Estimation of mangrove litter production by counting of living leaves in Nagura estuary, Ishigaki Island, southwest Japan

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Abstract Direct count of living leaves on mangrove trees was tried at a mixed forest of *Bruguiera gymnorrhiza* and *Rhizophora stylosa* in Nagura estuary, Ishigaki Island, southwest Japan on 2 and 3, August 1995. Number of leaves in a tree showed good relationship to the tree height, and similarly, total leaf weight to the structural index. Applying space length of trees and weight of artificially dried leaves, the leaf biomass in the experimental site was estimated as 5.35t/ha in riverine and 4.54t/ha in inner grove, with estimated tree density 20,732 trees/ha. In case of the former in riverine, the litter productivity was derived to 3.88 t. dry/ha. yr, and particulate organic matter produced from that was 4.42t. dry/ha. yr.

Key words : litter, mangrove, Nagura estuary, Ishigaki Island

Forwords

Mangrove litter-fall is the main source of enrichment for sediment under the forest and for the adjacent estuarine waters. Since the fact that decomposed leaf-fragments of mangroves serve as a substratum to grow bacteria community and then produce protein-rich particles existing as high turbidity in water was reported by Odum and Heald (1975) , the litter has been understanding having a possibility to take a part of primary production in aquatic ecosystem in stead of phytoplankton.

Although litter production is estimated by application of structural indexes in forest survey, that of a tree or some grove of a known number of tree must be aimed for considering primary consumers of the derived organic particles, like as estuarine benthic communities in the mangrove water zone. The purpose of study is, therefore, to know how many leaves would be produced from an expected mangrove tree, and to apply direct leaf-counting to estimation of the litter production in general studies.

Materials and Methods

The study was undertaken in a mixed mangrove forest of *Bruguiera gymnorrhiza* and *Rhizophora stylosa* in the estuarine coast of Nagura River (24°24′ N, 124°8′ 30″ E), Ishigaki Island, southwest Japan on 2 and 3, August 1995 (Fig. 1 and 2). Four trees of each species having a variety of size were experimented on counting of total number of the leaves and measurement of height, DBH or the modification, extent of branches and the others, in living condition, for riverine or isolate materials; and equally three trees of each species for the inside and completely groved part. Leaf counting was done by direct observation for every branches with self-climbing to stem of the experimental tree, which might lead to nearly 5% error in numbers over a thousand. Tree density was calculated by the average of space in the site. For estimation of organic matter derived from the litter-fall, some 10 leaves of each species was picked up and artificially dried in an oven at 105℃, 4 hours in laboratory.

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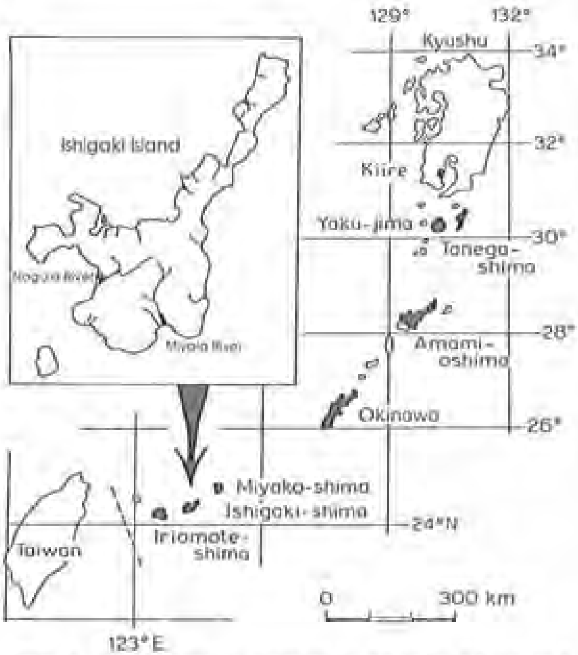

Fig. 1 Map showing mangal in Ishigaki Island and the islands of Nansei-Shoto, southwest Japan. The dark parts indicate mangal vegetation (Partially from Hosokawa et al., 1977)

Fig. 2 Location of the experimental site in Nagura estuary.

Results

Mangrove forest was distributed in the mouth of Nagura River and stretched the area to southern inner-coast of the lagoonal waters, almost same as a vegetation map shown by Tagawa and Suzuki (1985) who reported the biomass and others there. In the experimental site, woody flora includes almost only two species, *Bruguiera gymnorrhiza* and *Rhizophora stylosa*, composing fine closed forest just the inner of riverine with about 5 m height (Photo. 1). A row of trees along riverine and isolated tree mostly found at delta zone provide much branches and twigs, on the contrary, every stem of the inner grove has no branch except the part of the top with less leaves.

In experiment on *Bruguiera gymnorrhiza*, materials ranging from 80 to 457cm height were conducted for leaf counting of which the data showing with Photo. 1, and on *Rhizophora stylosa* ranging from 107cm to 340cm height, as that showing with Photo. 2, of which all belong to the riverine or isolate part. The results were arranged to height-leaf numbers relationship as Fig. 3, with the data of same experiment for the inner grove. Seeing Fig. 3, it is apparent that height of isolated tree has a fine allometric regression to number of leaves as in equation obtained from computer analysis $Y = 0.0134X^2 + 18.289X - 1.407$ for *B. gymnorrhiza* and $Y = 0.0218X^2 + 8.698X - 1.002$ for *R. stylosa*, where Y stands for number of leaves per tree and X for tree height (cm); but no in case of the inner grove in which number of leaves decreased almost to that of young trees at about 100cm height, though the approximate value is seen to be somewhat higher in *B. gymnorrhiza* than in *R. stylosa*. Considering the curves of this relation, the minimum would settled down to 150-300 leaves by 50-150 cm height for both species, and the maximum almost attains to 10,000 leaves for *B. gymnorrhiza* and 4,000 leaves for *R. stylosa* by 300-450cm height, at approximation.

A structural index, D^2H was referred to leaf biomass, in which D is diameter at 130cm height, but that at 1/2 of the height was tentatively adopted to small tree below 130 cm height (Fig. 4). The regression for riverine or isolate trees in *B. gymnorrhiza* was $Y = 0.014X - 0.022$ and in *R. stylosa* was $Y = 0.053X + 0.018$, where Y means weight of leaves (kg, dw) and X is D^2H (cm^2, m). The single leaf weight has less variance at random sampling, and that of a leaf was 1.75 ± 0.23 g in fresh, 0.66 ± 0.09 g in dry on *B. gym-*

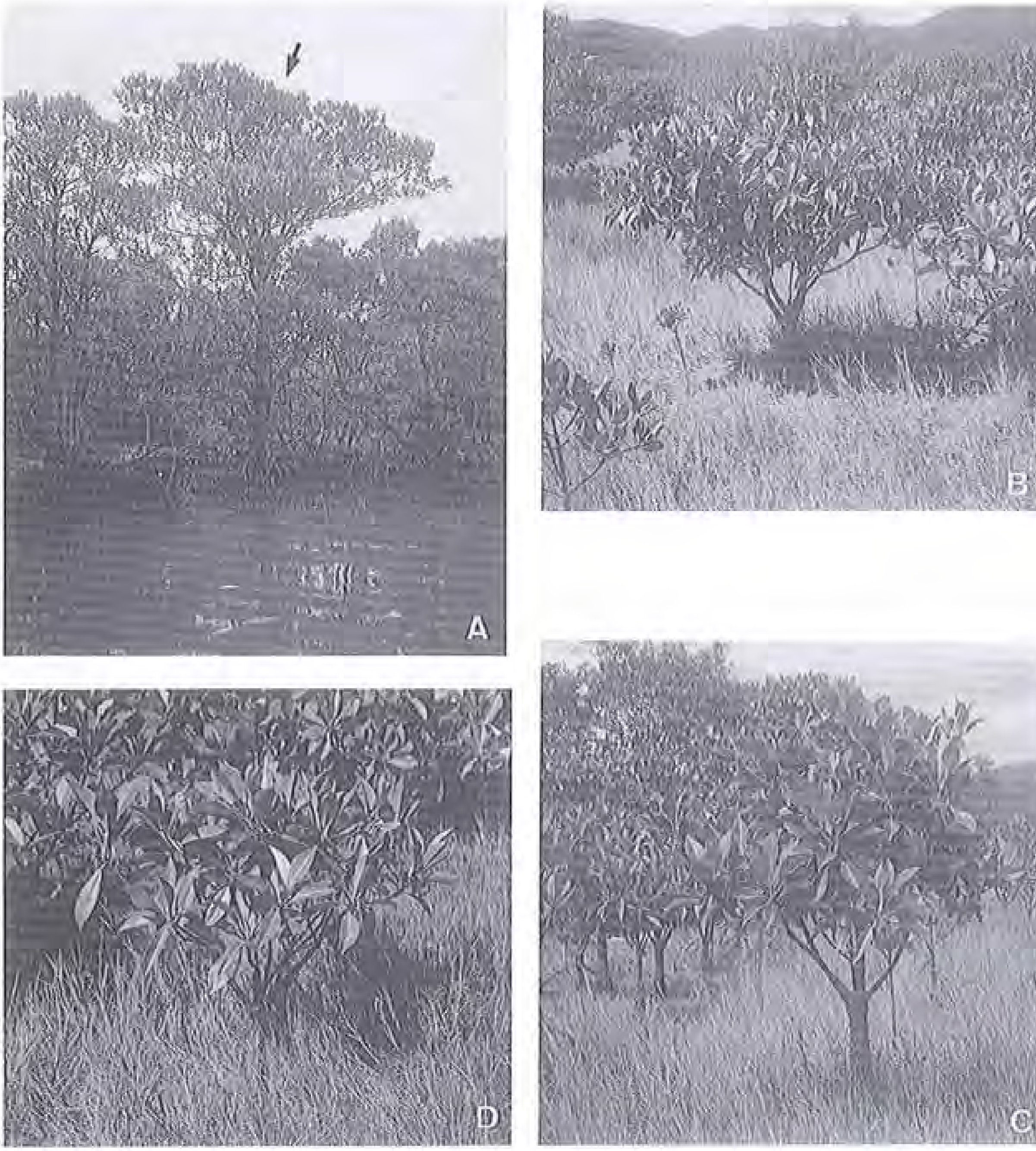

Photo. 1 *Bruguiera gymnorrhiza* used for leaf counting in Nagura estuary.
A: 9,747 leaves, 457cm high; B: 1,773 leaves, 155cm high, C: 717 leaves, 110cm high, D: 170 leaves, 80cm high.

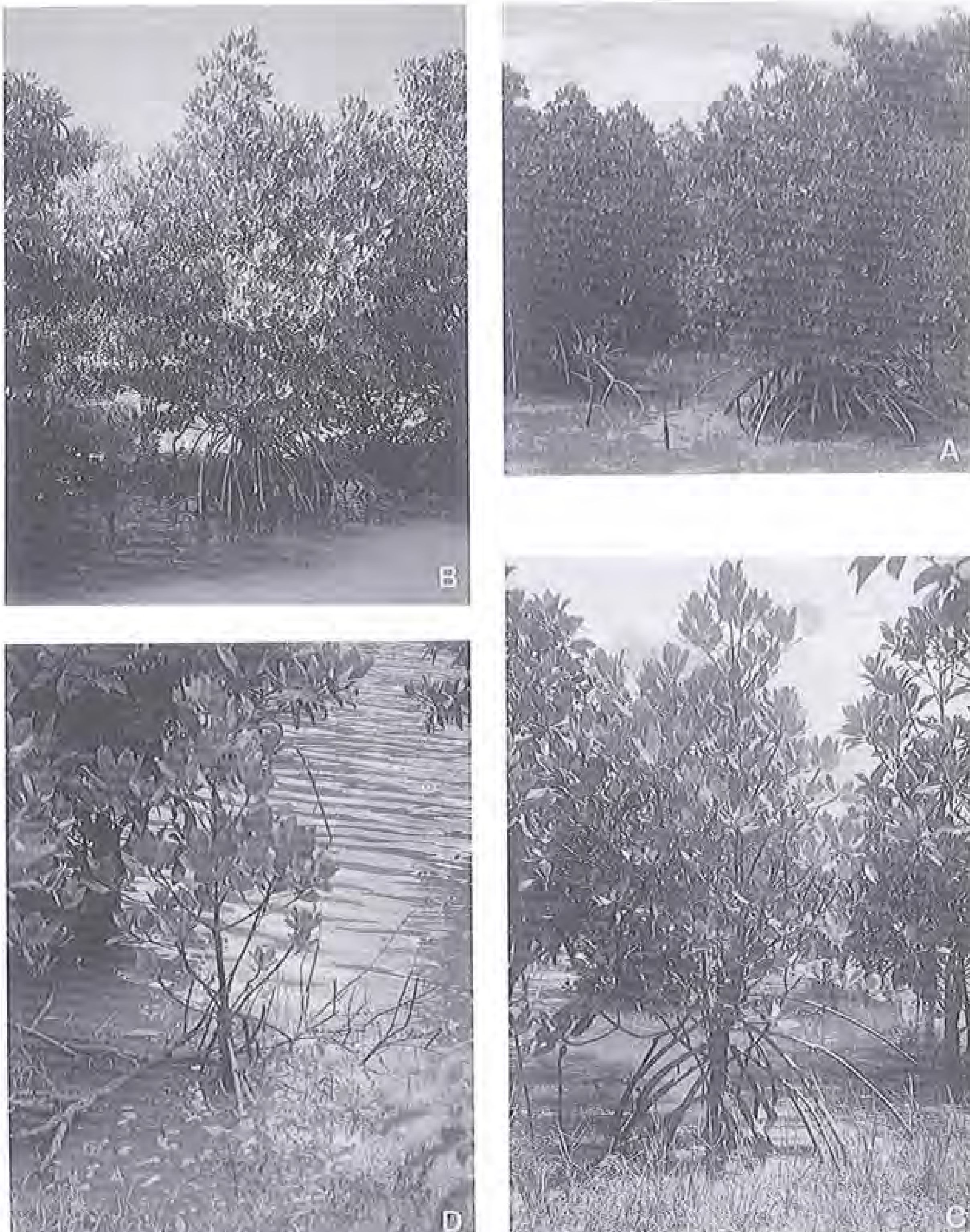

Photo. 2 *Rhizophora stylosa* used for leaf counting in Nagura estuary.
A: 4,289 leaves, 340cm high, B: 4,034 leaves, 267cm high, C: 1,300 leaves, 195cm high, D: 253 leaves, 107cm high.

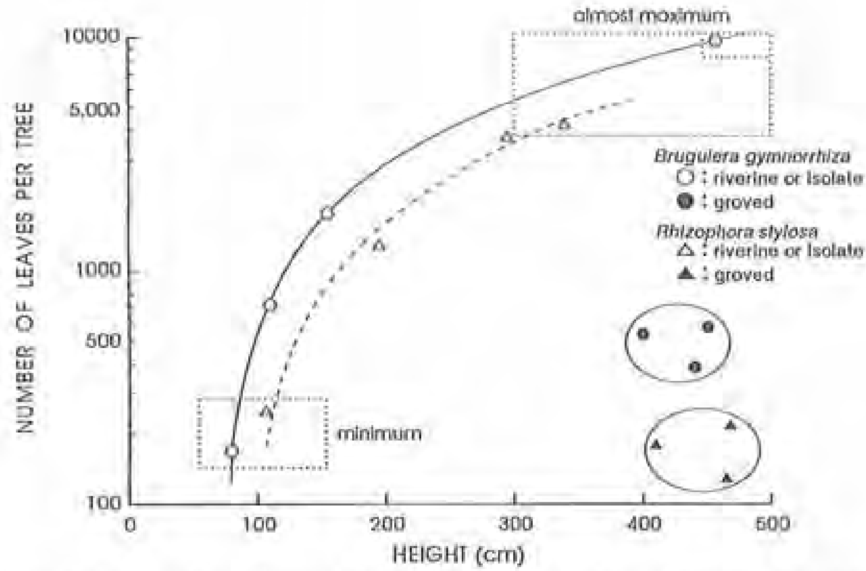

Fig. 3 Relationship between height of tree and number of leaves in *Bruguiera gymnorrhiza* ($Y=0.0134X^2+18.289X-1,407$) and *Rhizophora stylosa* ($Y=0.0218X^2+8.698X-1,002$) in the mixed vegetation at the experimental site.

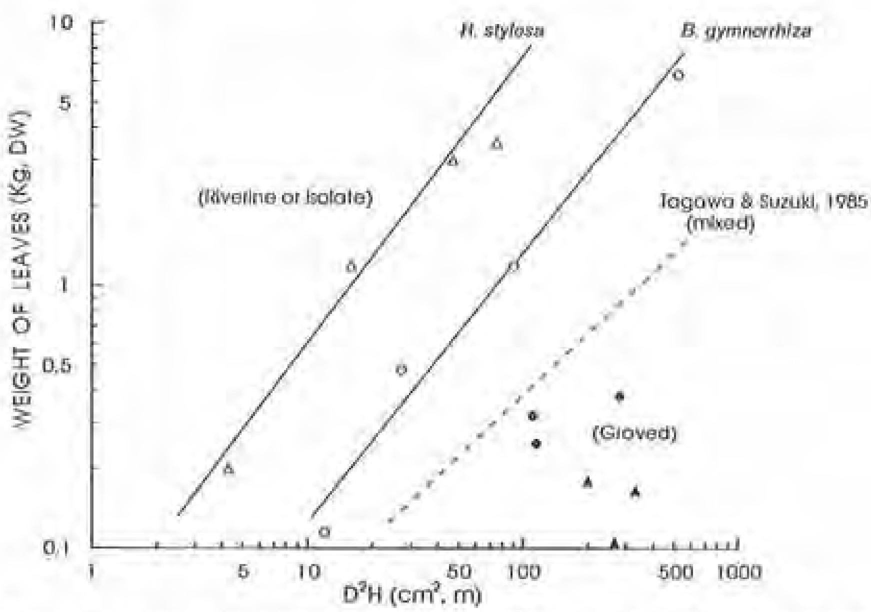

Fig. 4 Relationship between structural index (D^2H) and the total weight of leaves in *Bruguiera gymnorrhiza* ($Y=0.014X-0.022$) and *Rhizophora stylosa* ($Y=0.053X+0.018$) in the mixed vegetation at the experimental site.

norrhiza, and 2.10±0.33 g in fresh, 0.79±0.15 g in dry on *R. stylosa*, which was multiplied to total amount of a tree. Difference of leaf amount between two species is clear to the structural index, indicating *R. stylosa* having more leaves than *B. gymnorrhiza* at similar size, and showing similar structural pattern for both due to same inclination of the regression lines. Regression by Tagawa and Suzuki (1985) on mixed forest of both species at Nagura estuary showed lesser amount of leaves to same value of

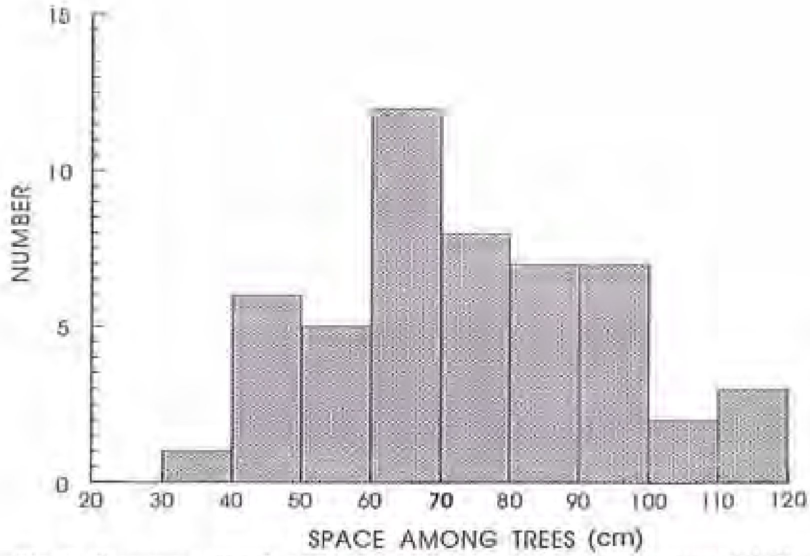

Fig. 5 Frequency distribution of space among trees in the experimental site. (Space 70㎝ was adopted as a value for calculation of stem density)

structural index than our result (Fig. 4). It might be due to different method or location. Both species at inner grove were almost of big size with a few of leaves, and could not form this relationship as the Figure.

For estimation of leaf and litter production, we applied space length of trees which was used to obtain a total number of trees per unit area. The result showed a mode is nearly 70㎝ (Fig. 5), which may not be enough for precise estimation due to the lesser measurements, nevertheless, this value should be tentatively adopted to the study in a limited discussion, because the space is changeable to conditions of forest itself, geological factors on soil distribution, and others.

Discussion

Purpose of the study is, as already mentioned, to try to estimate litter productivity for a limited mangrove forest including the experimental site, and to apply this procedure with counting of living leaves. Then, we explain a flow to calculate the leaf biomass by use of every results. When thinking a square of 1 ha, 20,732 trees can be exist by use of 70㎝ space. Suppose a side of square locates mostly in riverine, which is usually occupied with only a row of healthy trees and calculated as 144 trees having each 8,000 leaves of a maximum in an average of mixed forest with *B. gymnorrhiza* and *R. stylosa*, remainding 20,588 trees is unhealthy having 300 leaves as an average in inner grove of both species. As it is the mixed forest, dry weight of a leaf is postulated to 0.73 g by an average of 0.66 g and 0.79 g of two species. The calculation is: $(144\times8,000\times0.73)+(20,588\times300\times0.73)=5,349$kg, almost 5.35 t/ha., as dry litter. In case of inner grove, same square dimension has unhealthy 20,732 trees with each 300 leaves, therefore, the total amount is: $(20,732\times300\times0.73)=4,540$kg, namely 4.54 t/ha (Fig. 6). Where a square provides

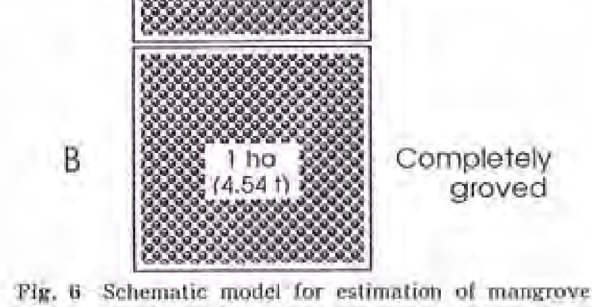

Fig. 6 Schematic model for estimation of mangrove litter production in the experimental site faced to river. A: quadrat including a row of riverine trees, B: quadrat inside and completely groved.

healthy trees in a side as in riverine, leaf amount increases about 20% of the value of unhealthy zone.

Former figure is close to the result, 5. 9 t /ha by Tagawa and Suzuki (1985) of an average of three sites at Nagura estuary. Angsupanich and Aksornkoae (1994) also presented 5. 5 t /ha.yr of total litter including 93-99 % of leaf litter on mixed forest dominated by *B. gymnorrhiza* and *R. stylosa* at a canal site of Phang-nga Bay, southwestern Thailand; in which they indicated that even though the value is lower than the other reported figures, it is not considerable only for leaf biomass, and height of trees in examined site was low.

On the data summarized by Day et al. (1989) from Brown and Lugo (1982), Twilley et al. (1986), and Day et al. (1987), the litter production was the highest as 1,170 g / m², yr in riverine and the least as 120 g / m², yr in scrub of mangal types, with the intermediate 730 g / m², yr. in basin which is close to results by us and Angsupanich and Aksornkoae (1994), thus, it is variable to situation and its environmental conditions. These variance of litter production was inversely relative to the tree density as that the case of the highest amount in riverine corresponded to the least density 1, 760 trees/ha and the least production in scrub to the highest density 25, 032 trees/ha from data of Pool et al. (1977), and Brown and Lugo (1982). The latter value of tree density is close to 20, 732 trees/ha of our result which is a case at inner grove having less leaves as same as isolated trees of about 1. 0m height, likewise, the cited value is also the case of 1.0m tree height in scrub. This coincidence will support our result to be included in some generalized property of mangrove vegetation.

Leaf counting of the experiment was carried out in August, an active growth season of mangrove leaves in the district, therefore, underestimating of the leaf production would be avoidable. Productivity of the litter fall was estimated to 3, 88 t . dry/ha. yr by use of the result 5. 35 t /ha, and 1. 38 yr., an average of the leaf renewal speeds in *B. gymnorrhiza* 1. 28 yr. and *R. stylosa* 1. 48 yr. by Kyuma et al. (1988) in Iriomote Island, adjacent to Ishigaki Island, on account of the mixed forest of both species. As for the amount of particulate organic matter or detritus produced from decomposed mangrove litter and supplied to aquatic environment, it was tentatively estimated on our result at present, with applying a coefficient 1. 14 derived from difference between values of litter fall and particles in a limited estuarine area (Tagawa, 1983), namely, 1. 14×3. 88 = 4. 42 t . dry/ha.yr. Transportation of the amount to aquatic ecosystem, especially to the consumer or benthos should be discussed in our next study.

References

Angsupanich, S. and Aksornkoae, S. (1994) : Mangrove litter production in phang- nga Bay, southern Thailand. Tropics, 4 (1), 35-40.

Brown, S. and Lugo, A. E. (1982) : A comparison of structural and functional characteristics of saltwater and freshwater forested wetlands. In Gopal, B. et al. (Eds.), Wetlands Ecology and Management. Proc. 1st Internat. Wetlands Conference, New Dehli. National Inst. Ecol. and Internat. Scientific Publ., New Dehli, India. Sept. 1980. 109-130. (Cited from Day et al. 1989)

Day, J. W., Conner, W., Ley-Lou, F., Day, R. and Machado Navarro, A. (1987) : The productivity and composition of mangrove forests, Laguna de Terminos, Mexico. Aquat. Bot., 27, 267-284.

Day, J. W., Hall, C. A. S., Kemp, W. M. and Yanes-Arancibia, A. (1989) : Estuarine Ecology. John Wiley and Sons, New York, 558pp.

Hosokawa, T., Tagawa, H. and Chapman, V. J. (1977) : Mangals of Micronesia, Taiwan, Japan, The Philippines and Oceania. In Chapman, V. J. (Ed.), Wet Coastal Ecosystems. Elsevier Sci. Publ., Amsterdam, Chapt. 14, 271-291.

Kyuma, K., Nishimura, K., Hirai, H. and Funakawa, S. (1988) : Characteristics of soil/ sediment under the mangrove forest. Rep. Environment. Sci., Ministry of Education, Science and Culture, Japan, B-344-R12-04, 123-147. (in Japanese)

Odum, W. E. and Heald, E. J. (1975) : The detritus-based food web of an estuarine mangrove community. In Cornin, L. E. (Ed.), Estuarine Research, Vol. 1, Academic Press, New York, 265-286.

Pool, D. J., Snedaker, S. and Lugo, A. E.(1977) : Structure of mangrove fores tin Florida, Puerto Rico, Mexico, and Costa Rica. Biotropica, 9, 195-212.

Tagawa, H. (1983). Ecology of mangroves and Mangals, (IV). Aquabiology (Japanese), 5 (1), 43-47.(in Japanese)

Tagawa, H. and Suzuki, E. (1985) : A mangrove in Nagura estuary, Ishigaki Island, South Japan. Studies on the Mangrove Ecosystem, Nodai Research Institu- te, 54-60.

Twilley, R., Lugo, A. E. and Patterson-Zucca, C. (1986) : Litter production and turnover in basin mangrove forests in southwest Florida. Ecology, 67, 670-

683.

桑原　連*・城間唯夫*：オヒルギおよびヤエヤマヒルギの葉枚数に基づく落葉由来有機物量の推定

1995年8月2-3日に沖縄県石垣島名蔵湾河口域のオヒルギ・ヤエヤマヒルギ混成林で，それぞれの種の樹高，幹径等を測定し，同時に一本の木の全葉枚数を数えた。葉枚数と樹高，全葉重量と胸高直径との間には強い回帰関係があり，これらと樹間間隔から密度20,732本／haを求め，一枚の葉の乾重量を用いて葉の現存量を河岸部で5.35 t /ha，林内で4.54 t /haと推定した。河岸部の年間枯葉供給量は3.88 t . dry/ha. yr，その分解により生じる水域の有機懸濁物量は暫定的に4.42 t . dry/ha. yrと推定された。

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