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硕 士 学 位 论 文

模拟海平面上升对秋茄红树林生态系统主要有机碳过程影响的现场研究

Field Study on Effects of Simulated Sea Level Rise on Main Processes of Organic Carbon in *Kandelia obovata* Mangrove Ecosystems

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摘要

本研究以厦门曾营海岸三个不同高程样地的秋茄红树林为研究对象，在模拟海平面上升 80 cm 红树林（SLR 80 cm）、模拟海平面上升 40 cm 红树林（SLR 40 cm）以及对照红树林（SLR 0 cm，大约相当于福建九龙江口红树林的滩面高程），探讨海平面上升对秋茄（*Kandelia obovata*，以前学名为 *Kandelia candel*）红树林生态系统主要有机碳过程的影响。

SLR 80 cm 样地的植株矮小、林相稀疏，生长状况明显不如 SLR 40 cm 和 SLR 0 cm 样地。各样地植株的生物量以及年增量总体均呈现出 SLR 0 cm>SLR 40 cm>SLR 80 cm 的规律，且 SLR 80 cm 样地与 SLR 40 cm 和 SLR 0 cm 样地有显著差异。三个样地植被有机碳的积累也表现出同生物量一致的规律，这表明随着海平面的上升，秋茄红树林植被的碳积累会随之降低。

各样地植被均体现出秋茄树种正常的物候节律，并遵循一致的季相变化。受台风影响，落叶、落枝、落花以及总凋落量都在 7、8 月份达到较大值，落果则受物种生物学特性的影响，在 4 月份达到最大值。在不同样地间，除落花在 SLR 40 cm 样地为最大值外，落叶、落枝、落果以及总凋落量都表现为 SLR 0 cm>SLR 40 cm>SLR 80 cm，且差异显著。三个样地凋落物 C、N、P 年积累量也表现出同生产量一致的规律，这表明随着海平面的上升，秋茄红树林凋落物生产量和养分归还量明显降低。

各季节各样地凋落叶的分解失重率都在分解的 12~40 天达到 50%，季节动态表现为夏季>秋季>春季>冬季。凋落枝的分解周期较长，各样地凋落枝分解 50 周后的失重率都仅在 30%~40%。各季节 SLR 0 cm 样地凋落叶的分解速率总体高于 SLR 40 cm 和 80 cm 样地，主要是由于底质差异导致。但三个样地凋落叶分解的差异仅在分解前期表现显著，随着分解时间的延长，差距逐渐缩小。不同样地条件下凋落枝的分解动态与凋落叶的结论类似。在分解过程中，各季节各样地凋落叶的有机碳含量变化趋势不明显；总氮含量总体呈现出先上升后下降的趋势，但总体高于初始含量；总磷含量总体呈现出先下降后上升的趋势，但总体低于初始含量。各季节不同样地凋落叶的有机碳、总氮和总磷含量总体上都表现为 SLR 0 cm 样地高于 SLR 40 cm 和 80 cm 样地，而凋落枝未表现出明显差异。总之，海平面上升不利于秋茄凋落物的分解以及养分的释放循环。

秋茄凋落叶的林地现存量和蟹类摄食率在不同样地间表现出相似的季节规律，即春夏季高于秋冬季；在不同季节间都表现出 SLR 0 cm>SLR 40 cm>SLR 80 cm 的趋势，且 SLR 80 cm 样地明显低于 SLR 40 cm 和 SLR 0 cm 样地。各样地全年的林地现存凋落叶碳和蟹类摄食碳都呈现出 SLR 0 cm>SLR 40 cm>SLR 80 cm 的规律，且差异显著。三个样地秋茄凋落叶蟹类摄食碳占总凋落碳的比重相近；SLR 80 cm 和 SLR 0 cm 样地秋茄凋落叶林地现存碳占总凋落碳的比重相近，而 SLR 40 cm 样地由于林内废弃物的滞留导致比重偏高。总的来说，海平面上升导致凋落叶各归宿量降低，但并未对各归宿量占总凋落量的比重有明显影响。

各样地三种温室气体 N_2O、CH_4 和 CO_2 的土壤-大气通量表现出相似的季节规律，即春夏季高于秋冬季。总 CO_2 当量通量的季节动态与 CO_2 通量的变化规律基本一致，这表明 CO_2 通量在总 CO_2 当量通量中占主导地位。不同样地间，N_2O 的年通量表现为 SLR 0 cm>SLR 80 cm>SLR 40 cm，SLR 40 cm 和 SLR 0 cm 样地间有显著差异；CH_4 的年通量表现为 SLR 80 cm>SLR 40 cm>SLR 0 cm，SLR 80 cm 样地显著高于 SLR 40 cm 和 SLR 0 cm 样地；CO_2 的年通量表现为 SLR 0 cm>SLR 40 cm>SLR 80 cm，SLR 40 cm 和 SLR 0 cm 样地显著高于 SLR 80 cm 样地。三种温室气体的总年通量则表现为 SLR 40 cm>SLR 0 cm>SLR 80 cm，SLR 40 cm 和 SLR 0 cm 样地显著高于 SLR 80 cm 样地。随样地和季节的变化，秋茄红树林土壤有机碳、总氮、总磷以及碳氮比都表现出相似的规律。在不同季节间，土壤各养分含量总体上都表现为春夏季高于秋冬季；在不同样地间，土壤各养分含量全年大体上都呈现出 SLR 80 cm 样地低于 SLR 40 cm 和 SLR 0 cm 样地的趋势。三种温室气体通量与土壤养分含量的相关分析结果表明，CH_4 通量与土壤有机碳和总氮含量呈显著正相关，CO_2 通量与土壤有机碳、总氮以及总磷含量呈显著正相关。

各样地秋茄红树林生态系统的碳预算显示，三个样地秋茄红树林生态系统的净碳固定值表现为 SLR 0 cm>SLR 40 cm>SLR 80 cm，即随着海平面的上升，秋茄红树林生态系统的净碳固定值降低。总的来说，海平面上升对秋茄红树林生态系统的主要有机碳过程有显著的影响，会明显削弱红树林生态系统的固碳能力。

关键词：海平面上升；秋茄；红树林；有机碳

Abstract

Three *Kandelia obovata* forests with different intertidal elevations, regarded as sea level rises (SLR) of 80 (lower elevation), 40 (middle elevation) and 0 (control, upper elevation) cm respectively, along the coastline of Zengying, Xiamen were studied to investigate the effects of SLR on main processes of organic carbon in mangrove ecosystems.

Plants at SLR 80 cm plot were short and sparse, so their growths were not as good as those at SLR 40 cm and SLR 0 cm plots. Accumulation and annual increment in biomass of *K. obovata* plants generally followed the order of SLR 0 cm > SLR 40 cm > SLR 80 cm, and SLR 80 cm plot had significant differences from SLR 40 cm and SLR 0 cm plots. Organic carbon accumulation in *K. obovata* plants at three plots exhibited the same order for biomass. This indicated that organic carbon accumulation in *K. obovata* plants would decrease with SLR.

Plants of *K. obovata* at three plots had normal phenology and the same seasonal dynamics. The highest values of leaf, branch, flower and total litter production were recorded in July and August due to strong typhoons, and the maximum value of fruit litter was in April due to the biological characters of this species. Except for flower litter with the highest value at SLR 40 cm plot, leaf, branch, fruit and total litter production significantly followed the order of SLR 0 cm > SLR 40 cm > SLR 80 cm. C, N and P annual accumulation in litter at three plots exhibited the same order as litter production. This showed that litter production and nutrient return of *K. obovata* plants would decrease with SLR.

Seasonal average half-time of leaf litter decomposition ranged from 12 to 40 d, with an order of degradation rate as summer > autumn > spring > winter. The decomposition period of branch litter was long, with weight loss rates of only 30%~40% after 50 weeks. Due to differences in sediments, seasonal decomposition rates of leaf litter were overall higher at SLR 0 cm plot than SLR 40 and 80 cm ones. However, these differences were obvious only at the earlier stage, and became close

with the extension of time. Seasonal dynamics of branch litter decomposition were the same as leaf litter. During seasonal decomposition process of leaf litter, changes in C concentration were not obvious; while N concentration increased first and then decreased, with values higher than the initial; P concentration showed an upward trend after the first drop, with values lower than the initial. Seasonal concentrations of C, N and P in leaf litter were overall higher at SLR 0 cm plot than SLR 40 and 80 cm ones, but the branch litter did not show significant differences. Overall, SLR is not conductive to the litter decomposition and nutrient release cycle in *K. obovata* forests.

Standing stocks of leaf litter and leaf consumption rates by crabs were all higher in spring and summer than in autumn and winter, and SLR 80 cm plot had significant differences with SLR 40 cm and SLR 0 cm plots, with a tendency of SLR 0 cm > SLR 40 cm > SLR 80 cm. Both organic carbon of standing stock and consumption by crabs followed the order of SLR 0 cm > SLR 40 cm > SLR 80 cm. Ratios of crab feeding carbon and total carbon in leaf litter were similar among three plots. Due to waste retention, ratios of standing stock carbon and total carbon in leaf litter were higher at SLR 40 cm plot than SLR 80 cm and SLR 0 cm ones. In general, the amount of each fate of leaf litter decreased with SLR, but ratios of each fate and total did not change obviously.

Fluxes of N_2O, CH_4 and CO_2 from soil to air showed similar seasonal dynamics among plots, with higher values in spring and summer than those in autumn and winter. Seasonal differences in fluxes of total CO_2-equivalent were in line with CO_2 fluxes, which showed that CO_2 was dominant in the total flux. Annual C-equivalent fluxes of N_2O followed the order of SLR 0 cm > SLR 80 cm > SLR 40 cm, and there were significant differences at SLR 40 cm and SLR 0 cm plots. Annual C-equivalent fluxes of CH_4 at SLR 80 cm plot had significant differences with SLR 40 cm and SLR 0 cm ones, with a tendency of SLR 80 cm > SLR 40 cm > SLR 0 cm. Annual C-equivalent fluxes of CO_2 followed the order of SLR 0 cm > SLR 40 cm > SLR 80 cm, and SLR 40 cm and SLR 0 cm plots were significantly higher than SLR 80 cm plot. Annual C-equivalent fluxes of all of the three gases were higher at SLR 40 cm and SLR 0 cm plots than SLR 80 cm one, with a tendency of SLR 40 cm > SLR 0

cm > SLR 80 cm. Soil nutrient contents were higher in spring and summer than in autumn and winter, and overall lower at SLR 80 cm plot than SLR 40 cm and SLR 0 cm ones. Fluxes of CH_4 were significantly correlated with contents of soil organic carbon and total nitrogen, and CO_2 were significantly correlated with contents of soil organic carbon, total nitrogen and total phosphorus.

According to carbon budget of *K. obovata* mangrove ecosystems, net carbon fixed in mangrove ecosystems followed the order of SLR 0 cm > SLR 40 cm > SLR 80 cm. In other word, the net fixed carbon of *K. obovata* mangrove ecosystem decreased with SLR. In a conclusion, main organic carbon processes in *K. obovata* mangrove ecosystem were obviously influenced by SLR, which may significantly weaken the carbon sequestration capacity of mangrove ecosystem.

Key Words: Sea level rise; *Kandelia obovata*; Mangrove; Organic carbon

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