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Young mangrove stands produce a large and high quality litter input to aquatic systems

B.T. Nga[1,]*, H.Q. Tinh[1], D.T. Tam[1], M. Scheffer[2] and R. Roijackers[2]
*[1]Department of Environmental and Natural Resources Management, College of Agriculture, Cantho University, Vietnam; [2]Department of Environmental Sciences, Aquatic Ecology and Water Quality Management Group, Wageningen University, Wageningen, The Netherlands; *Author for correspondence (e-mail: btnga@ctu.edu.vn; phone: +84-71-830635; fax: +84-71-830814)*

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Abstract

Mangrove swamps are key ecosystems along the Vietnam coast. Although mangrove litter is thought to represent an important input of organic matter and nutrients to the coastal aquatic systems, the factors determining the quality and size of this litter flux have not been studied so far. We monitored leaf, stipule, twig, and reproductive litter monthly in monocultures of *Rhizophora apiculata* mangrove forests of 7, 11, 17 and 24 years old in the Camau province, Mekong Delta, Vietnam. Litter traps were used to measure litter fall production from June 2001 till May 2002. Total litter fall was in the range of 8.86–14.16 t DW ha^{-1} $year^{-1}$. Leaves were the main component, and represented 70% of litter fall production in all stands. Total litter fall was lower in the older stands but the amount of reproductive litter was significantly higher in these stands (17 and 24 years). Biomass of leaf litter was highest between the end of the wet season and the beginning of the dry season. Phosphorus and nitrogen levels in leaf litter were significantly higher in younger than in older stands. Overall, our study indicated that young stands produced the highest input of litter and particularly of nitrogen and phosphorus to the surrounding aquatic system. Consequently, these stands contribute significantly to the fisheries.

Introduction

Mangrove swamps are extremely productive ecosystems, which export organic matter to support a variety of organisms (Odum and Heald 1975; Lee 1989). The export of these large amounts of organic material can have substantial effects on food webs in coastal waters (Alongi 1990). In the past decade, mangrove forests have been under severe pressure by a rapidly increasing human population, large scale deforestation practices and conversion of forests into aquaculture farms especially in Southeast Asia. The fast developments in aquaculture have resulted in non-sustainable farming systems (Graaf and Xuan 1998). Preservation of the mangrove forests is an important issue to protect the coastal ecosystem and to improve the water quality in the coastal areas. Therefore, the need for protection of the coastal forest belt has been an important issue (Loi et al. 2002). In recent years, studies on species classification, tree growth, succession, silviculture, forest utilization, and litter fall of mangroves have been carried out in Vietnam (e.g. Nam and Thuy 1997; Clough et al. 2000). However, information on litter fall from mangroves in Vietnam is lacking.

The mangrove forest in the coastal areas of Vietnam suffered severe damage over the past 50 years; it decreased from 400,000 to 290,000 ha due to overexploitation of forest timber, firewood and charcoal (Hong 1996). Since then, the deforestation continued by changing forests into agricultural land and primitive extensive and intensive shrimp farming i.e. about 53,969 ha of forest was left on the Ca Mau peninsula in 1993 (Department of Agriculture, Forestry and Fishery 1996). The Camau province (Camau Peninsula), situated in the south western part of the Mekong Delta, has a long shoreline and is the province with the most severe mangrove destruction. Following the cessation of hostilities in Vietnam, mangrove forests in the Camau peninsula initially recovered as a result of both natural regeneration and manual planting of the preferred forestry species, *Rhizophora apiculata* Blume. Although extension of shrimp farming in mangrove areas occurs at a rapid rate, world shrimp production has leveled off in recent years, as many aquaculture farms have either collapsed or experienced declining yields. For instance, production figures varied dramatically between the various shrimp culture systems with semi-intensive farms producing between 1000 and 2000 kg ha^{-1} $year^{-1}$, whereas extensive farms produced 100–400 kg ha^{-1} $year^{-1}$ in 1996 (Johnston et al. 2000), and 80–250 kg ha^{-1} $year^{-1}$ in 2000 (Ministry of Fisheries 2001). Fish production is believed to be dependent on mangrove areas, and the dependence of many penaeid shrimp species on mangroves has also been shown (Christensen 1978; Barbier 2000). In fact, the decline in mangrove areas in the Mekong delta certainly had an impact on the decrease in coastal fisheries production over the last decades (Graaf and Xuan 1998). The study described here was carried out as part of a larger study for Integrated Management of Coastal Resources (MHO8-project) in the Mekong Delta, Vietnam, where a number of provincial governments have established shrimp farming-forestry enterprises. In these mixed aquaculture and mangrove forestry systems, shrimp and other cultured species are dependent mostly on the natural food chains for their food supply. It is widely recognized that mangrove derived detritus might be a major source of carbon for estuarine food webs along tropical and subtropical coastlines (e.g. Odum and Heald 1972; Malley 1978; Robertson and Daniel 1989; Daniel and Robertson 1990), but data for the systems we studied in Vietnam were lacking. The present research focused on the question how the dynamics and quality of mangrove litter input to aquatic systems differ between tree stands of different age.

Materials and methods

Description of the research area

Sampling was carried out from June 2001 till May 2002 in monocultures of the planted *Rhizophora apiculata* of respectively 7, 11, 17, and 24 years old. The mangrove stands of 7 and 11 years old were selected from the mixed shrimp farming-mangrove forestry systems Tam Giang 3 enterprise. The *Rhizophora apiculata* stands of 17 and 24 years were selected in the 184, and Kien Vang enterprises respectively in Camau province, Mekong Delta, Vietnam (Figure 1). The average tree density varied from 7000–10,000 trees per hectare. The mixed shrimp-mangrove system is characterized by mangrove stands, surrounded by ditches. The area of each of the mangrove stands is 7–12 ha of which approximately 30% are ditches. Average width and depth of these ditches are 7 and 1 m respectively. The research area is located at a latitude of about 8°50′ N. The climate is humid tropical and dominated by monsoons. Mean annual rainfall was over 2400–3460 mm in 1996–2002. Annually, the temperature is relatively uniform with an average of 27–28 °C; the annual sunshine amounts 1918–2390 h and the humidity ranges from 80–84%. During the research period, average rainfall and humidity were the lowest, while temperature and sunshine were the highest recorded over the last 5 years. The rainy season lasts from May till November, and the rest of the year is the dry season with very little rainfall. During the research period the average rainfall, humidity, temperature, and sunshine were 1756 mm, 83.3%, 27.6 °C, and 891 h respectively in the wet season and 336 mm, 75%, 28.8 °C, and 1403 h in the dry season. There was a large difference in rainfall between the wet and dry seasons. The rainfall was very low in March and April and in February there was no rain at all.

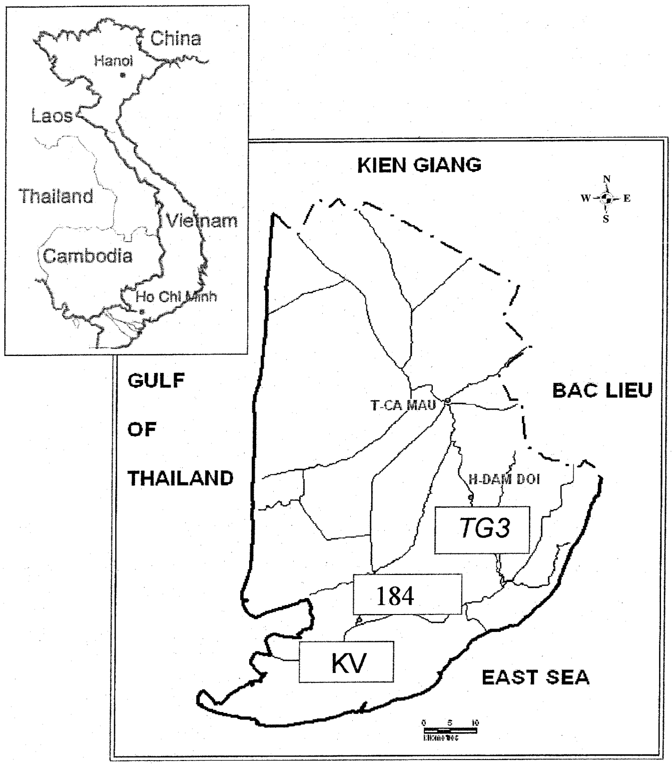

Figure 1. Map of the Camau province, showing the sampling locations.

Sample collection and analyses

Litter traps of 1 m^2 were constructed from nylon nets (1 mm mesh size) and positioned in each *Rhizophora apiculata* stand above the highest tidal water level. In each stand the content of four traps was collected at monthly intervals for 1 year. Total 16 traps were used in the whole. The samples were sorted into leaves, stipules, twigs, and reproductive litter. Dry weight (DW) and ash-free dry weight (AFDW) were analyzed for litter samples. From the leaf litter, total nitrogen (TN), total phosphorus (TP) were analyzed directly after sampling. The dry weight was determined by the drying the samples at 105 °C for 24 h, AFDW was determined by changing of weight before and after burning at 550 °C during 3 h. The Kjeldahl method was used for determining TN, colorimetry for determining TP.

Statistics

The difference of litter fall production between the different mangrove stands during one year were statistically compared using Repeated Measure in the General Linear Model (GLM – SPSS version 10.0 for windows). Significantly differences (at 95% confidence level) were distinguished using Tukey's post-hoc comparision test.

Results

Litter fall

Total litter fall varied from 2.43–3.88 g DW m^{-2} day^{-1} and was significantly highest at the 11 year old stand (Figure 2). A seasonal pattern in the total litter fall was not clear (Figure 3). The oldest stands had a significantly higher proportion of reproductive parts in the litter compared to the younger stands (Figure 2). Twig litter fall was relatively low throughout the year, and was significantly highest in the 7 and 11 year old stands. About 70% of the total litter was leaf litter (decreasing with increasing age) and stipule, twig and reproductive litter covered respectively 8, 12, and 10%. Leaf and stipule litter were significantly

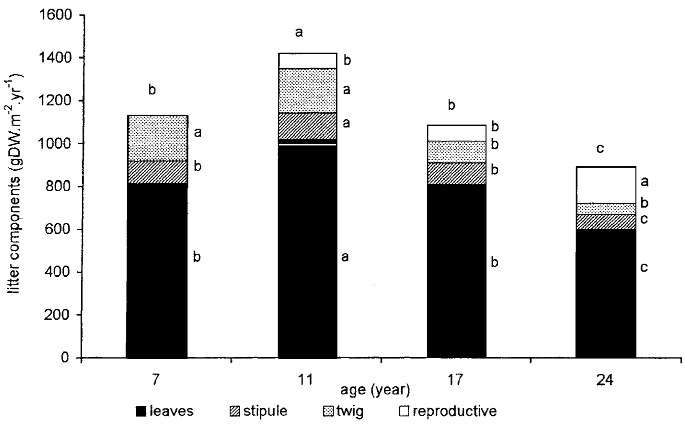

Figure 2. Average biomass (g DW m^{-2} $year^{-1}$) of litter fall components from June 2001 till may 2002 in the Camau province, Vietnam. Different letters indicate significant differences ($p < 0.05$) between the age classes for the total leaf litter (top) and for the different leaf litter components (next to the bars).

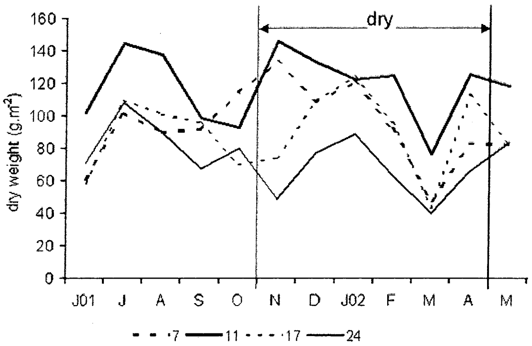

Figure 3. Total litter fall (mg DW m^{-2}) from June 2001 till May 2002 in Camau province, Vietnam. The dry period has been indicated.

highest in the 11 year old stands, and the lowest leaf litter fall was recorded in the oldest stands. The average ash-free dry weight accounted for 90% of the dry weight of the total litter fall. The highest AFDW was recorded in the 7 and 11 year old stands. Litter fall in the Camau forest is high compared to other mangrove systems (Table 1)

Nutrients in the leaf litter

The nitrogen and phosphorus contents in the leaf litter as well as the total yearly input of N and P *via* leaf litter were significantly higher in the younger stands (Figure 4). The input of nutrients *via* the leaf litter showed a clear seasonal pattern in both young and old stands (Figure 5a and b). As

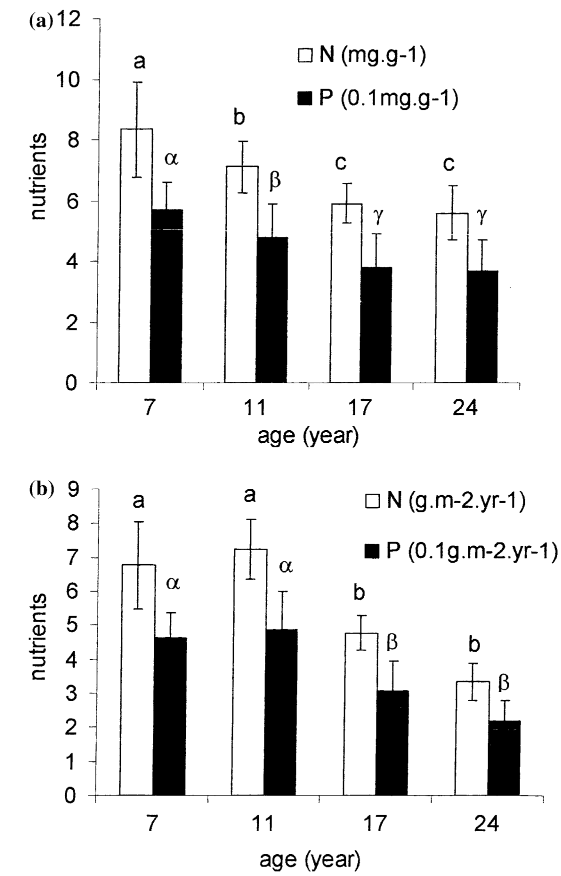

Figure 4. Nitrogen and phosphorus in leaf litter from June till May 2002 in the Camau province, Vietnam (a) nutrients in the leaves (mg g^{-1} DW), (b) total nutrient input through leaf litter (g m^{-2} $year^{-1}$).

Table 1. Literature data on total litter fall of *Rhizophora* spp. mangrove forests around the world.

Species (type of mangal)	Latitude of study area	Total litter (g DW m^{-2} day^{-1})	References
Australia			
Rhizophora apiculata		3.10	Bunt 1982
Rhizophora stylosa		2.55	Duke et al. 1981
Brazil			
Rhizophora spp.	23° S	2.38	Silva et al. 1998
Ecuador			
Rhizophora spp		1.75–2.90	Twilley et al. 1986, 1997
Florida			
Rhizophora spp.	27°41′ N	2.21–3.50	Pool et al. 1975
Rhizophora spp.	27°41′ N	3.10	Dawes et al. 1999
Rhizophora mangle		1.69–2.10	McKee and Faulkner 2000
Fr. Guyana			
Rhizophora spp		2.38–3.45	Betoulle et al. 2001
Hawai			
Rhizophora mangle		6.90	Cox and Allen 1999
India			
Rhizophora apiculata	6–14° N	1.95	Mall et al. 1991
Rhizophora apiculata		3.21–3.23	Wafar et al. 1997
Kenya			
Rhizophora mucronata		2.70	Slim et al. 1996
Rhizophora mucronata		3.22–4.66	Woitchik et al. 1997
Malaysia			
Rhizophora apiculata	4°50′ N	2.70	Gong et al. 1984
Rhizophora spp	3°15 N	4.32	Sasekumar and Loi 1983
Mexico			
Rhizophora spp.		3.40	Day et al. 1987
Papua New Guinea			
Rhizophora spp.	9°31 S	3.91	Leach and Burgin 1985
Tanzania			
Rhizophora mucronata		3.84	Shunula and Whittick 1999
Thailand			
Rhizophora apiculata	8°03 N	2.70	Christensen 1978
Rhizophora apiculata	9°97′ N	2.43–3.54	Aksornkoae 1993
Rhizophora apiculata	8°03 N	3.20	Nielsen and Anderson 2003
Tuvalu			
Rhizophora stylosa	7°28 S	2.12	Woodroffe and Moss 1984
Vietnam			
Rhizophora apiculata	8°50′ N	2.58–5.15	Clough et al. 2000
Rhizophora apiculata	8°50′ N	2.43–3.88	present study

the period between two sampling visits was rather long (1 month), particularly during the wet season leaching could play an important role. Therefore, the wet period data presented here are most probably an under-estimation.

Discussion

Litter fall production

Loi et al. (2002) showed that the soils at the sites in the Tam Giang 3 and Kien Vang enterprises are fairly homogeneous with respect to pH, salinity, total-N, total-P, and available-P. Therefore, differences in litter fall of *Rhizophora apiculata* stands, as we found, are directly correlated to the age of the trees. This is in line with findings of Clough et al. (2000) who published similar results for leaves in 6–10 year old stands of *Rhizophora apiculata*, and found a further drop in 36 year old stands. This may be due to the more densely leaved canopy in the young stands compared to the more open old stands. Also biological characteristics of the old trees play a role, as these trees produce much woody materials, such as stems, branches

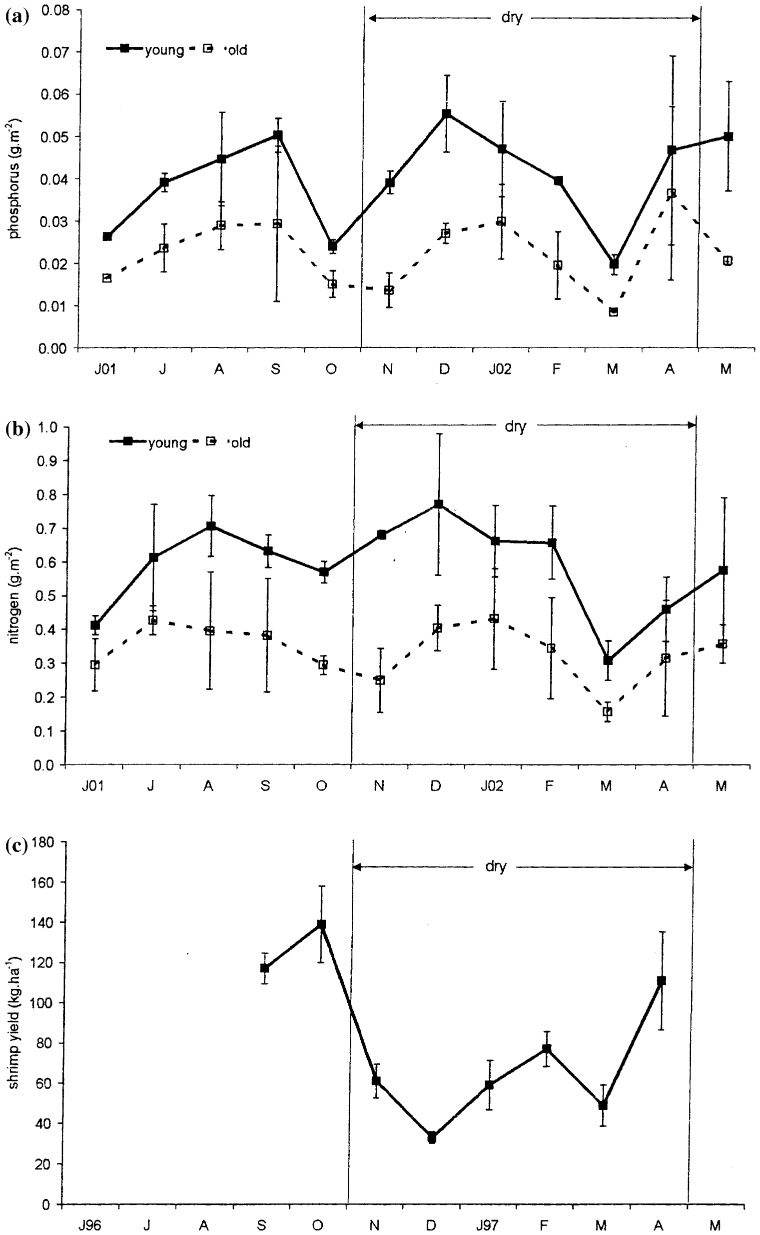

Figure 5. Monthly nutrient input *via* leaf litter (g m^{-2}; June 2001–May 2002) compared with shrimp yields (kg ha^{-1}) in the Camau province, Vietnam. (a) phosphorus, (b) nitrogen, (c) shrimp yield (kg ha^{-1}; from Johnston et al. 2000).

and reproductive parts, while the young trees produce more leaves (Hong and San 1993). Further, Clough et al. (2000) concluded that the leaf area index (LAI) declined as stands age in Camau forest. These certainly affect the litter fall. In conclusion, the decline of litter fall with age seems likely to be causally related to the forest ageing indeed.

Nutrient input through leaf litter

Much of the litter from mangroves can be exported *via* creeks to adjacent waters (Robertson et al. 1992; Bunt 1995), and the role of this matter in supporting a rich aquatic and benthic food supply for fisheries is well documented (Mackey and Smail 1996). Nutrients (N, P) derived from mangrove litter may also boost aquatic primary productivity. Nitrogen and phosphorus levels were considerably higher in the leaf litter of younger stands (7 and 11 years). Mangrove plants in the younger stands are able to take up more nitrogen and phosphorus than those in the older stands. Overall, our results suggest that young stands produce a large quantity of higher quality litter as input to the aquatic system. This may directly or indirectly enhance food availability to the shrimps in younger stands. Indeed, Morrisey et al. (2003) showed that numbers of faunal taxa were higher in younger stands, and numbers of individuals of several taxa were also higher at these sites.

The input of phosphorus and nitrogen peaked during the second part of the wet period and again during the first part of the dry period. This input of nutrients (and organic matter) to the aquatic systems surrounding the mangrove forests is a potential boost to the shrimp production. This can be either directly through the high amount of prime quality food, or indirectly *via* algae, fungi and bacteria. In fact, Johnston et al. (2000) found that shrimp yields peaked between July and October (1996/97) in the Ca Mau province (Figure 5c). We suggest that there may be a direct relationship between the input of nutrients *via* leaf litter and dynamics of shrimp production. The shrimp peak followed the N and P input peaks in the wet period when litter derived material may directly be washed into the ditches and become available to the foodwebs. In the subsequent dry period, the material will tend to stay on the mangrove soil for longer and only gradually becomes available to the ditches.

Our results suggest that litter of younger mangrove stands serves as a significant food source for aquaculture and fisheries in coastal areas. As the Mekong Delta is the most important commercial fishery area in Vietnam, local government and managers should focus on preservation and reconstitution of pristine mangrove system in the region.

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