Chapter 4

Biodiversity studies on seaweeds and sea grasses in the coastal waters of Southeast Asia (Project-3: Seaweed/ seagrass Group)

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Introduction

Coastal habitats play a pivotal role for the lives of human beings. They provide the base of food web, important feeding, shelter, breeding and nursery grounds for fish, birds and other species, improve water quality by trapping pollutant and stabilize the coastal zone from erosion. However, as a result of ever-increasing coastal development and possibly climate change, coastal habitats have been decreased and degraded at an accelerating rate. To assist the sound integrated coastal zone management, it would be necessary to grasp present spatial distributions of habitats with standardized mapping methods to provide baseline information for managers at different levels and to enhance the awareness on how their coastal habitats are changing under human activities and climate change.

As one of the field research project of the Japan Society for the Promotion of Science (JSPS) on Coastal Marine Science during the years 2001–2010, the Seaweed/ Sea grass Group decided to promote several actions against the above mentioned degradation of sound coastal habitats. Such actions are: 1) Instruction of native young researchers and/or students on the basic methodology of ecological and taxonomical studies in each member country, because it needs a long time for us to know the changes of coastal environment and marine biodiversity through seaweeds and sea grasses. 2) Establishment of more advanced methodology for exactly monitoring the changes of seaweed and sea grass communities. 3) Lectures on how to identify seaweeds and sea grasses, especially focusing on several important groups. 4) Improvement of our knowledge on seaweed and sea grass ecology and taxonomy through the workshops. 5) Clarification of local floras by diligent collection of seaweed and sea grass specimens in the field.

By these actions under the multilateral co-operation of Japan and five countries, Thailand, Malaysia, Indonesia, Philippines, and Vietnam, we endeavored to contribute to the preservation of sound coastal environment and in turn marine biodiversity in East and Southeast Asian regions.

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Table 1. List of members of the Seaweed and Sea grass Group.

Country	Name	Affiliation
Indonesia	Grevo Gerung	Sam Raturangi University
Indonesia	Wawan Kiswara	Research center for Oceanography- LIPI
Indonesia	Tri Edi Kuriandewa	Research center for Oceanography- LIPI
Japan	Tsuyoshi Abe	Hokkaido University
Japan	Ryuta Terada	Kaogoshima University
Japan	Shigeo Kawaguchi	Kyushu University
Japan	Satoshi Shimada	Ochanomizu University
Japan	Hisao Ogawa	Kitasato University
Japan	Kenichi Hayashizaki	Kitasato University
Malaysia	Muta Hara Zakaria	Universiti Putra Malaysia
Malaysia	Japar Sidik Bujang	Universiti Putra Malaysia
Philippines	Edna Fortes	University of the Philippines, Diliman
Philippines	Marco Montano	University of the Philippines, Diliman
Philippines	Miguel Fortes	University of the Philippines, Diliman
Thailand	Thidarat Noiraksar	Burapha University
Thailand	Anchana Prathep	Prince of Songkla University
Thailand	Chatcharee Kaewsuralikhit	Kasetsart University
Vietnam	Dam Duc Tien	Haiphong Institute of Oceanology
Vietnam	Nguyen Huu Dai	Institute of Oceanography Nhatrang
Vietnam	Nguyen Xuan Vy	Institute of Oceanography Nhatrang

Research Planning

After our agreement on the above mentioned actions during the "Workshop on the Biodiversity Studies in the Coastal Waters of the East and Southeast Asia" which was held at Lankawi Island, October 2002, the Seaweed/Sea grass Group decided to do this in two aspects: ecological and taxonomical. The purpose of ecological study is to clarify the present conditions of seaweed and sea grass communities in each member country and to keep monitoring the communities to assess their changes by a common methodology. For this purpose, we established a standard methodology that can be applied to selected seaweed and/or sea grass communities in each member country. Also, as this sort of investigation in seaweed and sea grass communities needs many years, we decided to bring up young researchers who will follow us by promoting workshops. In these workshops, the standard methodology was explained to native young researchers and/or students and it was demonstrated practically in the field.

Taxonomical studies are indispensable to exactly identify seaweed or sea grass species composing the target communities and are also necessary to know the biodiversity in full details. However, in some Southeast Asian countries, such taxonomical studies are insufficiently promoted and marine floras have not been well documented. Therefore, we included a taxonomical instruction program of some important groups of seaweeds (such as Ulvaceae, Caulerpaceae (green seaweeds), Dictyotaceae, Sargassaceae (brown seaweeds), Gelidiaceae, Halymeniaceae, Solieriaceae, Gracilariaceae, Ceramiaceae or Rhodmelaceae (red seaweeds)) and sea grasses in the workshops. In addition, we tried to collect specimens by ourselves around the workshop venue to improve our knowledge on the seaweed and sea grass species and to compile floral data. The core members of our group (Table 1) have made taxonomical, floral and ecological inves-

tigations in each member country.

In summary, the objectives of our research were: to clearly understand the present status of seaweed and/or sea grass communities; to know the changes of these communities by keeping monitoring them; to clarify the marine plant biodiversity in full details and to predict the future of the marine ecosystems in this region. Toward this ultimate goal, we have approached through: training workshops on methods of ecological and taxonomical studies; instruction of basic knowledge of biodiversity at species/community levels; utilization of genetic tools for biodiversity analysis; and compiling specimens (as fixed, dried herbarium sheets and other forms) for current and future investigations.

1st to 5th Workshops

Beginning from the one at the Talibong Island along the Andaman coast of Thailand in 2002, nine workshops were held in the member countries including Japan. Of these, the first five workshops were promoted in a similar way. In these workshops, at first, the reports on the present circumstances of seaweed and sea grass studies were made by the core members. For example, in the workshop held in the Philippines (2004), more than ten reports concerning the problems surrounding seaweed and sea grass in the member countries were presented. Through these reports, we could share the knowledge on the problems or the present conditions surrounding seaweed and sea grass communities in each member country. The next program of the workshops was to instruct young researchers and/or students about how to do ecological study by using line transects and quadrats. In this program, some core members of our group made lectures about the procedures of how to do the field work and how to treat the obtained data. Then the young attendants made practices in the field under the guidance of our group members. The obtained data in the field were analyzed according to the protocol by them. Thus, the young attendants could fully understand the methodology of ecological study.

In these workshops, our group also promoted several lectures on taxonomy of seaweeds and sea grasses, particularly focusing on some important groups as afore mentioned. Here also some core members who have special knowledge on the seaweed or sea grass taxa explained about the important distinguishing characters among them, followed by practical observations of the specimens to clearly understand our explanations with microscopes. In the Philippine workshop, for example, the taxonomical lectures were made on the Ulvaceae, Codiaceae (green seaweeds), Sargassaceae (brown seaweeds), Halymeniaceae, Solieriaceae, Gracilariaceae and Rhodomelaceae (red seaweeds), all these groups being economically important.

6th to 9th Workshops

After the five workshops were completed, we had the 6th workshop in Iwate, Japan in 2008 to discuss the next step and agreed to publish a book on our accomplishment, which is now in progress. It was also agreed to promote an advanced style of workshop thereafter.

Accordingly, the 7th workshop in Thailand 2008 was held with two sections. The first workshop, focusing on taxonomical aspect, was held at Kasetsart University, Bangkok, where advanced taxonomic knowledge on several groups of seaweed and sea grasses were presented and discussed, followed by the practical observation of voucher specimens. In this workshop, as the second section, was also included a field study at the Samui Island, where seaweeds and sea grasses were collected in the field and identified by the

participants to establish a floral list of the island. The 8th workshop of ecological group was held in the Prince of Songkla University and in the Samui Island in the same year, and more advanced methodology to know the ecological aspects of seaweed and sea grass communities was discussed and tested.

The last workshop was held at Kagoshima University, Japan in 2010 to synthesize our accomplishments during the project (see next section), with an agreement to publish a book on the sea grass studies.

Biodiversity of Seaweeds and Sea Grasses

Through the present project we obtained a considerable body of knowledge on various aspects of biodiversity and the current status of seaweed and sea grass communities in Southeast Asia. Some of our fruits are mentioned below.

Advances in productivity measurement

Productivity measurement of marine plants is essential to understand the response of plants to environment as primary producers. Photosynthetic measurement method using oxygen electrode has been established and well standardized among members. Using this method physical responses of sea grass to natural and cultured conditions were evaluated to determine optimal condition of sea grass culture (Abu Hena 2001a, b, Mohammad Rozaimi *et al*. 2006), and physical responses of seaweeds to natural environment that potentially determine their distributions were clarified (Phooprong *et al*. 2007, 2008).

Stable isotope methods were introduced for more detailed study. The relationships between productivity and carbon stable isotope level by isotopic fractionation of seaweed (Carvalho *et al*. 2009a) and sea grass (Kiswara *et al*. 2005) were clarified, and also new measurement method of carbon isotope fractionation during photosynthesis has been developed (Carvalho *et al*. 2009b), which enabled direct link between plant's carbon stable isotope level and its productivity.

Industrial contribution

Marine plants supply food sources and industrial materials for human. Clarification of chemical properties of carrageenan from disease-damaged seaweed greatly contributed agar industries (Mendoza *et al*. 2002). Seaweed and sea grasses are potential source of drugs. Taxonomy of seaweeds is crucial for survey of bioactive chemical components from them (Saengkhae *et al*. 2009, 2010a, 2010b).

Sea grass culture

Sea grass culture system was well established for *Halophila* (Japar Sidik *et al*. 2008) and related species, not only to supply seedlings to mitigate the decline of sea grasses (e.g. Japar Sidik and Muta Harah 2003b, Japar Sidik *et al*. 2007), but also to supply nutritious feeding for aquaculture. Establishment of aquarium culture of sea grasses and seaweeds is very important as scientific achievement as supplying experimental material and also industrial contribution.

In addition, from our studies, the current status of the seaweed and sea grass communities and the recent studies of them in each member country will be summarized as follows.

Thailand

At the start of the present project, little had been known on the biodiversity and structure/dynamics of seaweed/sea grass communities in Thailand. In particular, the taxonomic knowledge on Thai seaweeds was based mainly on the studies by foreign scientists. However, since 2000, several projects to protect coastal environments have been conducted with supports from the Government and the Royal Fam-

ily. In parallel with these activities, the present project provided opportunities for native young researchers to study in Japan for getting Master or Doctor degrees.

In Thailand ca. 350 species of seaweeds have been reported so far (Dawson 1954, Egerod 1974, Velasquez and Lewmanomont 1975, etc.), but this number comes from the investigations made in limited localities and we expected much more seaweed species by further investigations. During the present project, we collected seaweeds in Talibong (2002) and Samui Islands (2009). The latter, in particular, resulted in identification of >50 species of marine macrophytes, including several new records in Thailand, indicating necessity to continue basic floral researches. With this status of knowledge, we paid our effort to some particular groups of macrophytes, and were able to establish full inventories of the *Sargassum* species in the Gulf of Thailand (Noiraksar and Ajisaka 2008) and *Gracilaria* species in Thailand (Terada *et al*. 2003).

Of particular importance in our research in Thailand is monitoring of the impact of the 2004 Tsunami disaster in Talibong Island, where the Tsunami totally destroyed its marine vegetation. In this rare occasion we were able to monitor the changes of vegetation and found that they are gradually recovering, as exemplified by reappearance of some species after 2 years from the disaster (Prathep and Tantiprapas 2006). Other ecological studies under our collaboration include those on the distribution and biomass of sea grasses (Nakaoka and Supanwanid 2000) and the community structure (abundance and distribution) of seaweeds (Prathep 2003).

Malaysia

In Malaysia, a large body of knowledge has accumulated on the taxonomy and ecology of marine macrophytes by native researchers (Sivalingam 1977, Arumugam 1981, Phang and Wee 1991, etc.), resulting in a total of ca. 250 species of seaweeds recorded in Malaysian waters (Phang 1998). However, still there are many areas and habitats that have been poorly investigated. For example, our research in Bintulu, Sarawak, Borneo Island (2007), has identified 32 species of seaweeds from this relatively narrow area (Japar Sidik *et al*. unpublished), suggesting a magnitude of still unexplored biodiversity in the whole Malaysia.

In the meantime, the sea grass studies from not only taxonomical aspects but of ecological aspects are comparatively advanced in Malaysia, and these studies apparently contribute to the preservation of coastal environment and the marine biodiversity of this country. A part of the studies were eagerly promoted by some of our core members. For example, Japar Sidik *et al*. (2001) reported the present condition of sea grass communities at the Starits of Malacca. Japar Sidik and Muta Harah (2003a) reported all the sea grasses growing in Malaysia with their distribution. Japar Sidik *et al*. (2006) discussed the significance of sea grsasses as coastal ecosystems. Japar Sidik *et al*. (2007) described sea grass decline in Malaysia. These results will be included in a book under publication highlighting the current status of sea grass communities in East and SE Asian countries.

Indonesia

In Indonesia, until recently, seaweed taxonomy had been based on the studies by foreign researchers in 1920s. Since 1990s several studies have been started by native researchers (e.g. Verheij 1993, Atmadja *et al*. 1996). During the present project, we examined the seaweed floras of Sulawesi and the Ambon Islands, and recorded 170 and 48 species, respectively (Gerung *et al*. 2003, 2006).

In contrast, the sea grass flora in Indonesia has been extensively studied since

1980s through various types of international collaboration, e.g. LIPI Programs on Biology and Inventory of Marine Resources (1973–1998), ASEAN-Australia Cooperative Program on Marine Science (1986–1995), LIPI-JSPS Program on Indonesian Marine Biodiversity (1994–2004), and Indonesian-Dutch East Kalimantan Marine Research Program (2003–ongoing). From these studies, 14 species of sea grasses are known from Indonesian waters covering an area of 30,000 km^2 (Nienhuis 1993).

As outputs of our group, a core member and others published several papers on the sea grass community dynamics, the preservation of sea grass beds, the sea grass mapping based on Satellite Image Data, the transplantation for recovery of sea grass beds. For example, Kiswara *et al*. (2005) clarified carbon uptake by a sea grass in different light conditions. Kuriandewa and Supriyadi (2006) estimated ca. 2000 ha of sea grass beds by using satellite image in east Bintan coastal area. Kiswara *et al*. (2009) studied the root architecture of three sea grass species in different habitats.

Vietnam

In Vietnam, the seaweed study substantially started in 1923 when the Institute of Oceanography, Nhatrang, was established. Dawson (1954) published a paper with descriptions of some 200 species of seaweeds. Pham (1969) published a book on the seaweed of South Vietnam in which some 500 species were reported. Nguyen *et al*. (1993) published a book on the seaweed of North Vietnam where some 300 species were included. After that, several species have been added by several researchers. In spite of these studies, information on the current status of Vietnamese seaweed and seaweed communities is still limited.

The report of 14 species of sea grasses in Vietnam (Nguyen *et al*. 2002) and the taxonomical study of economically useful red seaweed, *Gracilaria* (Hau and Nguyen 2006) are the important outputs of our group during this project.

As for the ecological aspect, some core members studied the seaweed and sea grass communities in the central and northern areas (e.g. Dam 2003, Pham *et al*. 2006). According to the studies, in the central Vietnam, 20% of sea grass areas are lost due to human activities (Nguyen *et al*. 2004), and the recovery of these areas are now promoted (Nguyen H. Dai and Nguyen X. Vy unpublished).

The Philippines

Among the member countries of this project, the Philippines may be the most advanced in the seaweed/sea grass study. As shown by Ogawa *et al*. (2003), during 1990–2003, the scientific papers were much more actively published by the Philippine researchers than in other member countries. According to E. Ganzon-Fortes (unpublished), until the last century, over 900 seaweed species have been reported. The studies of sea grasses have also been actively made by some members of this project, resulting in a field guide for identification of east Asian sea grasses (Fortes and Ogawa 2006). Reflecting this background, in the workshop held in 2004 at the Marine Science Institute, the University of the Philippines, there were many reports on the current status of seaweed and sea grass communities within the member countries.

Ecological studies have also been much more active than in other member countries (Ogawa *et al*. 2003). Fortes (2003) reported current 20–30% loss of the sea grass communities due to human activities. Continuous ecological studies at several localities along the east coast of the Luzon Island are now in progress by some core members.

Conclusion

As described above, the present project has increased our knowledge on the current status of seaweed and sea grass biodiversity in East and South East Asian regions. However, our results are not sufficient yet because the target areas are very wide. In some member countries such as Indonesia, Thailand or Vietnam, for example, much more species will be discovered by further studies. For precise evaluation of the present status and future prediction of marine ecosystems, much more quantitative information on variability of seaweed and sea grass communities must be compiled.

In this sense, new ecological observation method (e.g. Hayashizaki and Ogawa 2006) on seaweed and sea grass will provide more efficient ground truthing. Long lasting monitoring of seaweed and sea grass communities is also necessary to detect the response to anthropogenic effect and global climate change. Stable isotope study will provide a clue to predict the response of marine plants to global climate change and ocean acidification. As we have developed the short term measurement method of carbon stable isotope fractionation (Carvalho *et al*. 2009), we can determine the effect of environmental factors such as temperature, pH etc. during photosynthesis in terms of isotopic fractionation (Carvalho *et al*. 2010a, b).

Marine plants are usually archived as dried herbarium specimens. Retrospective analysis using stable isotope and trace element on those specimens could supply information about historical change of plants communities and environment. Nitrogen stable isotope ratios of marine plants reflect those of environmental nitrogen sources (Evrard *et al*. 2005, Carvalho *et al*. 2008), and carbon stable isotope ratios were mainly affected by photosynthetic speed (Kiswara *et al*. 2005, Carvalho *et al*. 2009a, b).

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