| 21. | *Carya aquatica* | 0.47 | *Vaccinium corymbosum* | 0.89 | *Ligustrum japonicum* | 1.07 |
| 22. | *Persea palustris* | 0.43 | *Persea palustris* | 0.74 | *Ficus lyrata* | 0.99 |
| 23. | *Cephalanthus occidentalis* | 0.42 | *Vaccinium arboreum* | 0.61 | *Ulmus americana* | 0.84 |
| 24. | *Salix caroliniana* | 0.40 | *Lyonia lucida* | 0.52 | *Citrus x paradisi* | 0.69 |
| 25. | *Gleditsia aquatica* | 0.36 | *Schinus terebinthifolius* | 0.32 | *Carica papaya* | 0.67 |
| 26. | *Viburnum obovatum* | 0.30 | *Pinus palustris* | 0.26 | *Adonidia merrillii* | 0.66 |
| 27. | *Prunus caroliniana* | 0.30 | *Salix caroliniana* | 0.23 | *Melia azedarach* | 0.57 |
| 28. | *Morus rubra* | 0.23 | *Fraxinus caroliniana* | 0.21 | *Eriobotrya japonica* | 0.55 |
| 29. | *Citrus aurantium* | 0.12 | *Cinnamomum camphora* | 0.19 | *Wodyetia bifurcata* | 0.44 |
| 30. | *Salix* sp. | 0.11 | *Viburnum obovatum* | 0.14 | *Podocarpus macrophyllus* | 0.39 |
| 31. | *Crataegus marshallii* | 0.11 | *Prunus caroliniana* | 0.12 | *Baccharis halimifolia* | 0.36 |
| 32. | *Fagus grandifolia* | 0.11 | *Crataegus marshallii* | 0.07 | *Ficus elastica* | 0.34 |
| 33. | *Pinus elliottii* | 0.10 | *Diospyros virginiana* | 0.05 | *Psidium cattleianum* | 0.33 |
| 34. | *Magnolia grandiflora* | 0.07 | *Ilex vomitoria* | 0.05 | | |
| 35. | *Ilex* sp. | 0.06 | | | | |
| 36. | *Morus alba* | 0.05 | | | | |
| 37. | *Quercus* sp. | 0.04 | | | | |

**Table 7** (continued)

| | Remnant | | Emergent | Managed |
|---|---|---|---|---|
| 38. | *Callicarpa americana* | 0.03 | | |
| 39. | *Cornus florida* | 0.03 | | |
| 40. | *Gleditsia triacanthos* | 0.02 | | |
| 41. | *Lyonia lucida* | 0.02 | | |
| | Native species | 98.81 | 86.17 | 79.42 |
| | Non-native | 0.98 | 12.33 | 19.03 |
| | Unknown | 0.21 | 1.50 | 1.55 |

## References


Baldwin AH (2011) Plant communities of urban wetlands: patterns and controlling processes. In: Niemelä J (ed) Urban ecology and: patterns, processes, and applications. Oxford University Press, New York, pp 77–84

Curtis JT, McIntosh RP (1951) An upland forest continuum in the prairie-forest border region of Wisconsin. Ecology 72:476–496

Ehrenfeld JG (2008) Exotic invasive species in urban wetlands: environmental correlates and immplications for wetland management. J Appl Ecol 45:1160–1169

Ehrenfeld JG, Schneider JP (1991) *Chamaecyparis thyoides* wetlands and suburbanization: effects on hydrology, water quality and plant community composition. J Appl Ecol 28:467–490

Faulkner S (2004) Urbanization impacts on the structure and function of forested wetlands. Urban Ecosyst 7(2):89–106

FDEP (2011) Learn about your watershed: Tampa Bay Watershed Florida Department of Environmental Protection. http://www.protectingourwater.org/watersheds/map/tampa_bay/. Accessed June 1 2012

FLEPPC (2011) List of invasive plant species. Florida Exotic Pest Plant Council. http://www.fleppc.org/list/11list.htm. Accessed June 5 2012

FNAI (2010) Guide to the natural communities of Florida: 2010 edition. Florida natural areas inventory, Tallahassee, FL

Friedman MH (2011) Characterizating natural vegetative communities near freshwater hydrological features in an urbanizing watershed of west Central Florida. University of Florida, Gainesville

Friedman MH, Andreu MG, Zipperer WC, Northrop RJ, Abd-Elrahman A (2015) Species composition of forested natural communities near freshwater hydrological features in an urbanizing watershed of west Central Florida. Florida Sci 78(3):111–129

Groffman PM, Bains JB, Band LE, Belt KT, Brush GS, Grove JM, Pouyat RV, Yesilonis IC, Zipperer WC (2003) Down by the riverside: urban riparian ecology. Front Ecol Environ 1:315–321

Lau MK (2011) Dunnett-Tukey-Kramer pairwise multiple comparison test adjusted for unequal variances and unequal sample sizes. R package Version 3.1. http://CRAN.R-project.org/package=DTK. Accessed June 5 2012

Levenson JB (1981) Woodlots as biogeographic islands in southeastern Wisconsin. In: Burgess RL, Sharpe DM (eds) Forest island dynamics in man-dominated landscapes. Springer-Verlag, New York, pp 13–40

Matlack GR (1993) Microenvironment variation within and among forest edge sites in the eastern United States. Biol Conserv 66:185–194

McCune B, Grace JB (2002) Analysis of Ecological Communities. mjm Software Design, Gleneden Beach, OR

Messina MG, Conner WH (1998) Southern forested wetlands: ecology and management. CRC Press, Boca Raton

Muratet A, Porcher E, Devictor V, Arnal G, Moret J, Wright S, Machon N (2008) Evaluation of floristic diversity in urban as a basis for habitat management. Appl Vege Manag 11:451–460

Ranney JW, Bruner MC, Levenson JB (1981) The importance of edge in the structure and dynamics of forest islands. In: Burgess RL, Sharpe DM (eds) Forest Island dynamics in man-dominated landscapes. Springer-Verlag, New York, pp 67–96

USGS (2010) Boundary descriptions and names of regions, subregions, accounting units, and cataloging units. United States Geological Survey. http://water.usgs.gov/GIS/huc_name.html. Accessed June 1 2012

Welch BL (1947) The generalization of 'Student's' problem when several different population variances are involved. Biometrika 34:28–35

Wunderlin RP, Hansen BF (2008) Atlas of Florida's vascular plants. Institute for Systematic Botany, University of Florida. http://www.plantatlas.usf.edu. Accessed May 28 2012

Xian G, Crane M, Su J (2007) An analysis of urban development and its environmental impact on the Tampa Bay watershed. J Environ Manag 85:965–976

Zipperer WC (2002) Species composition and structure of regenerated and remnant forest patches within an urban landscape. Urban Ecosyst 6:271–290

Zipperer WC, Foresman TW, Sisinni SM, Pouyat RV (1997) Urban tree cover: an ecological perspective. Urban Ecosyst 1:229–246