MANGROVE FOREST STRUCTURE ON THE SITTEE RIVER, BELIZE

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Introduction

Measures of forest structure are one way to evaluate the development or maturity of a forest ecosystem. The standard measures are density of trees (number of individuals per unit area of land sampled), basal area (combined area of the cross-sections of tree trunks per unit area of land sampled) and tree height (usually some estimate of the maximum height for the area of land sampled). These kinds of measures are used by foresters to help estimate the amount of wood that a forest can yield upon harvest, but they are also used by ecologists to evaluate the dimensions of the forest as an ecosystem. The purpose of this paper is to estimate the indices of structure for the mangrove forest at the mouth of the Sittee River in central Belize. Because this forest is being threatened by human development, these measurements are especially important. They can be used to argue for preservation of the forest or at least they will be a record of what the forest was like before it becomes degraded by human impacts.

Methods

The mangrove forest at the mouth of the Sittee River was sampled by undergraduate students in the University of Maryland tropical ecology course during visits to the site in March 1998 and in March 2002, using standard methods (Cintron and Novelli 1984). Measurements were made in transects of five 10 meter by 10 meter square quadrat plots, starting at random locations within the forest near the river mouth. One transect on the north side and one transect on the south side of the river were studied in both 1998 and 2002. Thus, the total sampled area was 0.1 hectare on each side of the river mouth. In each quadrat plot all trees greater than or equal to 1 centimeter in diameter at breast height were identified and their diameters at breast height (DBH) were measured. Basal area of each tree was calculated with the formula for a circle (area = 3.1416 x r^2, where r is the radius or one half of the DBH). Height of the tallest tree in each quadrat plot was measured with a Haga altimeter during sampling in 1998.

Results

The forest at the mouth of the Sittee River is composed of three mangrove species: red mangrove (Rhizophora mangle), white mangrove (Laguncularia racemosa) and black mangrove (Avicennia germinans). Data from the sample plots are summarized in Table 1 with an index of the relative importance of each
tree species in relation to the total forest community (Importance Value = I. V.). This index combines contributions of density and basal area for each species and it ranges between 1 and 100 with higher values indicating greater relative importance. The forest structure is dominated by red mangroves with an I. V. of 43.5, followed closely by white mangroves with an I. V. of 38.5. Red mangroves had the highest density at 55% of the total community, while white mangroves had the highest basal area at 45% of the total community. Black mangroves were subordinate with an I. V. of 18.0 because they had the smallest relative contributions of both density and basal area.

While the species composition of a mix of red, white and black mangroves shown in Table 1 is typical of a mangrove forest anywhere in the Caribbean region, the overall structure of the forest at the mouth of the Sittee River is substantial and, in some regards, among the highest ever reported in the scientific literature. Comparisons are made between data from the Sittee River forest and other similar mangrove forests in Table 2. Because mangrove species can form fundamentally different kinds of forests depending on environmental conditions such as tidal fluxes, geomorphic position and salinity levels, only the riverine-type of forests are compared in Table 2. The riverine forest type is characterized by optimal growth conditions (Lugo and Snedaker 1974, Cintron et al. 1985), so the data in Table 2 represent the maximum levels of mangrove forest structural development. For simplicity of comparison only averages from the scientific literature are compared with the Sittee River forest in Table 2, but these averages represent more than 20 different studies of riverine mangrove forests in the Neotropics. The Sittee River forest has a lower density but a higher basal area than the average riverine mangrove forest. This suggests that the Sittee River forest is composed of fewer but larger trees per unit of land area in comparison with similar forests. The most significant comparison is for maximum tree height, shown in the final column of Table 2. The Sittee River forest is characterized by much taller trees than the average riverine forest. In fact, the measured tree heights at the Sittee River forest are taller than any comparable forest in the scientific literature for the Caribbean region. For example, Gilmore and Snedaker (1993) report a forest height for Florida riverine mangroves of 12.6 meters and the maximum height given by Pool et al. (1977) is 17.0 meters. Several taller forests are listed by Brinson (1990) from the west coast of Panama but these forests are dominated by species adapted to freshwater (such as Pterocarpus officinalis) rather than the typical mangrove species characteristic of higher salinities found at riverine sites such as at the mouth of the Sittee River.

The finding of very tall trees at the mouth of the Sittee River is consistent with other structural characteristics described above. Comparisons of density and basal area indicated that these trees are larger in diameter relative to other riverine sites. Thus, it seems reasonable to expect that trees that are larger in diameter would also be taller than average.

Conclusions

The most significant conclusion from this analysis of forest structure is that the
mangroves at the mouth of the Sittee River are apparently the tallest ever reported for the Caribbean region and among the tallest anywhere in the entire Neotropics! Tree height is an important measure of forest structural development since it is used by foresters as a direct indication of the quality of conditions for tree growth at a site. The conclusion is that the mouth of the Sittee River represents the optimal conditions for mangrove development and the forest found there has a very high level of structural development. The causal basis for the excellent site conditions are the freshwater flows and sediments carried by the river itself, draining from the Maya Mountains, along with tidal flushing from the Caribbean Sea.

This forest has some of the “old-growth” characteristics (Lugo 1997) that suggest that it has been free from human disturbance. The pristine conditions of the forest are probably due to its isolation from cities and towns. However, human development is beginning to increase around the forest, especially from the direction of Hopkins to the north. Impacts from this development will surely degrade the forest over time, as has happened along every other tropical coastline in the world (Valiela et al. 2001). The opportunity still exists for the people of Belize to preserve the forest at the mouth of the Sittee River as an example of the highest level of natural development of mangrove forest structure in the Caribbean region.

**Literature Cited**


Table 1. Relative contributions of different mangrove species to the overall forest structure at the mouth of the Sittee River. Numbers in parentheses are percentages of the total.

<table>
<thead>
<tr>
<th>Species</th>
<th>Basal Area (m²/ha)</th>
<th>Density (numbers/ha)</th>
<th>Importance Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>R. mangle (red mangrove)</td>
<td>20.8 (32)</td>
<td>775 (55)</td>
<td>43.5</td>
</tr>
<tr>
<td>L. racemosa (white mangrove)</td>
<td>28.7 (45)</td>
<td>450 (32)</td>
<td>38.5</td>
</tr>
<tr>
<td>A. germinans (black mangrove)</td>
<td>14.7 (23)</td>
<td>190 (13)</td>
<td>18.0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>64.2</td>
<td>1415</td>
<td></td>
</tr>
</tbody>
</table>

* Importance Value = average of the basal area percentage and the density percentage
Table 2. Forest structure data for riverine mangroves from the Neotropics. Measures of variation (standard error or range) for the data from the literature are listed as given in the original references.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Basal Area (m²/ha)</th>
<th>Density (numbers/ha)</th>
<th>Tree Height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flores-Verdugo et al. 1992</td>
<td>mean = 41.3</td>
<td>mean = 1730</td>
<td>mean = 17.7</td>
</tr>
<tr>
<td></td>
<td>standard error = 350</td>
<td>standard error = 350</td>
<td>standard error = 3.7</td>
</tr>
<tr>
<td>Brinson 1990</td>
<td>mean = 33.2</td>
<td>mean = 2131</td>
<td>mean = 14.0</td>
</tr>
<tr>
<td></td>
<td>range = 11.5-96.4</td>
<td>range = 400-4670</td>
<td>range = 7.5-21.8</td>
</tr>
<tr>
<td>Sittee River</td>
<td>64.2</td>
<td>1415</td>
<td>26.6</td>
</tr>
</tbody>
</table>