A Note on Paleobotany of Mangroves

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Abstract
There is little published research on the paleobotany of mangroves. According to Rollet (1981), from 1600-1975 the number of papers on the topic was 126, which was 2% of the 5,653 papers on mangrove research published in that period. Research on mangrove paleobotany since 1976 has also been minimal. We collected and reviewed papers on the paleobotany of mangroves, visited museums to obtain information on fossils, mainly pollen, and analyzed the collected data. The results are described below.

The first mangroves appeared during the Upper Cretaceous era, 100-65 million years ago (mya). The evolution of mangroves is thought to have been strongly related to sea-level change (transgression-regression cycles) in geological times. Some woody angiosperms growing in freshwater swamp forests succeeded at growing in tidal areas and acquired salinity tolerance when the vast extent of those areas underwent marine transgression. That event happened not only once but likely several times after the Upper Cretaceous, and each time the biodiversity of mangroves became richer. The origin of present mangroves can be divided into two groups, the Old and New (Worlds, and we predicted that the two mangrove groups could also be found in the period of the Upper Cretaceous. There were several questions we could not resolve, for example, how the expansion of their distribution proceeded. Mangrove propagules are spread by sea currents and they expand their habitats. The world’s seas were connected during the time from the Upper Cretaceous, when the first mangroves appeared, to the Miocene, when the Tethys Sea closed. Nevertheless, we assume that for over 80 million years, the Old and New Worlds did not mix. Genetic research on the migration and evolution of mangroves will be essential for complementing fossil studies.

Key words: New and Old Worlds, origin of mangroves, paleobotany, Tethys Sea, Upper Cretaceous-Miocene

1. Introduction
Our efforts at developing mangrove plantations date back to 1978. In the first ten years we developed mangrove plantation technology by creating experimental plantations along the coasts of the Arabian Peninsula, mainly in Saudi Arabia and the United Arab Emirates (UAE). We were successful at developing the technology for growing mangroves in arid coastal areas. Since 1993, mangrove reforestation and conservation activities have been conducted in Vietnam, Myanmar and Ecuador. In addition to conducting such activities, we have visited mangrove areas all over the world (Fig.1 and Table 1).

Very recently we became interested in the paleobotany of mangroves. The reason for this interest was our visit to Wadi el Hitan in the Western Desert of Egypt in May 2009. Not a single plant could be seen in the desert—it was like the surface of the moon—but it was there that we found an inlet of the Tethys Sea from the Eocene epoch (ca. 40 mya). In this area we found several fossilized whale bones from the Eocene and also some fossils which were said to be mangrove roots.

The next year, in February 2010, we again visited Egypt with five Japanese scientists, each from different academic fields. Prof. Moustafa M. Fouda, adviser to the Ministry of State for Environmental Affairs, Egyptian Environmental Affairs Agency, Nature Conservation Sector, kindly supported us as he had in the previous year. Some paleontological scientists belonging to the Nature Conservation Sector guided us to the fields. We surveyed three sites, Bahariya, Wadi el Hitan (Muller & Burns, 2010) and Qatrani. Bahariya is where Ernst Stromer had found dinosaur fossils (Tyrannosaurus rex, Palarititan stromeri) in 1914-1915. It was known, based on a shellfish fossil study, that this place was the coast of the ancient Tethys Sea in the Upper Cretaceous (ca. 100-65 mya). When we visited the Egyptian Geological Museum in Cairo, we saw fossilized Avicennia leaves collected from Bahariya. According to Darwish and Yousry (2007), the fossil was dated to 97 mya, within the Upper Cretaceous. If their identification could be confirmed, the fossil would be the oldest mangrove fossil ever found.
Our interest increased more than ever.

To further investigate worldwide mangrove paleobotany we visited many natural history museums around the world, for example, the Natural History Museum in London, the Field Museum in Chicago, the Natural History Museum in New York, the Royal Tyrrell Museum of Palaeontology in the Badlands of Alberta, Canada, and the Natural History Museum in Tokyo.

Since this study was based on geological and ecological uniformitarianism, we define first of all, the term "mangroves." Then we describe results of our analyses, mainly from reviews of the literature and the fossil record. Finally we remark on our expectations for further studies in this field.

“Mangrove” is not the name of a single plant, but a generic term. Mangrove forests are plant communities which occur in intertidal areas in the tropical and subtropical zones. They have characteristic tropical floras, hygrophytes and halophytes. Another unique characteristic is that they transfer their propagules by sea currents and spread their habitats. Mangroves mainly comprise woody angiosperm species, with no conifer species, and a few palm and fern species. Also mangroves are divided into two groups, mangroves and mangrove associates. This classification, however, is not clear as there are several different opinions taken by different scientists. This study focuses exclusively on “strict or true mangroves” (our classification approximately following Tomlinson, 1986), but not mangrove associates.

There were two objectives to our research: 1) to find the origin of mangroves, i.e., when, where and why they appeared in geological time; and 2) to ascertain when and why their distribution was divided into Old World mangroves (which occur in Asia, Oceania and the east coast of Africa), and New World mangroves (which occur in the Americas and west coast of Africa). (Fig. 2 and Table 2)

2. Methods

We carefully analyzed the mangrove paleobotany literature and examined the fossil record. For our literature search up to 1975, we used the bibliography by Rollet (1981). There were only 126 mangrove paleobotany studies, accounting for 2% of the total number of 5,653 mangrove studies listed in this bibliography (Table 3). There was no complete bibliography like

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**Table 1** Main mangrove-related activities carried out by the Al Gurm Research Centre/Action for Mangrove Reforestation (Actmang).

<table>
<thead>
<tr>
<th>Year</th>
<th>Main activities on mangroves</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985 - 1987</td>
<td>Research on restoring mangrove forests in the Truk Islands, Pakistan and Bangladesh requested by UNESCO.</td>
</tr>
<tr>
<td>1990 - 1992</td>
<td>Establishment of techniques for mangrove plantation in Myanmar, as requested by UNDP/FAO.</td>
</tr>
<tr>
<td>1993</td>
<td>Provision of advice on mangrove reforestation requested by Muscat Municipality, Oman.</td>
</tr>
<tr>
<td>1993-present</td>
<td>Mangrove reforestation support to local people in Vietnam and Myanmar.</td>
</tr>
</tbody>
</table>
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Rollet’s for the post-1976 period. Studies such as Spalding et al. (1997) and Plaziat et al. (2001) have also noted few recent mangrove paleobotany publications. We assumed that few scientists were interested in the paleobotany of mangroves.

In interpreting the fossil record, we found two competing explanations as to how mangroves came to exist in a given area. One was that terrestrial plants acquired salt tolerance to survive in brackish areas and became the ancestors of the mangroves in their place of origin where their fossils were deposited, and the other was that they migrated from their place of origin by expansion of their distribution through a long drift after they had already become ancestral mangroves. The latter idea gained support from our planting experience in Khafji, Saudi Arabia: We were trying to keep *Rhizophora* propagules vital longer at our station. When they were kept in sea water (4% salinity), they retained their ability to germinate for more than half a year. Based on our observation, we surmised that when the propagules traveled by tidal currents in the condition of floating on seawater and being shaken by waves, their ability to germinate may have lasted longer. Their ability to germinate might be maintained much longer than we found in our experiment. Therefore, propagules might have been able to migrate long distances from their place of origin to the places where their fossils were found. However, the sea currents during geological times are not known. We hope that our hypothesis will be supported when data on sea current patterns in geological times become available.

3. Results and Discussion

3.1 Mangroves and environmental change in geological times

The fossils recorded in each geological time from the Upper Cretaceous to the Miocene (100-7 mya) are shown in Table 3. The records from the Pliocene to the Holocene (7 mya-recent) are not shown, because there are few records.

The transition of continents, oceans and currents during these epochs shown in Fig. 4 is predicted to have had a strong relationship with the expansion of mangrove distribution. Also, climates and characteristic organisms in geological times are shown in Table 4.

Table 2 Genus and species of mangroves distributed in old and new worlds (arranged from Tomlinson, 1986 and Spalding et al., 1997).

<table>
<thead>
<tr>
<th>Genus name</th>
<th>Number of species</th>
<th>Old World</th>
<th>New World</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acanthus</td>
<td>2</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Acrostichum</td>
<td>2</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Aegicelitis</td>
<td>2</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Aegiceras</td>
<td>2</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Avicennia</td>
<td>5</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Bruguiera</td>
<td>6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Campsiestemon</td>
<td>2</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>Ceriops</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Conocarpus</td>
<td>1</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Cynometra</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Diospiros</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Dorichandre</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Excoecaria</td>
<td>2</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Heritiera</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Kandelia</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Laguncularia</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lumnitzera</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mora</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Nypa</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Osbornia</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Pelliciera</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Pemphis</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Rhizophora</td>
<td>6</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Scaphiphora</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Sonneratia</td>
<td>8</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Tabebia</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Xylocarpus</td>
<td>2</td>
<td>-</td>
<td>2</td>
</tr>
</tbody>
</table>

Total: 51 spp. in 23 genera 12 spp. in 7 genera

Table 3 Number of papers on mangroves paleobotany 1600-1975 (arranged from Rollet, 1980).

<table>
<thead>
<tr>
<th>Period</th>
<th>Epoch</th>
<th>No. of papers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cretaceous</td>
<td>Upper</td>
<td>8</td>
</tr>
<tr>
<td>Tertiary</td>
<td></td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Paleocene</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Eocene</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>Oligocene</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Miocene</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Pliocene</td>
<td>2</td>
</tr>
<tr>
<td>Quaternary</td>
<td>Pleistocene</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Holocene</td>
<td>16</td>
</tr>
</tbody>
</table>

Total: 126
there are few leaf, stalk, root, fruit and seed fossils. As far as we were able to determine, only twelve genera out of 22 extant mangrove genera identified have been recorded; the ten remaining genera have yet to be recorded (Table 5).

It is assumed that the number of fossil records depends on the number of scientists in those fields or their research activities. Most scientists in mangrove paleobotany have worked in developed countries such as Europe, the USA, Australia and Japan. For instance, in Britain, four genera of mangrove fossils have been recorded because not only have there been many scientists, but also many active studies concentrating on “London Clay fossils” (Collinson, 1983; Kenrick & Davis, 2004). In Japan, eight genera, the greatest number among the studies, have been reported. It is said that those results were made by long-term efforts carried out by three scientists, K. Tsuda, J. Itoigawa and T. Yamanoi (Tsuda et al., 1986). There are very few fossil records in Asia, except Japan; and Africa, except Egypt and Nigeria, due to fewer opportunities for research on fossils.

**The Upper Cretaceous (100-65 mya)**

Since this period was warm, the sea was remarkably larger. At the end of the period, however, the sea area decreased because of cold weather. It was reported that from the middle of the Upper Cretaceous, angiosperms flourished (Stewart & Rothwell, 1993). We believe that the first mangrove appeared during this period, because the oldest mangrove fossils found so far have been *Avicennia* leaves (97 mya) in Egypt (Darwish & Yousry, 2007) and *Nypa* pollen (69 mya) in Brazil (Spalding et al., 1997).

The countries where fossils have been found are Sarawak, Malaysia, in Asia; Czechoslovakia in Europe; Egypt in Africa; Australia in Oceania; the USA in North America; and Guiana in South America.

Mangrove fossils found in this period consist of five genera from five families, *Avicennia* in Avicenniaceae, *Nypa* in Palmae, *Pelliciera* in Pellicieraceae, *Acrostichum* in Pteridaceae and *Conocarpus* in Combretaceae. Usually mangrove fossils are identified only at the genus level because of difficulty in identifying species, and those may not be the same as present species anyway. These fossils were recorded in different parts of the world but still in limited numbers.

**The Paleocene (65-54 mya)**

Paleocene mangrove fossil records include only *Nypa* in Nigeria and Brazil. Such few records may be due to global cooling at the end of the Upper Cretaceous, which is known as the time of dinosaur extinction. Mangroves might have survived, however, in tropical areas near the equator. It is expected that mangrove fossils will be found in that area.

Fig. 3 Global distribution of mangrove fossils found from the Cretaceous to Miocene (data from Rollet, 1981; Tsuda et al., 1986; Spalding et al., 1997 and Darwish and Yousry, 2007).
The Eocene (54-38 mya)

The Eocene Epoch was a time of warm or tropical climates across the whole earth. It is assumed that temperate flora flourished even in the present Arctic Circle. Mangrove fossils have been reported from seven genera of four families. Those are *Laguncularia* in Combretaceae; *Acrostichum* in Pteridaceae; *Bruguiera, Ceriops, Kandelia* and *Rhizophora* in Rhizophoraceae; and *Sonneratia* in Sonneratiaceae. In addition to the five genera of five families found in the Upper Cretaceous, a total of twelve genera in nine families of mangrove fossils have been recorded up to the Miocene Epoch.

The countries where the fossils were found are listed below: they are much more numerous than those of the Upper Cretaceous.

- Europe: UK, Belgium, France, USSR (Odessa, Turkmenia, Ukraine)
- Asia: India, Malaysia (Malaya, Sarawak)
- Oceania: Australia, PNG
- Africa: Egypt, Libya, Senegal
- North America: USA (Alabama, Georgia, Kentucky, Mississippi, Carolina, California, Tennessee, Texas)
- Middle and South America: Mexico, Panama, Jamaica, Puerto Rico, Columbia, Venezuela

It is thought that mangroves were at their prime during this period.

The Oligocene (38-26 mya)

The climate of the Oligocene is thought to have been mildly temperate. It is said that organisms characteristic of the Miocene tended to decline, and modern types flourished.

Mangrove fossils have been found in four countries:
regions: an unidentified genus in Borneo, Asia; Sonneratia in Australia, Oceania; Acrostichum (disputed) in Hungary, Europe; and Pelliciera and Rhizophora in Puerto Rico, Middle America.

• The Miocene (26-7 mya)

The climate was warm and wet, and becoming cooler and more arid in the late Miocene. The Tethys Sea still extended up to the area where Europe currently is. The climate was warm and wet, and becoming cooler and more arid in the late Miocene. The Tethys Sea still extended up to the area where Europe currently is.

• The Pliocene-Holocene (7 mya-recent)

This epoch extended over 7 million years. We assume that the interests of scientists have not been focused on mangroves, and their main themes might have been prevalent woody angiosperms (disputed) Acrostichum in Poland,

- Mangrove fossils have been found in nine countries/regions as listed below:
  - Asia: Borneo (genus not identified), Sonneratia in Australia, Oceania; Acrostichum in Australia, and an unidentified genus in the Marshall Islands.
  - Europe: Acrostichum in Poland.
  - Middle and South America: Pelliciera and Rhizophora in Brazil and Colombia, Avicennia in Colombia, Laguncularia in Cuba, Avicennia in Trinidad and Rhizophora in Puerto Rico.

- Even in the ice ages of the Pleistocene, however, we suppose that mangroves flourished around the equator.

4. Concluding Remarks

4.1 Reasons plants become mangroves

As mentioned above, the first mangroves appeared in the Upper Cretaceous. It is thought that there were four reasons for the evolutionary origin of mangroves in that period.

The first of these was the prevalence of woody angiosperms. Most of the early mangrove species were woody angiosperms except for Acrostichum. This period was the time of the Cretaceous Transformation, when angiosperms were eminently flourishing. This was a prerequisite condition.

The second was a tropical climate. Generally this period was warm, except for a reduction in temperatures after the giant meteor crashed into the earth (which led to the dinosaur extinction). Mangroves, it must be remembered, are tropical plants.

The third was sea-level change (transgression and regression). It is thought that the direct reason for the transformation of terrestrial plants into mangroves was sea-level change. Sea levels in the Upper Cretaceous were more widely varied than at any other geological time. The sea extended its reach, but at the end of the epoch, tropical plant distributions decreased due to coldness. It is thought that such a phenomenon (transgression and regression) happened not only once. It is estimated to have repeated several times during the 35 million years of the Upper Cretaceous. Huge tidal land areas remained even after regression. Over the course of time, woody angiosperms which acquired salt tolerance successfully extended their habitats as niches in coastal tidal lands.
The fourth reason was hygrophytic adaptation. Marine organisms have evolved to occupy land via fresh water wetlands, but mangroves migrated from the land to the sea, which is thought to be an easier adaptation. The ancestral plants which evolved into mangroves might have grown in coastal swampy forests near tidal areas.

As mentioned above, based on fossil records, five genera in five families of mangroves appeared in the Upper Cretaceous and an additional seven genera in four families appeared in the Eocene. We assume that those which evolved into mangroves increased after the Eocene, so that the biodiversity of mangroves became richer.

At the present time, the highest diversity of mangrove species in the world occurs in Southeast Asia. Many mangrove species may have arisen here in geological times, and it is possible the first mangroves appeared in this region. There are still very limited fossil data to verify this idea and further studies are anticipated in the future.

4.2 Origins of Old and New World Mangroves

Modern mangroves are divided into two major groups: Old and New World mangroves. We hypothesize that the origins of mangroves go back to the Upper Cretaceous, the same period in which the oldest mangrove fossils are found.

Why did these two groups occur? We reply that the answer is not simple, because many things happened during geological history, but we suppose that angiosperms growing in wetlands near sea shores faced selective pressure to evolve salinity tolerance. We assume that the three genera of Avicennia, Nypa and Rhizophora occurring along the Tethys Sea coasts might be ancestors of the Old World mangroves, and the four genera of Avicennia, Nypa, Pelliciera and Rhizophora occurring along America’s coasts might be ancestors of the New World mangroves (Fig. 3), but this should be verified.

Fossils of Rhizophora have been found on both continents, including Czechoslovakia in Europe and the USA in North America. Modern Rhizophora varieties occur in both the Old and New Worlds, but as different species. Since Rhizophora was recorded in both Worlds, the ancestral genus must have occurred before the separation of the Old and New Worlds, and then evolved independently after the separation. Incidentally, there are five Old World species of Rhizophora: R. apiculata, R. mucronata, R. stylosa, R. x lamareckii and R. x selala, and three New World species: R. harrisonii, R. mangle and R. racemosa.

The same idea applies in the case of Avicennia. Fossils of Avicennia occurring along Tethys Sea have been found in Egypt from the Upper Cretaceous, and in Australia from the Eocene; and those occurring along the coasts of America have been found in the USA from the Eocene.

Modern Avicennia species also differ between the Old and New Worlds. After separation of the continents, the ancestral species evolved into five species in the Old World: A. alba, A. integr, A. marina, A. officinalis, and A. rumphian; and three in the New World: A. bicolor, A. germinans and A. schauerian.

Mangroves on the western coast of Africa are categorized as New World mangroves, but there is almost no record of mangrove fossils in that region. We tried to explain mangrove distribution from the data of Nigeria and Cameroon in West Africa having records of mangrove fossils (Ellison et al., 1999).

There are a few papers on Nypa fossils in the Upper Cretaceous in Nigeria (Germeraad et al., 1968) and Cameroon (Salard-Cheboldaeff, 1981), as well as Nypa fossils in the Paleocene and Eocene, and Rhizophora fossils in the Oligocene and Miocene. What do these data indicate? The paleo-Atlantic Ocean between America and Africa grew as the continents divided during the Upper Cretaceous. The mangroves occurring in West Africa since the Paleocene have possibly been of American origin. Mangroves may have migrated from America through the current circulation of the Paleo-Atlantic Ocean.

There are several questions not resolved. Mangrove propagules are spread by sea currents, and then they expand their habitats. The seas of the world were connected during the time from the Upper Cretaceous, when the first mangroves appeared, to the Miocene when the Tethys Sea closed (Fig. 4). We assume that for over 80 million years, mangroves of the Old and New Worlds did not mix. For example, neither fossils nor present species of Conocarpus or Pelliciera are found in the Old World, centrally, and neither Bruguiera nor Hertiiera have been found in the New World, but Pelliciera was widely distributed along the Tethys Sea (Ellison et al., 1999).

Since there has been very little research on mangrove paleobotany we need to apply new methods to answer questions about ancient mangroves. We believe that genetic research on migration and evolution is essential for complementing fossil studies. On the subject of modern mangroves, for example, comparative studies are needed on Acrostichum, Avicennia and Rhizophora which are distributed in both Worlds. We hope that if someone will continue this kind research, the origin and expansion of the distribution of Old and New World mangroves will become clear before long.

Genetic research on fossils is also important. We therefore hope that if DNA can be extracted from fossils, museums around the world might provide fossil materials for extracting DNA. Well preserved fossils of Nypa fruits and Ceriops propagules found in London Clay are kept in the Natural History Museum in London. A leaf impression of a 97 mya Avicennia is kept in the Geology Museum in Cairo.

We look forward to the frontiers of paleo-molecular biology being extended. The mangrove fossils listed in Table 5 are found in New and Old World continents.

Figure 5 shows photos from our travels to Egypt and London in 2009 and 2010.
Fig. 5 Our travels in the Western Desert of Egypt and in London in 2009 and 2010.

A) Fossil of *Dorudon atrox*, an ancient whale, in Wadi al Hitan.
B) It is said that this is a fossil of mangrove root system.
C) Nummulitidae, an indicator of the Eocene.
D) Second research team, 2010.
E) Stromer found dinosaur fossils on the hill.
F) Scenery of a corner of the Bahariya depression.
G) Impression of a lotus leaf found.
H) Fossils of seashells, evident of the Tethys sea.
I) Impression of an *Avicennia* leaf, 97 mya.
L) Fossil of *Ceriops* propagule found in London Clay.
Acknowledgements

We really appreciate the support and advice of many people for this study. Their names are mentioned below with our great gratitude (in random order, prefixes and titles omitted).


References


Motohiko KOGO

Motohiko KOGO established the Exploration Club at the Tokyo University of Agriculture when he was a student. In 1962-1963, he organized and joined a Himalayan expedition (exploring the area from the Barun Glacier to the Kangchenjunga Glacier and attempting to climb Mt. Twins, 7,350m, in Eastern Nepal). He has been studying mangroves since 1978. He successfully pioneered development of mangrove plantation technology on the Arabian coast in 1978-1991. Books he has written include Alone in the Himalayas (in Japanese, 1964) and The Green Adventure, Growing Mangroves along the Coasts in Arabia (in Japanese, 1988) among others. Prizes he has received include the Rolex Award for Enterprise (1987), NIKKEI Award for the Technology of Global Environments (1994), and others. He loves adventure in various fields, including academic.

Kiyomi KOGO

Kiyomi KOGO is a research fellow at Action for Mangrove Reforestation (an NGO). She received her M.Sc. (1967) in Geography at the University of Tokyo. She has been a writer, editor and part-time lecturer at many universities, including University of Tokyo, Ochanomizu Women’s University and Waseda University, among others. She has traveled to 80 countries and lived London, Seoul, Kuwait and Peking. She was an Associate Professor of Tohoku-Gakuin University. She has visited and co-operated with local people (especially women) in mangrove areas of Ecuador, Vietnam and Myanmar (Burma). She loves adventure as well as flower arrangement.

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