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Vegetation of Coastal Wetlands in Biscayne National Park: Blocks 6-8 (L-31E Wetland and Flow Monitoring)

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L-31E Wetland and Flow Monitoring

(SFWMD Contract C-12409)

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Introduction:

Beginning in the 1920's, coastal drainage efforts for mosquito control, land reclamation, and storm surge protection combined to compartmentalize the coastal wetlands of Biscayne National Park (**Figure 1**). Culminating in the construction of the L-31E levee in the mid-1960's, these projects: 1) isolated the coastal wetlands hydrologically from the interior freshwater watersheds that once flowed freely by sheet flow into Biscayne Bay; 2) altered the seasonal variability of surface water salinities throughout the coastal wetland gradient; and 3) decreased the volume and altered the kinetics of freshwater runoff into the bay via creeks and tributaries. In conjunction with a steady rise in sea level over the twentieth century, these activities elicited large-scale changes in vegetation composition and structure.

Since 1993, however, efforts to develop the technical and ecological expertise necessary to minimize the effects of compartmentalization and restore coastal ecosystems in southern Biscayne Bay have been ongoing. The restoration tool in this case is the redistribution of fresh water from the C-103/102 canal systems into the coastal wetlands within and adjacent to Biscayne National Park. Besides improving the health of the coastal wetlands, other potential benefits include minimizing point source discharges of canal water into Biscayne Bay, and restoration of more natural estuarine conditions in a narrow zone along the coastline. Directed by Florida International University's Southeast Environmental Research Center, the research has gone through several stages. The L-31E Freshwater Rediversion Pilot Project developed the protocols for conducting and assessing the effects of delivery in an experimental setting north of Canal C-103 (Mowry Canal) from 1993-2000. Beginning in 1997, controlled monthly releases of up to 200,000 m^3 were passed from the canal system to a single coastal watershed, and the biological and hydrologic effects were monitored in a Treatment and Control basin. For 2001-2002, monitoring activities in the Pilot Project site were reduced to a maintenance level, and baseline inventory for a second potential delivery site north of the Military Canal was initiated. In this report, we describe the vegetation patterns within and adjacent to that site.

The area described in this report comprises the first three blocks north of the Military Canal (**Figure 1**). These are Blocks 6-8 in a 13-block complex extending east of the L-31E Levee and from the Mowry Canal to the Princeton Canal. The latter two canals are 2.1 & 3.3 km south and north of the Military canal, respectively. While it is anticipated that the diversion treatment will direct water through the central unit (Block 7), data from the adjacent areas were also obtained in order to provide a baseline for potential off-site effects. The vegetation information included in this Report will be supplemented by ongoing studies of the salinity and hydrologic patterns in the area by Dr. Jack Meeder.

Methods:

Vegetation sampling. Vegetation was sampled in 98 plots distributed along 13 transects (Figure 1). Transect position and the locations of sample plots were pre-determined in the office on the basis of aerial photographs. Coastal transects in each Block included between four and six plots apiece. These three transects followed the shoreline at about 50 meters distance inland, and plot locations were distributed evenly. The ten interior transects ran N-S from one end of a

Block to the other, with sample plots established at intervals of 50 meters. Interior transect locations were chosen to provide adequate representation of broad vegetation zones, as determined by the preliminary photo-interpretation.

A nested design was used to describe vegetation within a 10 x 10 meter plot at each sampling point. The sampling procedure was as follows:

1. Upon reaching each point, a 10-meter N-S transect was established.

2. For trees (stems >2 meters height), we recorded the species and diameter class (5-cm DBH ranges) of all live and dead individuals within one meter of the line (stems <10 cm DBH), two meters of the line (stems 10-25 cm DBH), and five meters of the line (>25 cm DBH). We recorded the species and diameter class of all dead fallen stems (> 5 cm DBH) whose trunk intersected the line. We estimated live cover by species in a 4- meter-wide band enclosing the center line, using the following cover classes: 1, 0-1%; 2, 1-4%; 3, 4-16%; 4, 16-33%; 5, 33-66%; and 6, >66%. Finally, we recorded the upper and lower height of each species that intercepted or was within 1 meter of a vertical height pole positioned at three locations along the centerline, i.e., 0, 5, and 10 meters from the origin.

3. For shrubs (woody stems between 60 cm and 2 meters in height), we recorded the density of all stems in five 1-m2 plots established at five locations along the center line, i.e., west of the line, at 0, 2, 4, 6, and 8 meters from the origin. Stems were counted by species in two size categories: small shrubs (60-100 cm tall) and large shrubs (1-2 m tall).

4. For seedlings (woody stems 0-60 cm in height), we recorded the density of all stems in a 3 x 3 dm subplot in the southeast corner of the 1 m^2 plot described above. Stems were counted by species in two size categories: small seedlings (0-30 cm tall) and large seedlings (30-60 cm tall).

5. For all plants < 2 meters height (herbs, seedlings, shrubs), we estimated cover in the 1 m2 plots described above, using the same cover classes as described above for tree cover.

Vegetation mapping. Mapping products presented in this document were created by integrating black & white and color-infrared aerial photography with field data processed through the model-building module in Arcview GIS 3.2. The aerial photographs allowed the demarcation of block boundaries and vegetation units, including some that weren't sampled directly (i.e., Casuarina Forest and Tree Island). The field data also allowed us to create a contour map that represented average maximum tree height throughout the study area (**Figure 2**). In conjunction with the vegetation data collected at each point and our field observations, the canopy heights incorporated in Figure 2 helped to define the forest communities, and to determine their distribution in the study area (**Figure 3**).

Importance Values (IV) & Cover Estimates. The distributions of the mangrove species *Avicennia germinans, Conocarpus erectus, Laguncularia racemosa,* and *Rhizophora mangle* within the study area were examined by calculating an understory and overstory Importance Value (IV) for each species at each sampling point. IV's are indices derived from relativized scores for each species at each sampling point, i.e., Relative Abundance (RA), Relative Density (RD), and (for understory individuals only) Relative Frequency (RF). As relativized scores, RA, RD, and RF are each calculated as (100*(Species Value/Total for all woody species)). We calculated Understory IV as ((Relative Abundance + Relative Density + Relative Frequency)/3). Relative Abundance was based on mean cover, Relative Density was based on total density/ha across all four understory height classes, and Relative Frequency was based on the number of 1 m^2 quadrats in which each species was present. Tree IV was calculated as ((Relative Abundance + Relative Density)/2). For trees, Relative Abundance was based on basal area instead of cover, while Relative Density was again based on density of all stems, regardless of size.

Point estimates of species IV, as well as herb, shrub, and total understory and overstory cover, were subsequently processed through the model-building module in Arcview to create the maps shown in Figures 4-6.

Results

Canopy Height. Forest canopy height was inversely related to distance from coast and was highest in the SE corner of Block 6, where the height of the tallest trees reached 14 meters at several sampling locations (**Table 1, Figure 2**). The trend of decreasing height with coastal distance held true throughout the study site, except for a section of coastal forest in Block 7. The canopy in this section of forest, defined by a network of tidal creeks and tributaries, ranged from 4 to 8 meters in height, which was considerably lower than along adjacent coastlines. In conjunction with the higher total understory cover in the area (Figure 4), the low canopy is in keeping with the observation of Meeder *et al.* (2000) that this section of coastline is relatively young and presently building up. Meeder *et al.* (2000) attribute this to the infilling of the creeks and coastal basins by mangroves following the construction of the L-31E levee.

Table 1: Mean (± 1 S.E.) differences between the mangrove forests of Biscayne National Park (Blocks 6-8).

Forest Attribute	Dwarf Mangrove Forest (n=21)	Transitional Mangrove Forest (n=24)	Interior Mangrove Forest (n=39)	Coastal Mangrove Forest (n=14)
Mean Distance From Coast (m)	600	480	290	70
Total Area (ha)	12	21	35	20
Max. Canopy Height (m)	1.1 ± 0.1	3.6 ± 0.2	6.6 ± 0.2	9.8 ± 0.7
Shrub Density (stems x 10^4/ha)[a]	830 ± 82	302 ± 43	124 ± 18	41 ± 17
Tree Density (stems x 10^4/ha)[b]	0.8 ± 0.7	19 ± 2	16 ± 2	14 ± 3
Tree Basal Area (m^2/ha)[b]	0.6 ± 0.5	15.8 ± 2.1	19.3 ± 1.3	24.6 ± 3.0
Mean Understory Cover (%)[c]	56.7 ± 4.2	46.6 ± 5.3	16.4 ± 2.5	7.3 ± 5.4
Mean Overstory Cover (%)[d]	0.5 ± 0.5	61.4 ± 5.9	87.3 ± 3.2	119.0 ± 7.4

a – stems < 2 m height; b – stems ≥ 2 m height; c – vegetative cover < 2 m in height; d – total vegetative cover ≥ 2 m in height

Forest types. The vegetation map of the study area is presented in Figure 3. Based on our data and observations, six forest types were distinguished: Dwarf Mangrove Forest; Transitional Mangrove Forest; Interior Mangrove Forest; Coastal Mangrove Forest; Tree Island; and Casuarina Forest. A detailed definition of each forest type is included in Table 2. Two of these types, Tree Island and Casuarina Forest, were not sampled. Tree Islands were of limited distribution in Blocks 6-8, and thus were missed by our regular sampling matrix. We did not sample Casuarina Forest because it was largely restricted to an abandoned levee road bisecting Blocks 6 and 7 (**Figures 1** & **3**).

Extent. Within the study area, coverage of Interior Mangrove Forest was highest (~35 ha, 39%) and coverage of Dwarf Mangrove Forest was lowest (~12 ha, 14%) among the four main forest types (Table 1). The Transitional and Coastal Mangrove Forests together accounted for about 41 ha (20 and 21 ha, respectively), or almost half (46%) of the total forested area. The Tree Islands and the Casuarina Forest combined accounted for just 1 percent of the total forested area in the Biscayne National Park study area.

Table 2: Description of forest types found in Biscayne National Park (Blocks 6-8).

Forest Type	Forest Description
Dwarf Mangrove Forest	Forest dominated by trees generally < 2 meters in stature. Dominant species *Rhizophora mangle*. *Avicenia germinans*, *Laguncularia racemosa*, and *Conocarpus erectus* are present within this community but are not a major component. This forest type is analogous to the scrub mangrove community described by Lugo (1980).
Transitional Mangrove Forest	Forest dominated by trees between 2-5 meters in stature. Dominant canopy species is generally *Laguncularia racemosa*. However, *Avicenia germinans*, *Rhizophora mangle* & *Conocarpus erectus* are commonly found emerging from the canopy. Understory is predominately *Rhizophora mangle*. *Schinus terebinthifolius* is sometimes found within this forest type.
Interior Mangrove Forest	Forest dominated by trees between 5-9 meters in stature, however trees may exceed 10 meters in more productive sites. The dominant canopy species are *Avicenia germinans* & *Laguncularia racemosa*. As a rule, *Rhizophora mangle* is the dominant understory macrophyte. *Schinus terebinthifolius* is sometimes found within this forest type, as well. This forest type is analogous to the basin mangrove community described by Lugo (1980).
Coastal Mangrove Forest	Forest dominated by trees generally exceeding 9 meters in stature and in some locations reaching 13-14 m in height. This forest is found adjacent to the shoreline and rarely extends beyond 175 meters from the coast. Like the Interior Mangrove Forest, the canopy is mainly composed of *Avicenia germinans* & *Laguncularia racemosa* while the understory and shrub stratum are predominantly *Rhizophora mangle*. This forest type is analogous to the fringe mangrove community described by Lugo (1980).
Tree Islands	Small, slightly elevated sections of vegetation within the Dwarf Mangrove Forest community type which resembles the Transitional Mangrove Forest type in both species composition and canopy height. This community type, as a rule, is found on topographic highs relative to the surrounding marsh and is slightly more productive than the Dwarf Mangrove Forest community type.
Casuarina Forest	Forest dominated by the invasive exotic *Casuarina equisetifolia*. This community type, which can reach up to 20 meters in height, is generally found on topographic highs like levee roads, spoil mounds, canal banks or in interior freshwater wetlands.

Forest structure. In general, overstory cover (stems $\geq$ 2 m in stature), forest basal area, and maximum canopy height increased toward the coast (**Table 1**, **Figure 4**). The Coastal Mangrove Forest had by far the highest overstory cover, basal area, and maximum canopy height. Understory cover and shrub densities increased with distance from the coast, and thus were inversely related to overstory cover, forest basal area and maximum canopy height.

Excluding the interior-most forest (the Dwarf Mangrove Forest), total tree density (stems $\geq$ 2 m in height) also increased with distance from coast (**Table 1**), but differences among forest types were not statistically significant at $p<0.05$.

Overall, herbaceous cover was relatively low throughout the study area except for four locations in the Transitional Mangrove Forest of Block 7. The understory of this forest was dominated by *Acrostichum aureum,* which in places had a total cover exceeding 80% (**Figure 4**). Another important herbaceous species within the study area was *Juncus romoerianus.* This species, though never exceeding 4% in total cover, is a significant component of the Dwarf Mangrove Forest in Block 7.

Species distributions. Species importance values in the forest understory and overstory are tabularized within forest type in Table 3, and are modeled from point estimates independent of forest type in Figures 5 and 6, respectively.

Table 3: Mean understory and overstory tree species Importance Values by forest types in Biscayne National Park (Blocks 6-8).

Canopy	Species	Forest Type: Dwarf Mangrove Forest	Transitional Mangrove Forest	Interior Mangrove Forest	Coastal Mangrove Forest
Understory	*Avicennia germinans*	2.4	6.8	11.4	2.8
	Conocarpus erecta	6.0	4.7	1.4	0.0
	Laguncularia racemosa	41.9	26.3	15.1	9.5
	Rhizophora mangle	49.7	60.4	68.4	87.8
	Schinus terebinthifolius	0.0	1.9	3.7	0.0
Overstory	*Avicennia germinans*	0.0	1.6	4.6	14.8
	Conocarpus erecta	50.0	8.3	3.1	0.0
	Laguncularia racemosa	3.2	29.7	41.6	26.4
	Rhizophora mangle	46.8	60.4	49.8	58.8
	Annona glabra	0.0	0.0	0.1	0.0
	Schinus terebinthifolius	0.0	0.0	0.8	0.0

In general, the understory importance value of *R. mangle* decreased as distance from coast increased, but the species remained dominant or co-dominant throughout the study area (**Figure 5**). In contrast, *L. racemosa* decreased in importance toward the coast. Like *L. racemosa*, the understory distribution of *C. erecta* was weighted toward the interior portions of the study area but never exceeded 45 at any given point. Unlike the IV of the latter three species, the importance of *A. germinans* in the forest understory is highest in a N-S band midway between the coast and the L-31E levee, where its IV reached 60 at one location in Block 7.

Species' overstory importance values (**Figure 6**) resembled understory IV's (**Figure 5**) with several notable differences. The decrease in importance of *R. mangle* toward the interior was more pronounced in the tree stratum than it was in the understory. While it remained the leading canopy species throughout most of the coastal forests, *R. mangle* was clearly subordinate to *L. racemosa* in the southwest section of Block 6. As in the understory, *L. racemosa* and *C. erecta* reached their highest importance in the canopies of the western-most portions of Blocks 6 & 7. However, in comparison to its central location as an understory plant, *A. germinans'* distribution in the tree stratum is weighted much more strongly toward the coast, where its IV ranged between 45-60 at two coastal points in Block 7 & 8.

Species composition of the major forest types. In the understory, *A. germinans* was most important in the Interior Mangrove Forest with an IV of 11.4 (**Table 3**). This value was slightly less than that calculated for *L. racemosa* (11.4 vs. 15.1) in the same forest and canopy location. In the overstory, however, *A. germinans* was most important in the Coastal Mangrove Forest with an IV of 14.8. Even in this forest type, *A. germinans* was only the 3rd most important species. Considering both understory and overstory IV's together, *A. germinans* importance increased in the order Dwarf < Transitional < Interior < Coastal.

L. racemosa reached its highest importance in the understory of the Dwarf Mangrove Forest and in the overstory of the Interior Mangrove Forest (**Table 3**). Furthermore, the importance of *L. racemosa* in the understory appeared to decrease with increasing overstory height and cover (**Tables 2** & **3**). However, no such trend was evident for the overstory.

R. mangle is the dominant species in the understory and overstory of the Transitional, Interior, and Coastal Mangrove Forests within our study area (**Table 3**). However, despite being dominant in the understory of the Dwarf Mangrove Forest, *R. mangle* is subordinate to *C. erectus* in the overstory of this forest type (**Table 3**). This role reversal between *R. mangle* and *C. erectus* is caused by: 1) the lack of *R. mangle* stems greater than 2 meter in stature, and 2) the presences of well established tall *C. erectus* stems in the SW corner of the Dwarf Mangrove Forest in Block 8 (**Figure 6**).

The importance of *C. erectus* in the understory and overstory of these forest types decreases from Dwarf to Transitional to Interior to Coastal (**Table 3**). However, as stated earlier, *C. erectus* is the dominant species in the Dwarf Mangrove Forest with an overstory IV of 50 (**Table 3**). Not surprisingly, the IV of *C. erecta* in the understory and overstory of the Coastal Mangrove Forest is 0.0.

For the overstory in the Interior Mangrove Forest, two freshwater species, *Annona glabra* and *Schinus terebinthifolius*, combined for an IV of 0.9 (0.1 & 0.8, respectively) (**Table 3**). The presence of these two species in the brackish environments of the study area indicates that they retain some tolerance to salt water. In the case of *A. glabra* its IV (0.1) and presence is interesting but of no management concern. However, *S. terebinthifolius* is an invasive exotic, and its presence is of concern even though its IV was less than 1, and was found only in a single forest type.

Conclusion:

For the most part, the distributions of the four mangrove species within Blocks 6-8 follow the classic zonation pattern described by Davis (1942). Davis observed that South Florida mangroves commonly exhibited a zonation pattern in which *R. mangle,* which was dominant adjacent to the coast, was replaced a little further inland by *A. germinans*, only to be itself replaced by *L. racemosa* and finally *C. erectus* as the uplands of the interior were approached. Davis (1942) attributed this pattern to the mangroves' capacity to "landbuild" through peat accretion, in conjunction with the four species' differential ability to compete in environments that varied in the duration and depth of flooding. Our data show that this pattern varies depending on whether understory or upper canopy individuals are considered. The data also indicate that the vegetation types mapped in **Figure 3**, though defined on structural criteria and on local geography alone, also differ predictably in species composition (**Table 4**).

Table 4: Species occurrences in the mangrove forests of Biscayne National Park (Blocks 6-8).

Species List	Dwarf Mangrove Forest	Transitional Mangrove Forest	Interior Mangrove Forest	Coastal Mangrove Forest
Acrostichum aureum	✓	✓	✓	
Annona glabra			✓	
Avicennia germinans	✓	✓	✓	✓
Bacopa monnieri	✓	✓		
Batis maritima				✓
Borrichia frutescens		✓	✓	
Conocarpus erecta	✓	✓	✓	
Juncus roemerianus	✓			
Laguncularia racemosa	✓	✓	✓	✓
Lycium carolinianum				✓
Philoxerus vermicularis		✓	✓	
Rhabdadenia biflora	✓	✓	✓	
Rhizophora mangle	✓	✓	✓	✓
Sarcostemma clausa		✓	✓	
Schinus terebinthifolius		✓	✓	

Based on our data, field observations, aerial photo interpretation, and the findings of Meeder *et al.* (2000), it seems that the present mosaic of forests types within our study site are a direct result of tidal influence freshwater wetlands becoming polyhaline after compartmentalization. The transformation of these wetlands facilitated the colonization and expansion of mangroves into what once was either a *Cladium jamaicensis* dominated wetland or a *C. jamaicensis – R. mangle* community similar to Egler' (1952) white zone — a narrow coastal zone, between the coastal mangrove forests and the interior freshwater ecosystems, characterized by low plant density and dwarfed vegetation form. Following drainage and compartmentalization of the Biscayne Bay watershed: 1) Mangroves began to slowly replace the non-halophilic vegetation east of the levee. This replacement probably proceeded from the more productive coastal forest zone to the less productive wetlands immediately east of the levee; and 2) Soil accretion increased with the inland encroachment of mangroves and the decrease in organic material export occasioned by the cutoff of freshwater runoff by the levee. As surface elevations increased through the accumulation of mangrove peats, productivity increased throughout the gradient, because of (1) reduced flooding frequency and duration, and (2) changes in the physical and chemical characteristics of the soil (marls to peats). The result was a vegetation mosaic with altered composition and structure, but still exhibiting the underlying gradient in productivity, represented in recent times by decreasing production from Coastal to Interior to Transitional to Dwarf Mangrove Forest (e.g., Ross *et al.* 2001). The extent of the latter three communities in the pre-development landscape was probably minimal. With production now increased throughout the gradient, the once easily identifiable Coastal Mangrove Forest has become less well defined, and extends several hundred meters further inland than it did prior to compartmentalization.

General trends in the distribution of forests types within our study site suggest that the impacts of compartmentalization on this basin have not been uniform (**Figure 3**). The lack of a Dwarf Mangrove forest in Block 6 suggests that the ecological conditions within this Block were significantly different than those of Block 7 & 8 initially. Furthermore, the obvious trend in the extent of the Transitional Mangrove Forest from north to south is probably related to higher ground surface elevations toward the south.

Although it is probably not possible to restore the L-31E wetlands to their pre-drainage form via local hydrologic manipulations alone, efforts to move in that direction will require a restoration of freshwater flow and the removal of many of the levees and canals that have contributed to compartmentalization. Removal of the L-31E levee itself is probably impractical, given its current function as a barrier to storm surge and saltwater intrusion. However, it may be possible to remove all east-west running ditches and the coastal section of the Military Canal, which partition the study area from north to south (**Figure 1**). The removal of the drainage ditches would reconnect 13 separate basins, combining them into one functioning wetland and facilitating management. The specific impacts of restoration efforts, e.g., the rediversion of fresh water or the removal of hydrologic barriers, will vary from place to place, depending on factors such as freeze events, hurricanes, sea level rise, and the nature of the underlying drainage pattern. All indications from the L-31E Surface Water Rediversion Pilot Project (Ross *et al.* 1999) is that the re-introduction of non-halophilic cover will be slow and sporadic, but do not pose much risk to the existing mangrove community.

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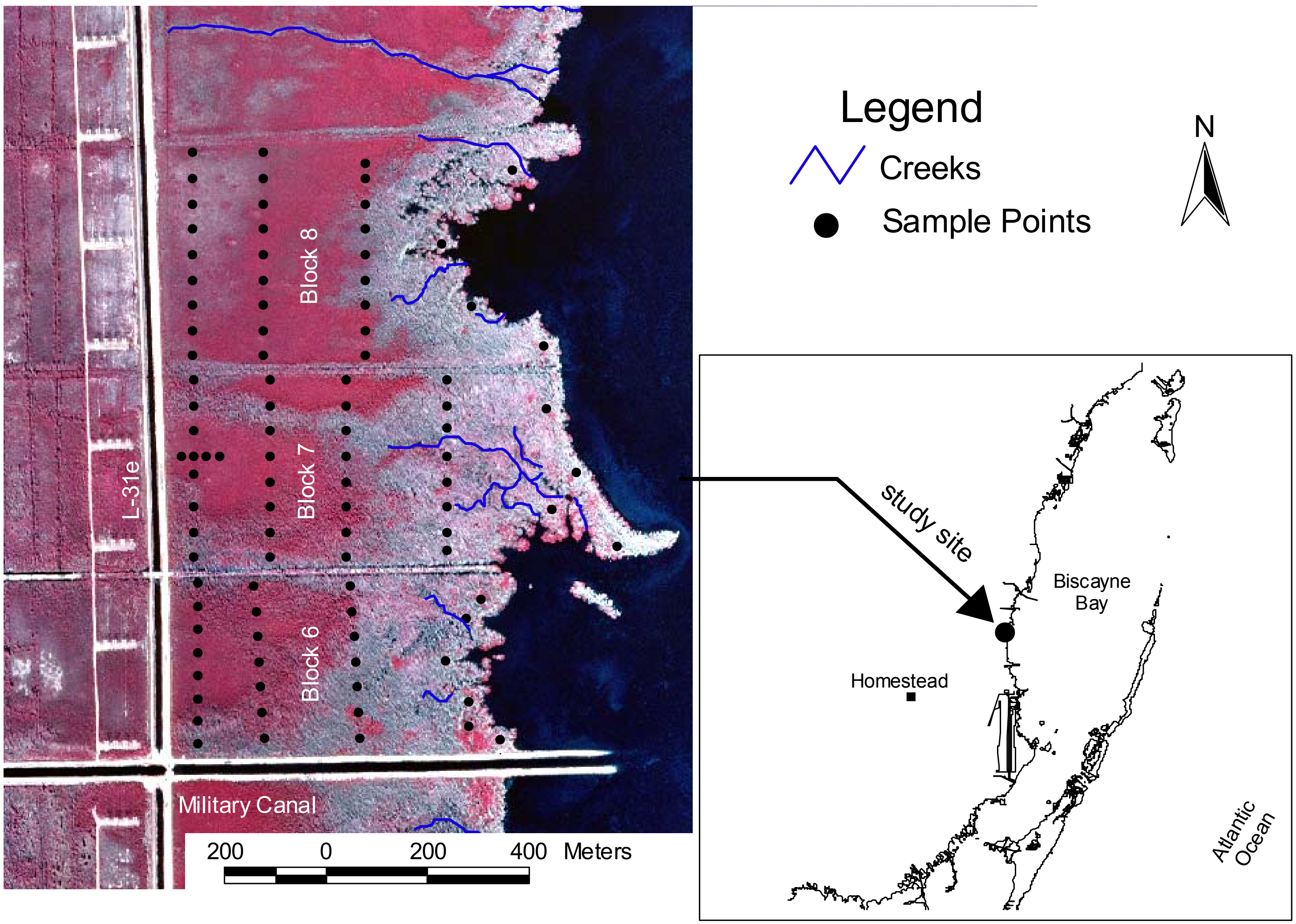

Figure 1: Location of Biscayne National Park study site and sampling matrix. Color-infared photo date: January 1994.

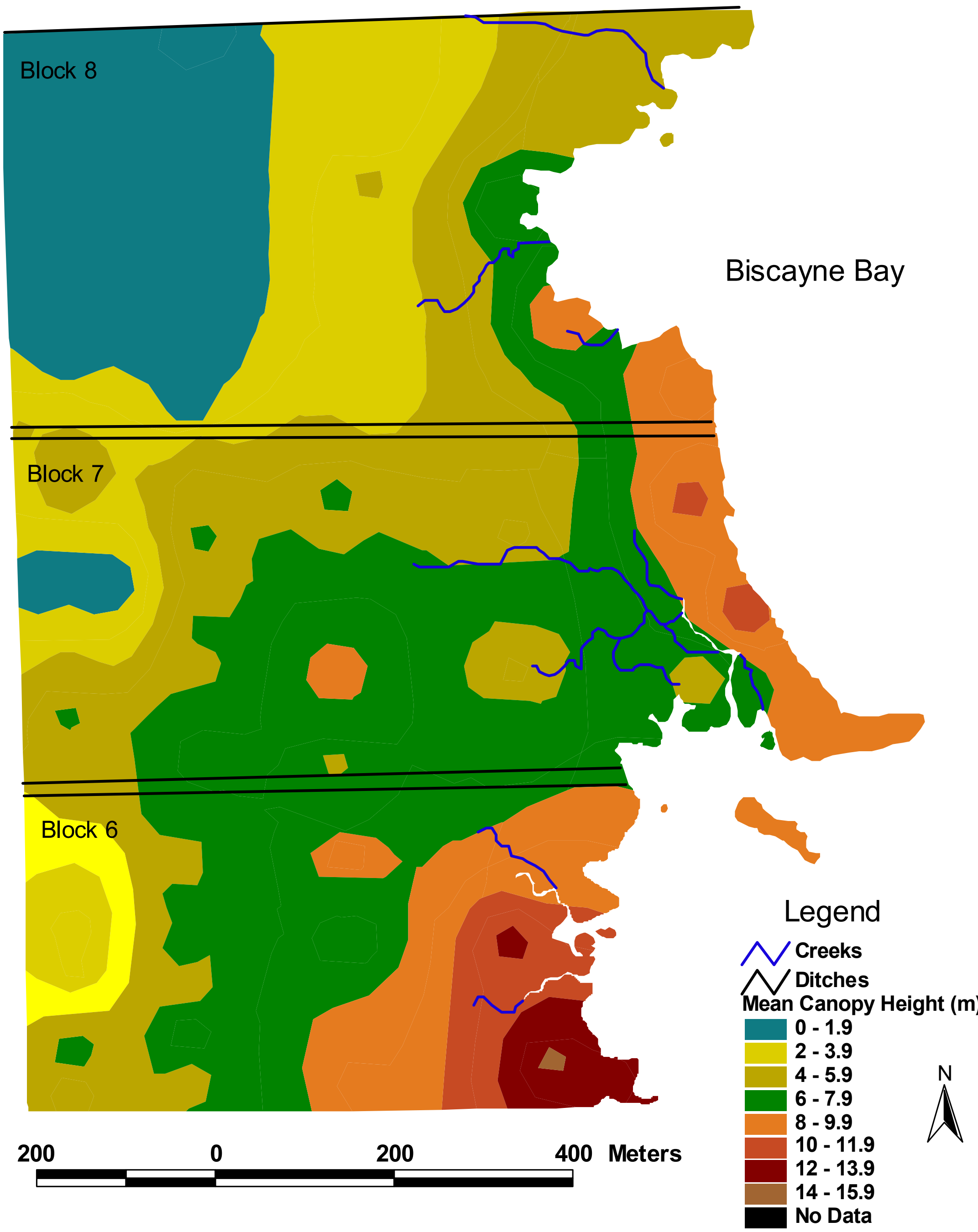

Figure 2: Contour map of mean canopy height for the mangrove forests of Biscayne National Park, Blocks 6-8.

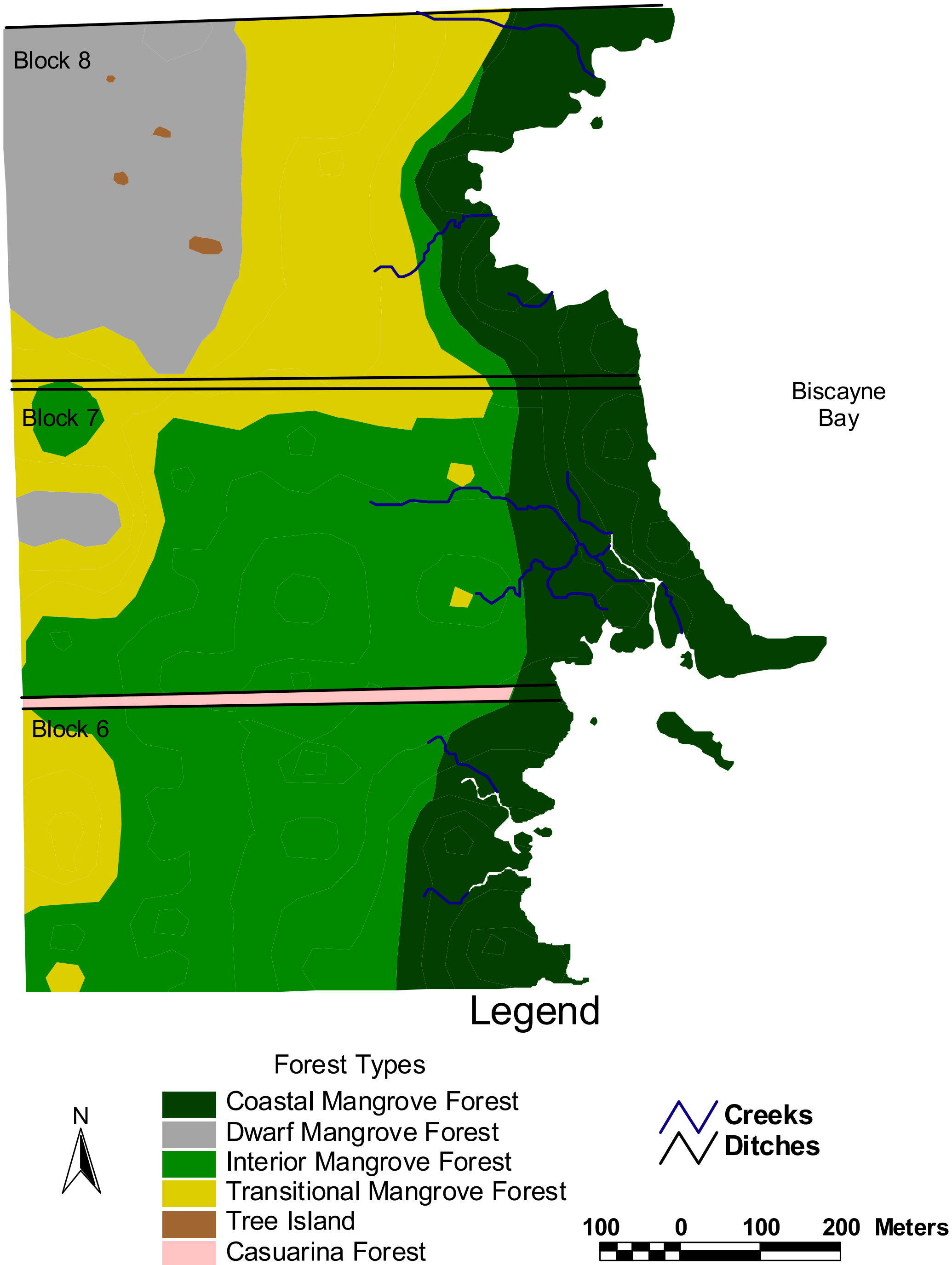

Figure 3: Vegetation map of study site, Biscayne National Park, Blocks 6-8.

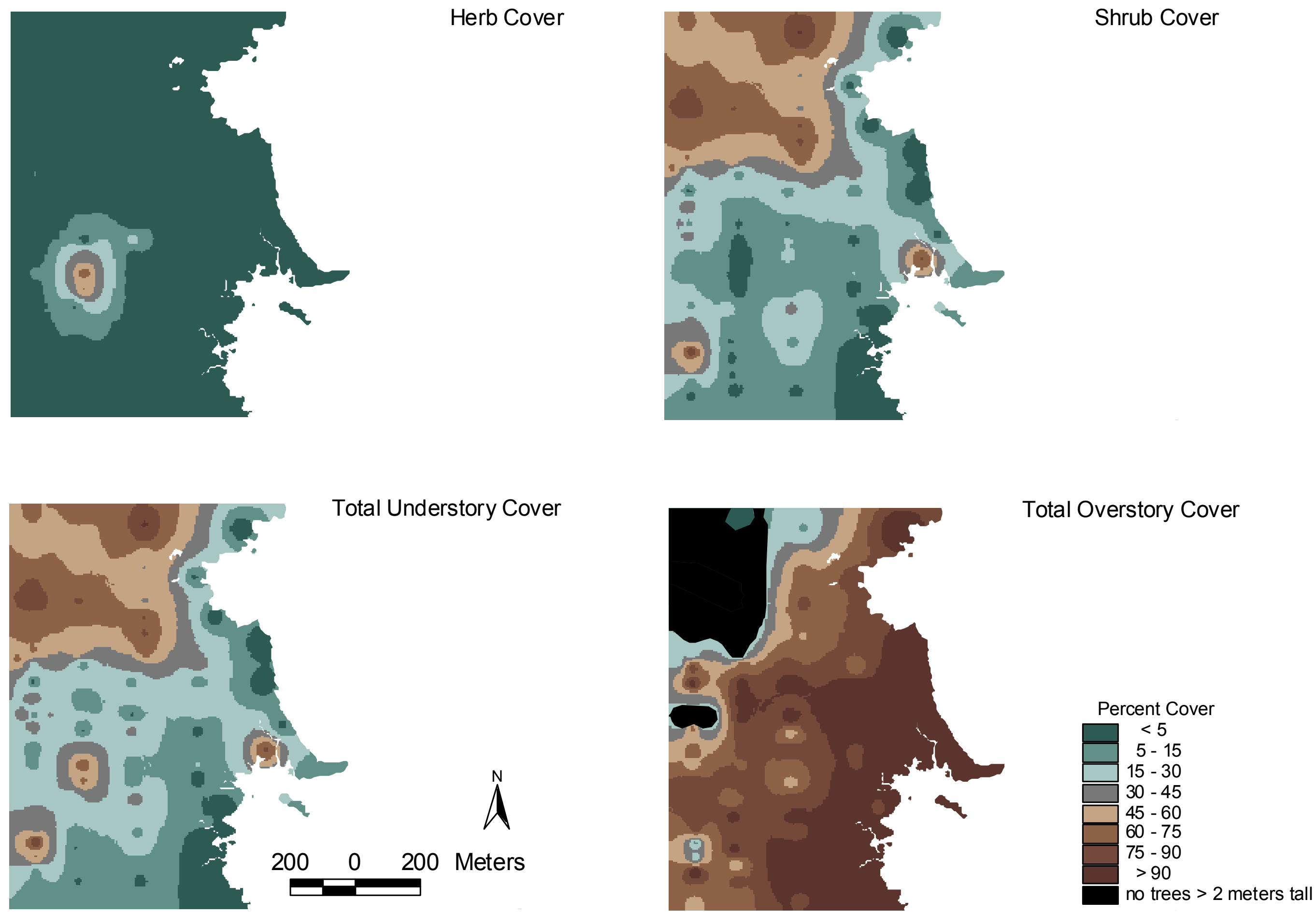

Figure 4: Canopy cover in several categories of understory and overstory vegetation, Biscayne National Park, Blocks 6-8.

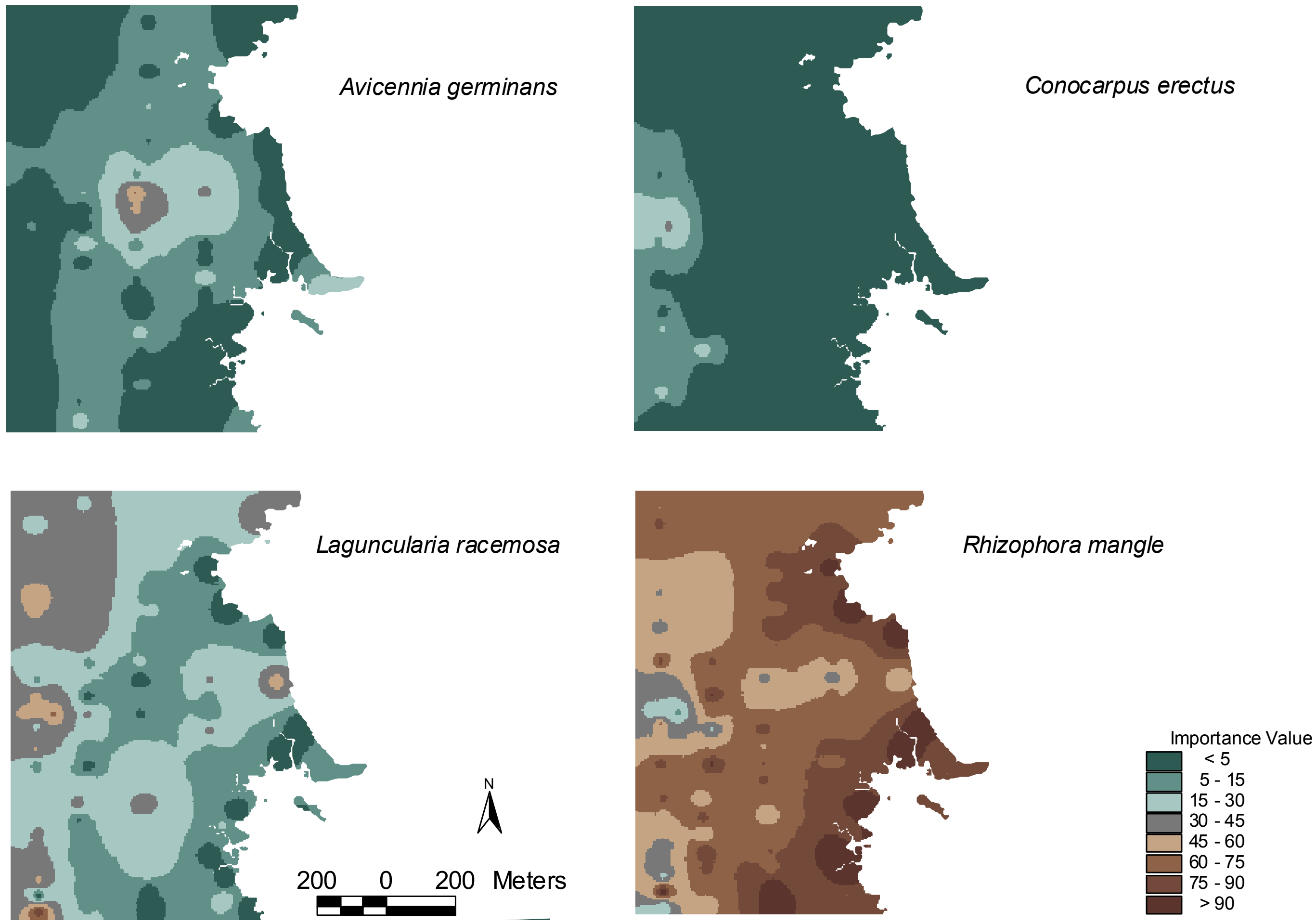

Figure 5: Understory importance values of four mangrove species, Biscayne National Park, Blocks 6-8.

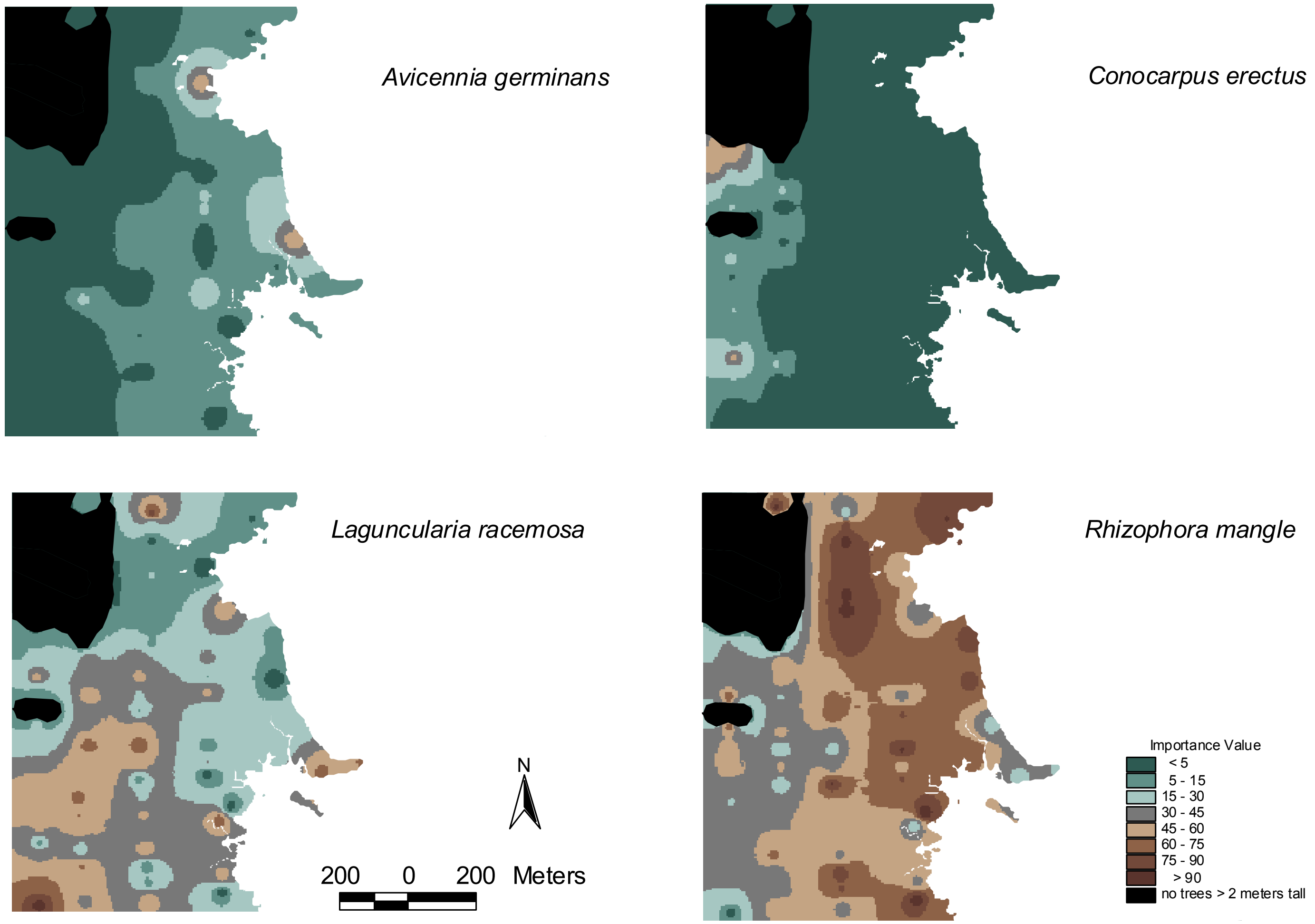

Figure 6: Overstory importance values of four mangrove species, Biscayne National Park, Blocks 6-8.