MANGROVE HABITAT DYNAMICS AND SEA-LEVEL CHANGE

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MANGROVE HABITAT DYNAMICS AND SEA-LEVEL CHANGE
–A Scenario of the Changing Process of Delta and Estuary Type Mangrove Habitat and the New Role of Pendulum and Buffer for the Global Environment–

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1. Introduction

This project adopted a comprehensive evaluation of mangrove habitat response against the predicted rapid sea-level rise by the global warming based on the multidisciplinary field research. The IPCC informed that the amount of rapid sea-level rise will reach to 1 meter in coming one century (IPCC: 1995). Such rapid sea-level change will cause a severe effects to the mangrove ecosystem because of the spatial limitation and situation.

The total area of mangrove habitat is about 180 thousand square kilometers (ISME;1996) and it covers one third of tropical to sub tropical coast like a narrow forest belt. The ecosystem is located in a delicate environmental situation, for instance only in the upper half of tidal zone, or as a buffer or frontier where fluvial and marine processes interact. As a result, the rapid sea-level rise will affect to the habitat firstly. Besides, the following habitat changes are considerable. The habitat will move towards inland accompanying with the expansion of saline water. It will cease by rapid change of their own ecological environment. The arrangement of mangrove zonation or plant sociological forest structure must be deformed with the changing tidal situation. Such environmental deformation will not only affect to the ecosystem but the adjacent shallow marine and human settlement area also will be suffered.

Although, the mangrove ecosystem is a typical human deformed biogeomorphological ecosystem. The large amount of forest biomass production and organic matter accumulation are distinctive components of the biogeomorphological processes. The complicated and densely developed stems and aerial root system may have a role to trap transported sediments. The mangrove biogeomorphic function is a source of organic material including a sink of sediment. Actually, the habitat kept the level along with moderate sea-level rising by their own peat accumulation during 2,000 to 1,000 years BP. It is needless to say that the biogeomorphic processes vary between geomorphic situation, which deform by various kinds of human interference.

2. System based approach

In fact the present-day mangrove ecosystem is characterized by human interfered biogeomorphological system. Thus the mangrove habitat dynamics should be analyzed and synthesized in term of the forest dynamics, biomass production, accumulation or erosion of peat, organic matter and sediments, material transportation, environmental changes in the surrounding inter tidal areas, categorization and estimation of human impacts, and sea-level fluctuation. Such an approach will lead to more extensive knowledge of mangrove ecosystem and permit the prediction of its response to future rapid sea-level rise.

3. Field research for basic knowledge completion

The field research activities intended to obtain the basic knowledge for fabricating the scenario of the mangrove habitat environmental change. In this project from 1996 to 1997 the following research items were carried out at Satun and Khrong Thom area in the western coast of Malay peninsula, Thailand, Kuala Kemaman in eastern coast of Malay peninsula, Malaysia and Sematan island near Kuching city Sarawaku.

1). Holocene sea-level change

Sin Sinsuckle (1993) discussed and reviewed the research related to Holocene sea-level change in Thailand. The higher sea-level (about 2 meters above sea-level) was deduced using the height of retreat points of Notch at Ko Phiphi, Krabi, and Satun (Kawana & Ichikawa,1998). The Holocene sea-level change at the study area is clarified as follows. The sea-level rose as the middle Holocene transgression during 7,000 yrs.B.P. The highest sea-level might be marked 2 meter a.m.s.l at middle Holocene. About 2,200 yrs.B.P., the sea-level was lower about 1 meter than at present one. After this period, sea-level rose again very graduary, and it reached to the present sea-level until 1,000 years ago.

2). Geomorphological development of mangrove and its surrounding area

Mangrove habitat is classified into seven environmental setting (Woodroffe,1992) and categorized into three kinds of geomorphic situation(Miyagi et al,1989). The investigated areas are categorized as a type of "estuary and delta" in the geomorphic setting and in the environmental setting it was evaluated as "river dominated and tide dominated". Small but typical delta is developing at the Satun and Khlong Thom. It means that the large amount of sediments supply from drainage basin compare with the other kinds of geomorphic setting.

Prof. Umitsu revealed the arrangement of lowland topography and the Mid Holocene marine transgression. He pointed out the area of the Holocene coastal plain, which is limited only in the mangrove area in case of Satun area. It means there is no place where the mangrove habitat can move towards land along with sea-level rise.

3). Mangrove habitat development and maintenance during the Late Holocene environmental change

Remarkable organic rich to peaty mangrove deposits indicate the existence and the scale of mangrove habitat. The start of the present day mangrove habitat formation was 1,000 years ago. The sea-level fluctuation is a negligible quantity. The mangrove forestation started at the level of mean water, then, the sedimentation of mangrove organic matter has been risen their ground level to the highest high water level during this 1,000 years. It amounts to 1 to 2 meter because of the macro tidal situation.

Lower organic clayey deposits developed as a basal peat (the term of basal peat is named by Sinsakul; 1984, 1985) between under the estuary clay and on the Pleistocene sediment, which indicates the time of 6,000 to 7,000 years BP. Mangrove forest moved from sea-ward to land-ward during the stage of the Holocene marine transgression, although the habitat was small and temporal comparing to the present one. C^{14} dating yielded that thick organic rich mangrove deposit (mangrove peat or organic clay to silt loam) developed on the estuary clayey deposit during 2,920 to 2,200yr. BP. It means the actual mangrove habitat was developed and expanded after 2,000 to 3,000 years ago.

4). Micro-topography and substructure of mangrove habitat related to tidal level

Micro-topography was resolved from cross profiles taken by auto leveling from the fixed relief of the mean water level. Substructures were clarified by boring by Hillar type pollen sampler and non contaminated thin wall sampler. The typical cross profiles of the mangrove habitat micro-topography of two areas are drawn in Fig.1. The height of most mangrove habitat exists between the M.H.W to H.H.W.L. The spatial arrangement of the habitat differs in two areas (Fig.2a,b).

5). Estimation of the maximum velocity of organic matter accumulation in selected habitat

The velocity of peat accumulation in case of tidal flat (Miyagi et al, 1995) is amount to more than

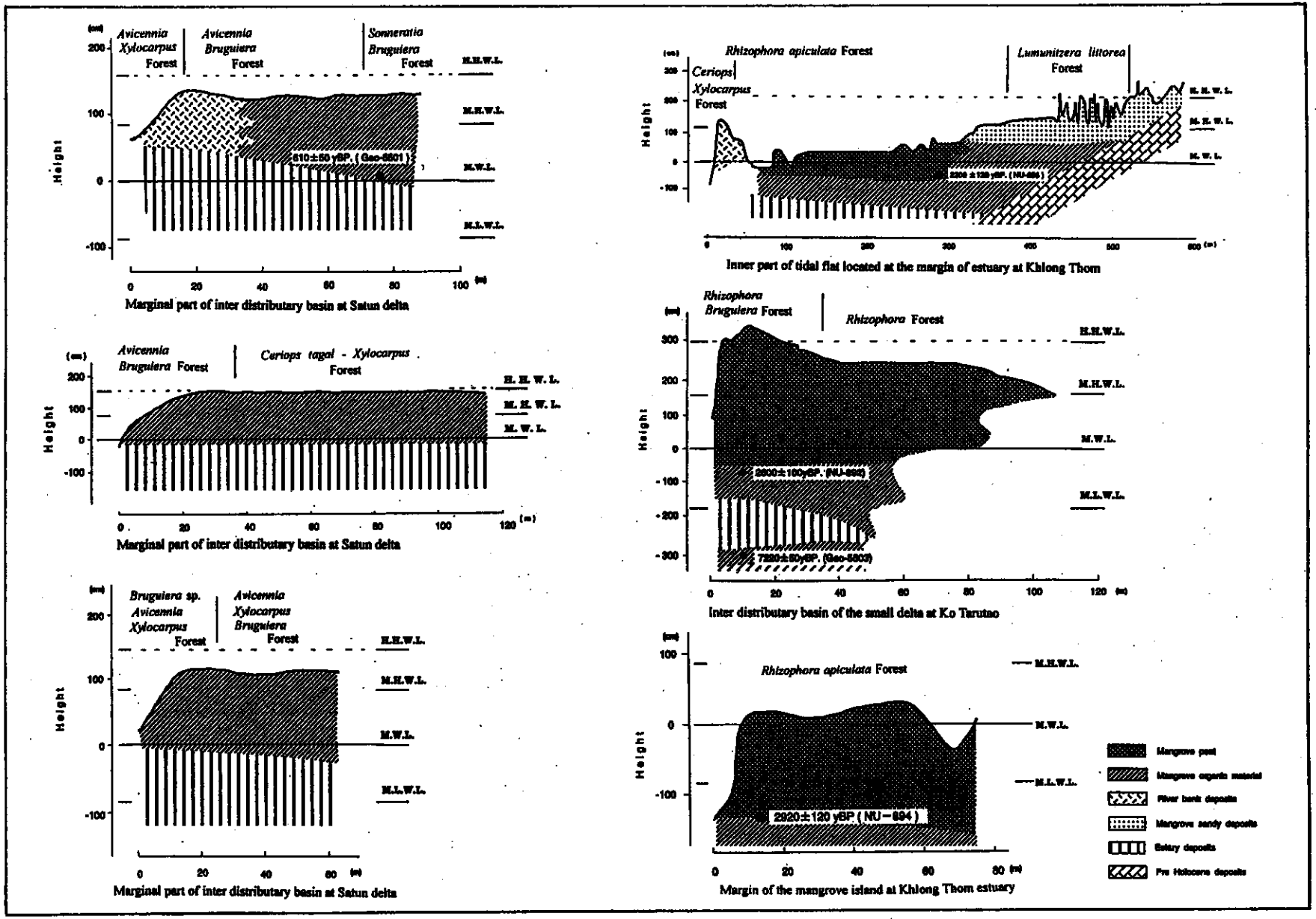

Fig. 1 The typical cross profiles of the mangrove habitat micro-topography, deposit, forest type

2mm/yr. and lesser than 5mm/yr. We are able to deduce the relation of mangrove habitat development and sedimentation rate from the relationships between the C-14 ages and the depth of the collected samples (Miyagi et al, 1998). The "recent mangrove deposit" (Miyagi et al. 1998) accumulate 1 to 2 meter since 1,000 years. It means the velocity of accumulation is amount to 2mm/yr. In case of Satun (Loc. 1-2), it accumulated 150cm since 610 years. It indicate the mean velocity is up to 3mm/yr. On the contrary, at the transgression stage, the velocity of sea-level rise was up to 4mm/yr. during 7,000 years ago. The sediment of this stage which called the" basal peat" the organic matter contains is much poor than the "recent mangrove deposit". It seems that the small or poor mangrove habitat had developed at the stage. As a result, we are able to estimate the considerable maximum velocity of mangrove material sedimentation in these areas are 3mm/yr.

6). Mangrove forest structure and zonation by phitosociological approach of forest structure are analyzed and categorized in Fig.3.

The vegetation zone of mangrove forest is well correlated to the level of tidal zone.

7). Regeneration process of mangrove forest

8). Trace the succession in early stage of mangrove forest at Sematan island Sarawaku

9). Categorize and estimate the characteristics of shallow marine sedimentolological processes

10). Estimation and classification of the strength of human interference to the mangrove ecosystem

11). Land use and forest use in and adjacent mangrove habitat

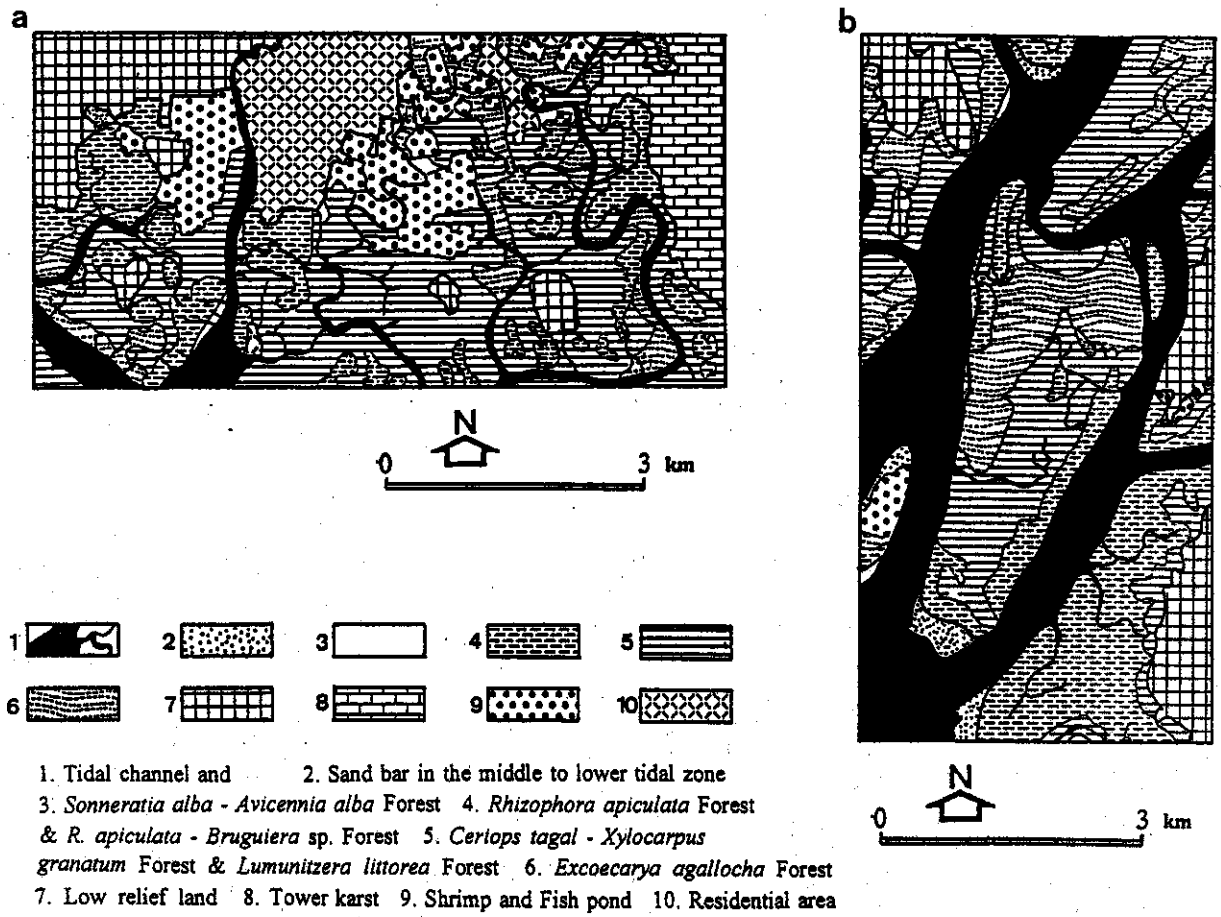

Fig. 2 Vegetation arrangement of mangrove habitat in a part of Satun area (a) and Khlong Thom area (b), Thailand

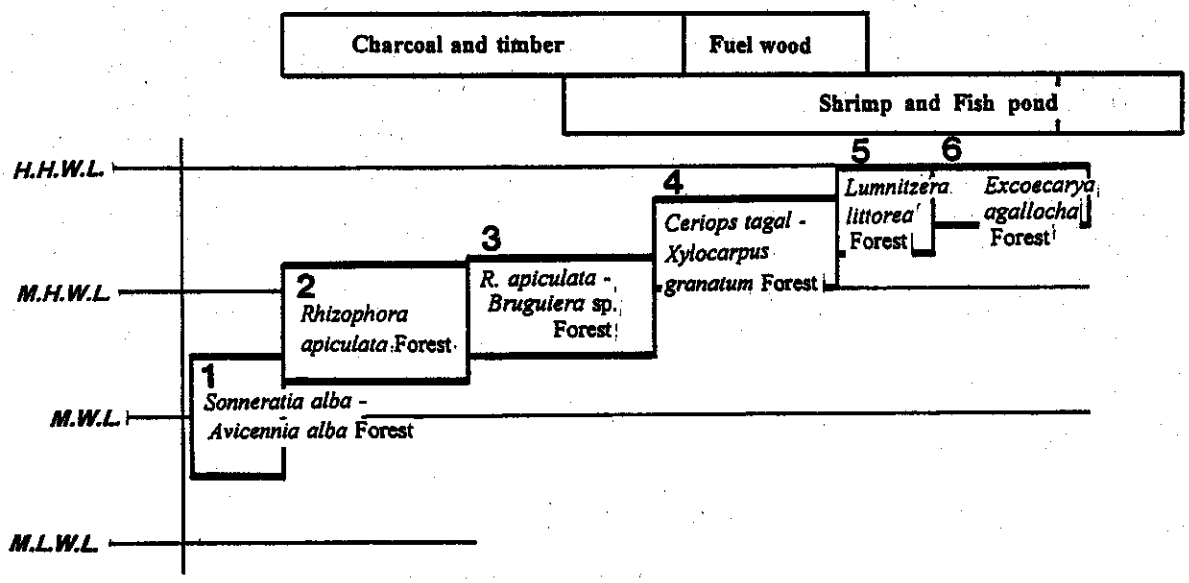

Fig.3 Mangrove zonation and major land use related to the tidal situation in Southern Thailand

4. Scenario of mangrove habitat dynamics

The following factors are estimated to evaluate the changing mangrove habitat.

1). Basic factors

(1) Estimated sea-level rise by global warming (IPCC 1995)

Case-1 50mm/100yr. (Mean of predicted sea-level rise in the coming century)

Case-2 100mm/100yr.(Maximum of predicted sea-level rise in the coming century)

(2) The factors related to the habitat development and maintenance (vary with the geomorphic setting).

The sedimentation velocity as a habitat level maintenance is 3 mm/yr. for example in the estuary and deltaic area. The maximum velocity of peat accumulation is estimated to 2mm/yr.

(3) Geomorphic setting

The geomorphic setting is categorized into tidal flat without sediment supply, estuarine and deltaic area, beach ridge and its lagoon area, and mangrove island.

2). Local factors

(1) Tide amplitude

It is the range between the lowest low water level to the highest high water level and the mangrove habitat develops in the upper half of the range. It has approximately 3 meter in Satun area and 4 meter in Khrong Thom area.

(2) Micro-topography and habitat arrangement

The mangrove forest is classified to *Sonneratia alba - Avicennia alba* forest, *Rhizophola apiculata* f., *R. apiculata - Bruguiera* sp. f., *Ceriops tagal- Xylocarpus granatum* f., *Lumnizera littorea* f., and *Excoecarya aggallocha* f. from the marginal lower part to inner of the upper part.

(3) Adjacent landform of mangrove habitat

The area of coastal lowland of flood plain is very limited. The habitat is not able to shift to land-ward for the shortage of area. A large amount of suspended sediment transported from the upper reaches and submerged in the upper half of the estuarine area because of high salinity.

(4) Land use and land deformation

Land deforms for shrimp and fish pond development. Pond development is divided into two types. One is developed in the inner marginal area of mangrove forest and the other is developed in just inland beside of the mangrove habitat. The former one is common in Satun area and a type of exclusive mangrove utilization. The later one is common in Throng Thom area, which is a type of co-existed use of mangrove ecosystem. Bank of the shrimp ponds has a role to block the movement of the bank of mangrove habitat to land-ward and sediment transportation by fluvial processes from land-ward. Timber cutting for charcoal production was a type of human interference for mangrove ecosystem.

3). Minor factors

The change of coastal erosion, sedimentation, and change of the energy of tidal current and wave actions are not considered. Bioturbation by crustaceans is also not evaluated.

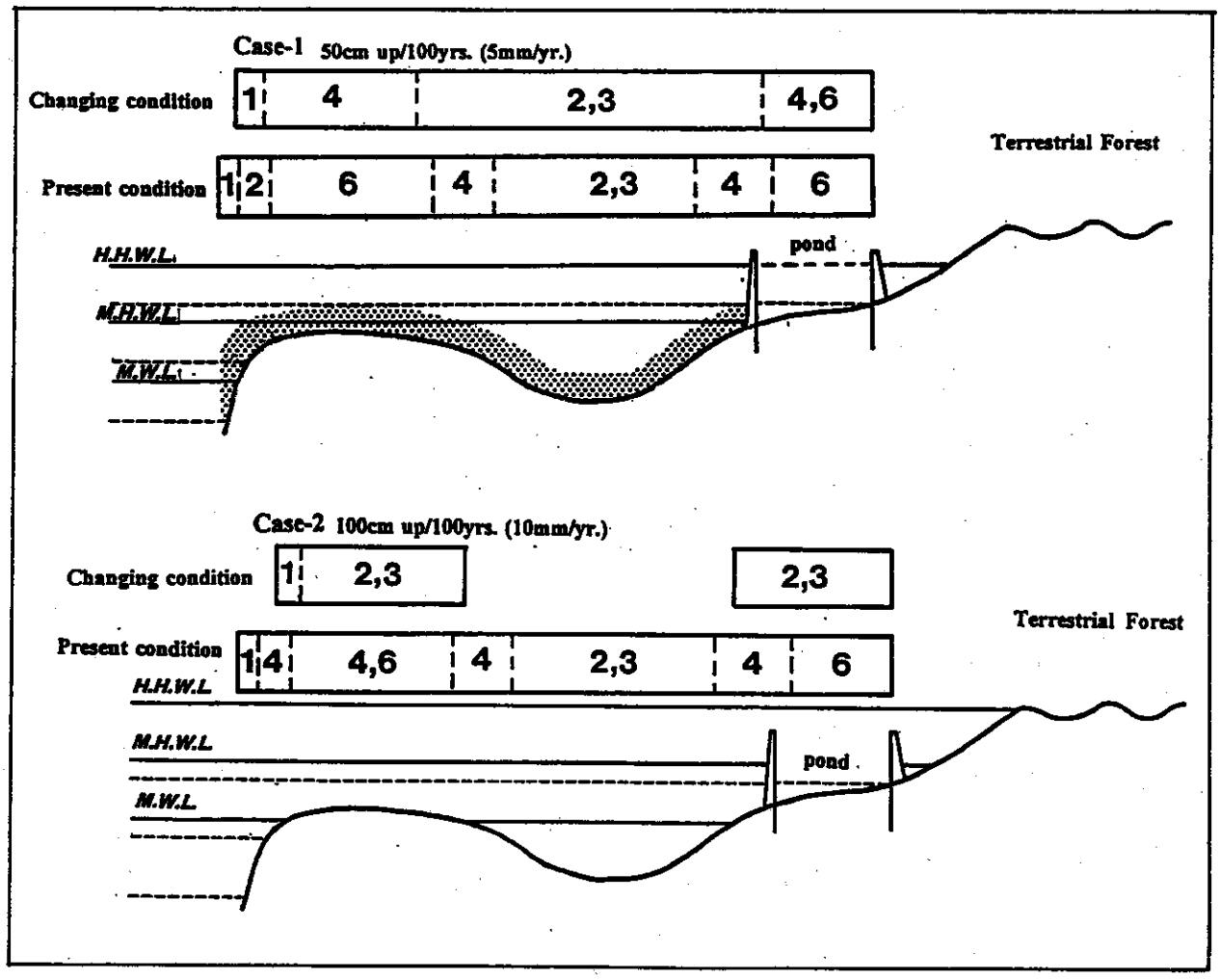

Fig. 4a Change of mangrove habitat in Satun area, Thailand

Habitat type 1: *Sonneratia alba – Avicennia alba* foretst 2: *Rhizophora apiculata* forest 3: *R. apiculata – Bruguiera* sp. forest 4: *Ceriops tagal – Xylocaopus granatum* forest 5: *Lumnizera littorea* forest 6: *Excoecarya agallocha* forest *Break lines are initial tide levels

5. Sea-revel rise and mangrove habitat dynamics

The project estimated the change of mangrove habitat, the probability of habitat survival, change of the forest zonation etc. in two cases. The changes are illustrated to Fig. 3a,b.

1).Change of mangrove habitat in the Satun area

Case-1: The ground level will rise by organic matter accumulation. The change of micro topography is very weak because of this accumulation. The total of mangrove habitat is able to keep the own area by organic matter accumulation against the moderate sea-level rise. Vegetation arrangement might be change by the minor change of the habitat level. According to this change, *Excoecarya agallocha* forest will decrease widely instead of *Rhizophora apiculata* forest, R. *apiculata – Bruguiera* sp. Forest, *Ceriops tagal – Xylocarpus granatum* forest expansion.

Case-2: The ground level is change widely and strongly. Organic matter accumulation might be weak because of the sea-level rise is too rapidly.

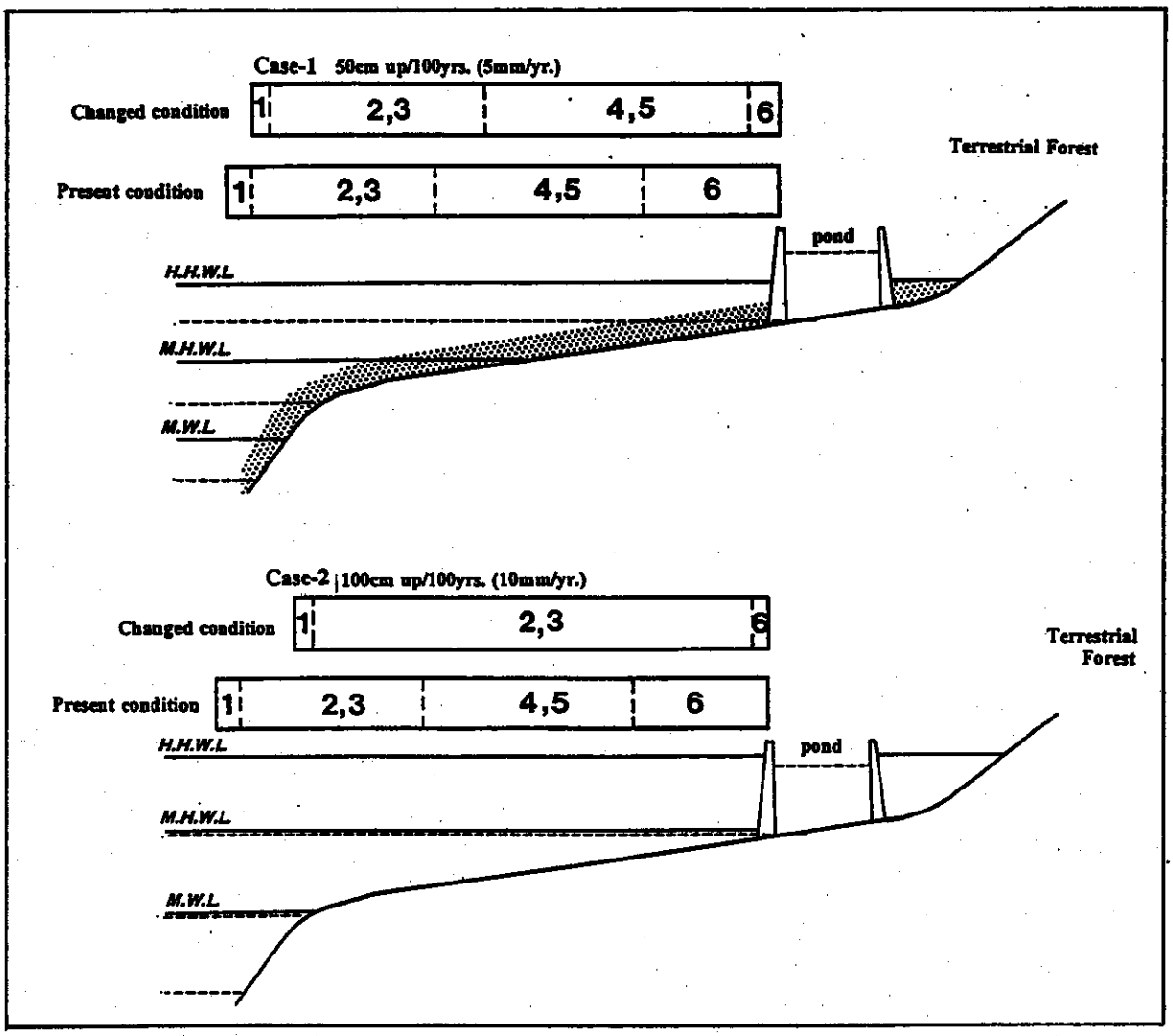

Fig. 4b Change of mangrove habitat in Khlong Thom area, Thailand

Habitat type 1: *Sonneratia alba – Avicennia alba* foretst 2: *Rhizophora apiculata* forest 3: *R. apiculata – Bruguiera* sp. forest 4: *Ceriops tagal – Xylocaopus granatum* forest 5: *Lumnizera littorea* forest 6: *Excoecarya agallocha* forest *Break lines are initial tide levels

The area of mangrove habitat will be much smaller than initial one. All most of all habitat will sink few decades cm. According to this change, *Ceriops tagal – Xylocarpus granatum* forest, *Excoecarya agallocha* forest might be die out in course of this rapid sea-level rise. *Rhizophola apiculata* forest and *R. apiculata – Bruguiera* sp. forest will shift to higher portion.

Mangrove habitat is not able to move to land ward because of the bank of ponds and the lacking of lowland.

2). Change of mangrove habitat in the Khrong Thom area

Case-1: The ground level will rise by organic matter accumulation. The change of micro topography is very weak because of this accumulation. The total of mangrove habitat is able to keep the own area by this accumulation against the sea-level rise. The area of *Excocarya agallocha* forest will getting smaller and smaller instead of other types of forest expansion.

Case-2: The level up of ground surface is very small. By this reason, the tidal situation will changes. In spite of this ground level change almost of all mangrove area is located in the mean water level to mean high water level. The area of mangrove forest slightly decrease from frontal zone. The area of total mangrove habitat can keep itself.

The *Ceriops tagal – Xylocarpus granatum, Lumunizera littorea* forest and *Excoecarya agallocha* forest will much smaller instead of *Rhizophola apiculata* forest and *R. apiculata – Bruguiera* sp. forest expansion widely.

6. The new role of the mangrove ecosystems- the role of pendulum and buffer for the global environment

The present-day mangrove habitat is developed since 2,000 yrs. B.P. accompanied with the gradual rise of the lower sea-level, or is developed since 1,000 yrs.B.P. in the stable sea-level. During the gradual sea-level rise, the mangrove habitat is able to keep the vertical situation in the tidal range by accumulation of mangrove organic sediment (Miyagi & Fujimoto,1989, Fujimoto & Miyagi, 1993, Fujimoto et al.,1996). In the phase of stable sea-level, during this 1,000 years, and particularly at the delta and estuary type mangrove , the large amount of the habitat has been risen their own vertical situation from mid to higher portion in the tidal range.

The stable condition of sea-level since recent 1,000 years is vary important for the evaluate the survivability of the habitat by rapid sea-level rise. In the **macro tidal area**, such as the Andaman sea coast mangroves, the vertical situation of the habitat is located on 0.5 to 2 meter higher than the mean sea-level because of the large sedimentation and the large tide amplitude.

It is needless to say that the mangrove habitat can survive between the mean water to the highest high water level. As a result, the mangrove habitat where located in the macro tidal area which has been preserved in spite of great change in the inner structure of mangrove forest by 50 cm rise of sea-level in 100 yrs because of the higher location of the habitat and the gradual accumulation of mangrove organic materials.

On the contrary, the influence of rapid sea-level rise is relatively severe in the **micro tidal area**. The reason suggests that the thinner tidal area of the upper portion of the micro tidal range has greater effects of the rapid sea-level rise. For example in case of Thailand Bay the tidal amplitude is less than 1 m. It means that the upper half of the tidal range as the mangrove habitat is only 50 cm and there is no sedimentation for the small area of the upper drainage basin. In such case, if the sea-level rise reaches up to 50 cm the habitat will be effected by completely different tidal condition and that will enhance the diminish of habitat. Three factors play a great role in the estimation of habitat change are as follows: **(1) the velocity of sea-level rise, (2) the tidal amplitude and (3) the rate of sedimentation**.

The tidal amplitude is more or less 2 m in almost all the coastal area of the world. In case of less than 50 cm (5 mm/yr.) rise of sea-level we can think that mangrove habitat can survive in almost all

the area. In such case the mangrove forest can accumulate the organic material. It means that mangrove forest has a role of CO_2 sink and that mitigates the global warming.

In case of more than 50 cm rise of sea-level almost all of the mangrove forest will be diminished severely. At the same time, the accumulated organic material might be decomposed and diffused in the shallow marine area. So the mangrove forest signify as a great source of CO_2 in the global environment. According to our estimation the mangrove ecosystem holds a double role in the decreasing and enlarging capability of CO_2 in the mitigation and provocation of global warming. Therefore, the mangrove ecosystem is like a pendulum of global environment. Thus the human activity can only control the appropriate role of mangrove ecosystem in the global warming.

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