Kuroshio Science **2**-1, 41-46, 2008

Recent Changes in the Distribution of *Sargassum* species in Kochi, Japan

Hiroko Haraguchi and Satoko Sekida*
Graduate School of Kuroshio Science, Kochi University
(2-5-1, Akebono, Kochi 780-8520, Japan)

Abstract

Various seaweed and seagrass beds (*Moba* in Japanese) grow in the coastal waters of Japan. In this presentation we introduce *Sargassum* beds, which are classified as brown algae. *Sargassum* species are distributed widely along not only the Japanese coast but also the Philippine and Taiwanese coasts. The occurrence of common species is due to the Kuroshio Current. From the 1970s to the 1990s, species of *Sargassum* beds in Tosa Bay were changing. That is the temperate *Sargassum* species declined and were replaced by the tropical *Sargassum* species. We propose two possible reasons this phenomenon. One reason is that the water temperature rose in Tosa Bay. Specifically, the winter water temperature during the 1990s was much higher than during the 1970s and the 1980s. We discuss how this has enabled the growth of the tropical *Sargassum* species. With this in mind we conducted culture experiments to compare the growth characteristics between the temperate species and the tropical species in low temperature. The results indicated that the growth rates of the tropical species are significantly higher than those of the temperate species for temperatures of over 14 degrees. This may be one of the causes of the expansion in the distribution of the tropical *Sargassum* species. Second reason is that barren grounds have increased in area in Tosa Bay. This phenomenon is a serious problem. However when we change the environment, new tropical species may have opportunities to grow instead of existing seaweeds. To understand these phenomena it is important for us to research the ecology and physiology of seaweeds occurring along the Kuroshio Current.

Introduction

Seaweed beds and seagrass beds refer to the communities of seagrasses and large algae (macroalgae). Main seaweed and seagrass beds are kelp forests composed of *Eisenia*, *Ecklonia* and *Laminalia* species, *Sargassum* beds composed of *Sargassum* species and *Zostera* beds composed of *Zostera* species, marine phanerogams. Seaweed and seagrass beds play an important role in the conservation of primary producers in coastal waters, where marine animals grow up, and help to conserve the coastal ecosystem.

Recently the rises in seawater temperatures, the main cause of which is considered to be global warming, are growing more and more serious, resulting in declines and changes in the species composition of seaweed and seagrass beds, i.e., the decay of temperate species and the expansion in the distribution of tropical species in the coastal waters of Japan. This paper reports these changes in seaweed and seagrass beds in the coastal areas of Kochi, examining the case of *Sargassum* species.

1. Common features of *Sargassum* species

As shown in Figure 1, *Sargassum* species grow richly in the coastal areas of the Philippines, and 28 species have been reported thus far. All of these *Sargassum* species are tropical species. Eight of them grow in the Ryukyu Islands and four of them, in the coastal areas of Kochi. The appearance of these tropical species in Japanese waters is greatly influenced by the Kuroshio Current. The current is a large-scale warm current that links the Philippines and Japan, and many common seagrass and seaweeds are found in the coastal waters of the two countries, especially in the Ryukyu Islands in Japan. But recently, some tropical seagrasses and seaweeds native to the Philippines have begun to be observed frequently in the coastal areas of Japan other than the Ryukyu Islands, too. It has been supposed that this phenomenon has occurred due to the strong influence of rises in seawater temperatures due to global warming.

*Coresponding author: e-mail sekida@cc.kochi-u.ac.jp

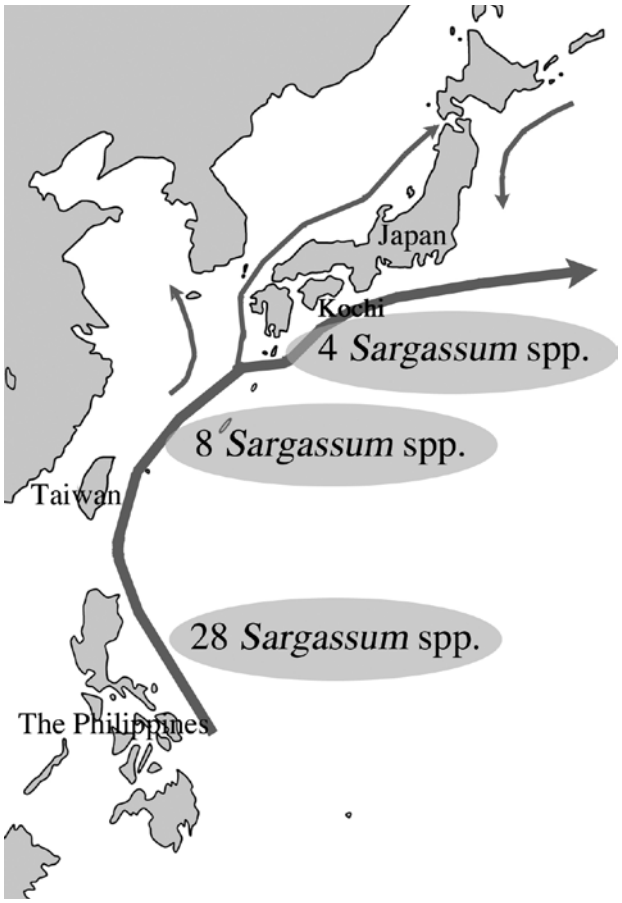

Fig 1. Relationship between the Kuroshio Current and tropical *Sargassum* species.

2. *Sargassum* species in Japan

Sargassum species are large-sized algae that belong to the Fucales (Phaeophyceae) and are distributed extensively in the coastal zones of Japan. These species form beds known as *Sargassum* beds (*Garamoba* in Japanese). *Sargassum* beds are composed of many *Sargassum* species and can be regarded as beds with high diversity because they can maintain their community even when some species decline and other species grow instead. The bodies of *Sargassum* species consist of holdfasts, stems, main branches, leaves and vesicles, and these species are classified according to the morphological characteristics of these parts.

In Japan, 60 *Sargassum* species grow, and most of them are temperate ones. The growth of *Sargassum* species in Japan is affected by the seasonal change of seawater temperature. The growth of *S. horneri*, for example, slows down in summer when seawater temperatures are high and is greatly increased in fall when the temperature decreases (Fig. 2). Its growth becomes inactive again in winter when the seawater is at 10 °C or so and begins to start again toward maturity in spring when the temperature rises(Fig. 2). As noted, the seasonal change in the growth of *Sargassum* species in the coastal areas of Japan is greatly affected by the seasonal change of seawater temperatures.

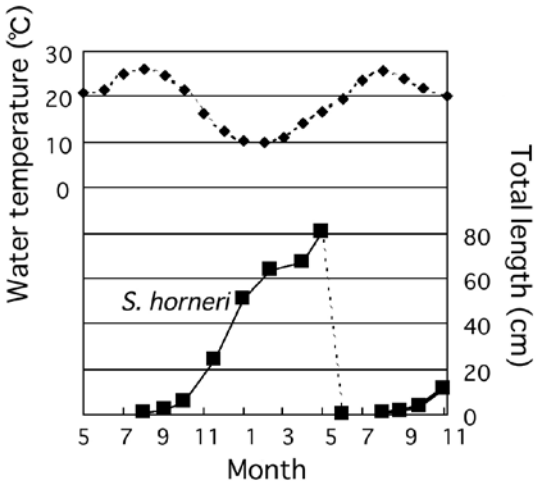

Fig 2. Relationship between seasonal prevalence in *Sargassum* species and seasonal change of seawater temperatures.

3. Changes in the distribution of *Sargassum* beds in Kochi

Kochi is situated in the southwestern part of Japan and has the semicircular Tosa Bay with two capes, Ashizuri and Muroto, at each end. In the period from the 1970s to the 1990s (to the present), the composition of species of *Sargassum* beds changed: temperate species have declined and have been replaced by tropical ones. This section deals with changes in the distribution of *Sargassum* beds in the coastal areas of Kochi in the 1980s and the 1990s.

1) Distribution of *Sargassum* beds in the 1970s

As shown in Figure 3, in the 1970s, temperate *Sargassum* species dominated the *Sargassum* beds in the coastal waters of Kochi. In particular, *S. micracanthum* and *S. okamurae* were distributed extensively.

2) Distribution of *Sargassum* beds in the 1980s

In the 1980s, temperate *Sargassum* species continued to grow dominantly in Tosa Bay, but *S. duplicatum* and *S. crispifolium*, which are tropical *Sargassum* species, began to dominate in the western waters of Kochi (Fig. 4). These western waters are strongly affected by the Kuroshio Current and are the warmest sea areas of the coastal waters of the prefecture.

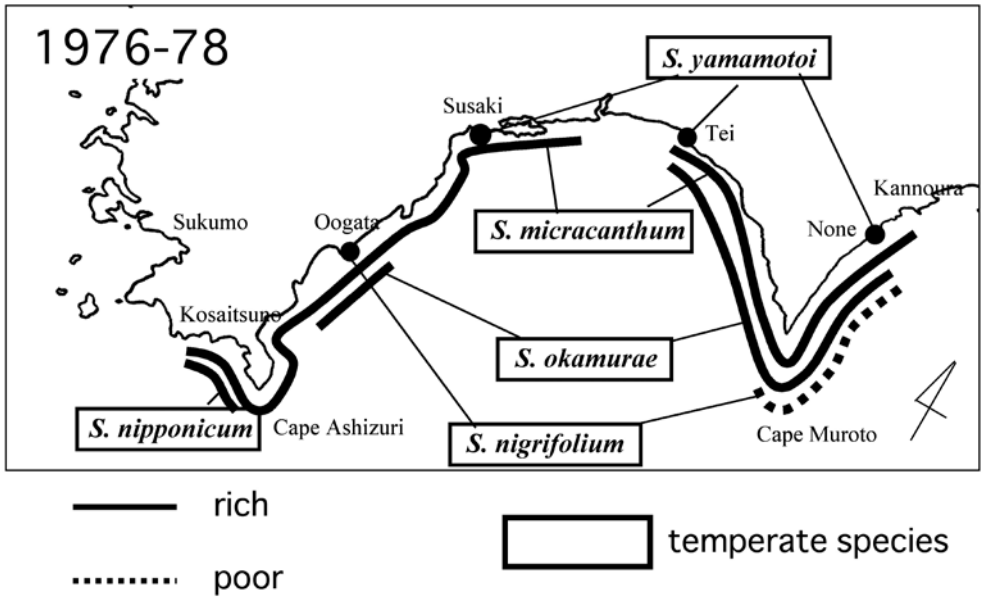

Fig 3. Distribution and the dominant species of *Sargassum* beds along the Kochi coast during the 1970s.

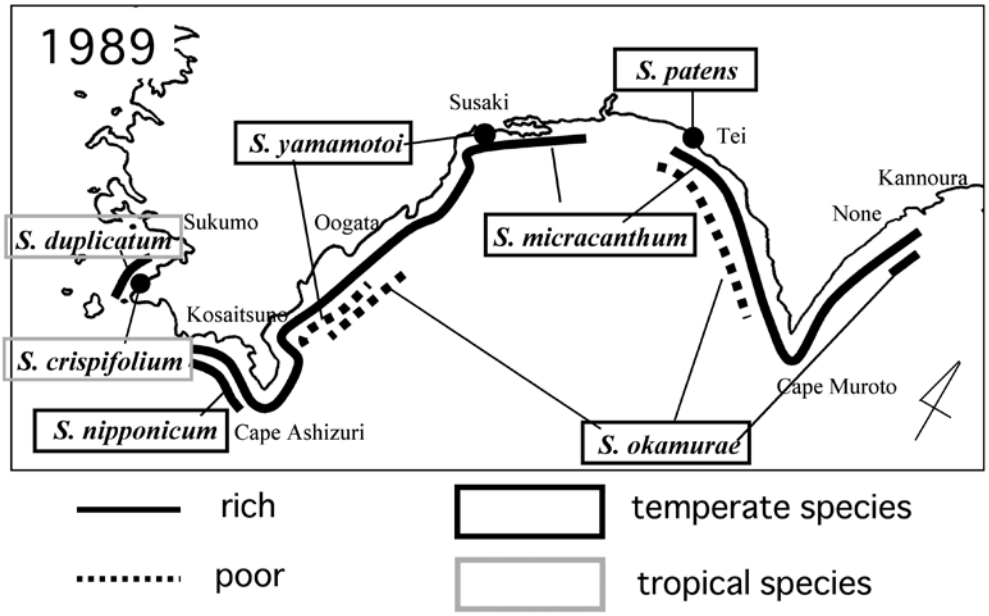

Fig 4. Distribution and the dominant species of *Sargassum* beds in Kochi during the 1980s.

3) Distribution of *Sargassum* beds in the 1990s

As shown in Figure 5, in the 1990s, changes in the distribution were beginning to be observed clearly. By the 1980s *S. micracanthum* and *S. okamurae*, temperate *Sargassum* species, dominated in Tosa Bay, but in the 1990s the distribution of these two species became sparse. On the other hand, the distribution area of *S. duplicatum*, tropical *Sargassum* species, expanded even in Tosa Bay. In the 1990s and after, *S. duplicatum* became the *Sargassum* species most frequently observed in the coastal areas of Kochi.

4. Decline and expansion of the distribution of *Sargassum* species

1) Decline in the distribution of *Sargassum okamurae*

S. okamurae, a temperate *Sargassum* species, had dominated in Tosa Bay until the 1980s. Figure 6 shows the distribution of *S. okamurae* in the same sea area in Tosa Bay in 1985 and in 2005. While in 1985 this species formed large communities, the communities disappeared almost entirely by 2005. In addition, the investigation in 2005 confirmed the growth of *S. dupli-*

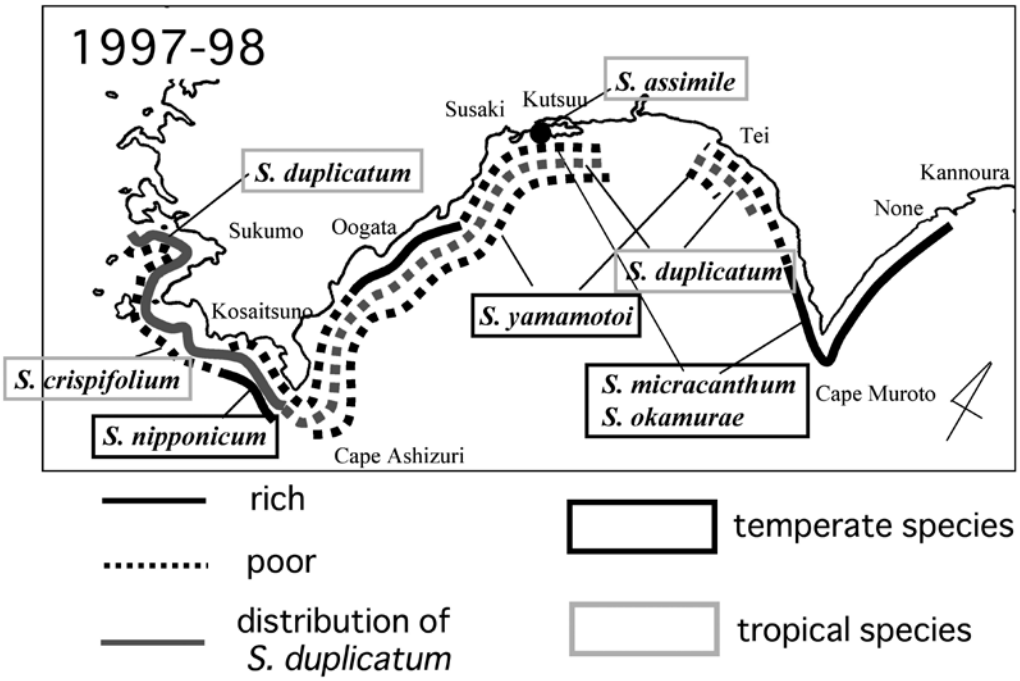

Fig 5. Distribution and the dominant species of *Sargassum* beds in Kochi of 1990s.

catum, a tropical *Sargassum* species, in the sea area. These are only a part of the findings in the investigation but they suggest that the distribution of *S. okamurae* declined.

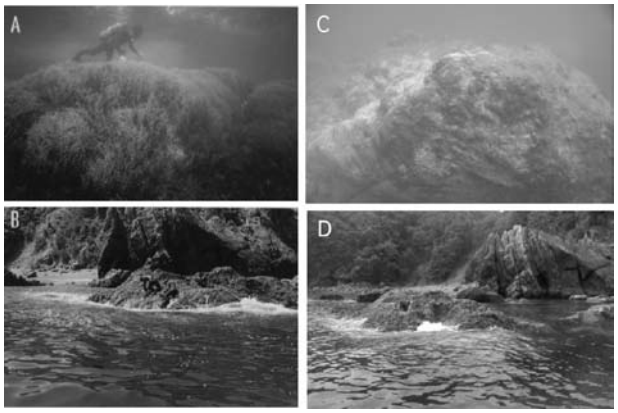

Fig 6. Growing conditions of *Sargassum okamurae* in Kochi in 1985 (A, B) and 2005 (C, D).

2) Expansion in the distribution of *Sargassum duplicatum*

S. duplicatum is the tropical *Sargassum* species whose distribution has expanded in the coastal waters of Kochi since the 1980s. Figure 7 shows the horizontal distribution of *S. duplicatum* in the same western sea area of the prefecture in the same season. As of 1997, this *Sargassum* species was found only sparsely along the eastern coast of Ohtoshima Island and the western coast of Kirishima Island. By 2005, the species' distribution had expanded greatly. The growth of *S. duplicatum* was newly confirmed on the southwestern coast of Ohtoshima Island, and its distribution also expanded along the coast of Kirishima Island. In 2005, the growth of tropical *Sargassum* species other than *S. duplicatum*, i.e., *S. alternato-pinnatum* and *S. carpophyllum*, was confirmed, on the eastern coast of Kirishima Island. This result indicated that *S. duplicatum* and other tropical *Sargassum* species had widened their distribution by 2005.

5. Factors contributing to changes in distribution

1) Rises in seawater temperatures

Seawater temperatures in the coastal areas of Kochi have risen remarkably in recent years. Figure 8 shows the seasonal changes in seawater temperatures in the 1970s, the 1980s and the 1990s. Seawater temperatures in the 1990s were higher than those in the 1970s and the 1980s. Rises in seawater temperatures in winter are especially noticeable. It is supposed that higher seawater temperatures in winter have made the wintering of tropical *Sargassum* species easier, which has then led to expansion in the distribution of the species in the 1990s and after. In the culture experiment on temperate and tropical *Sargassum* species that paid attention to the growth characteristics at low seawater temperatures, almost no change in the growth rate was observed for temperate species at 10-20°C. However, the growth rate of tropical species increased with rising temperatures

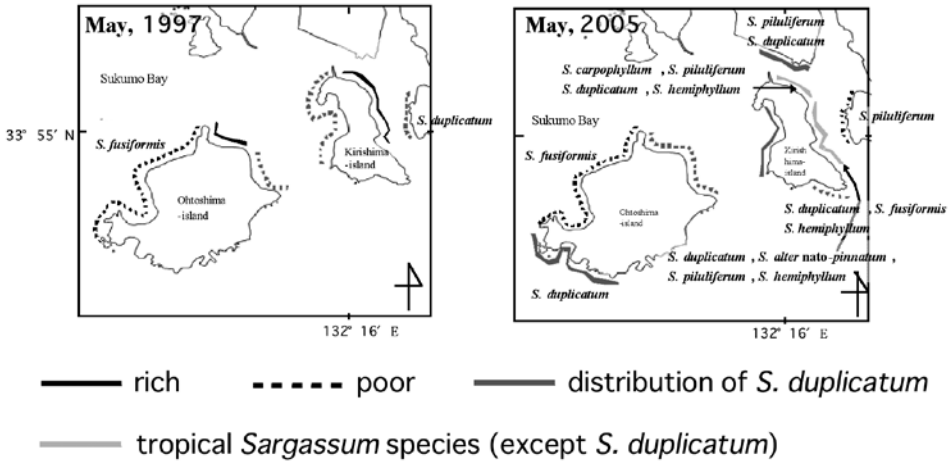

Fig 7. Distribution and the dominant species of *Sargassum* beds in the western sea area of Kochi prefecture in May, 1997 and May, 2005.

(10-13°C) and became almost stable at temperatures of 14°C and higher, the values of the growth rate of tropical species being higher than those of temperate species. This result indicated clear differences in growth characteristics related to seawater temperatures between temperate and tropical species. This suggests that seawater temperature is an important factor that controls the distribution of *Sargassum* species, and it is considered that rising seawater temperatures will accelerate changes in the type of species in the seaweed and seagrass beds a that is, decline in temperate species and an expansion in the distribution of tropical species.

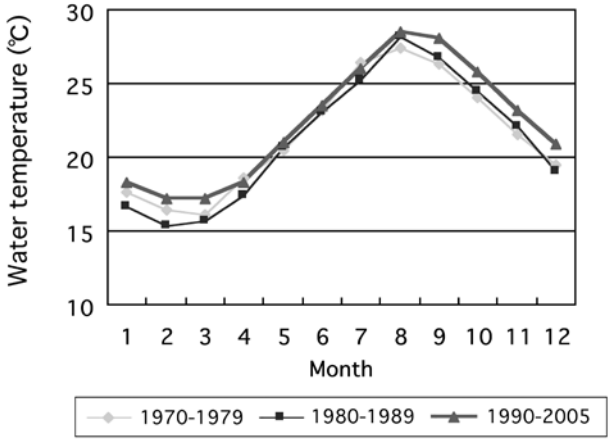

Fig 8. Seasonal changes of seawater temperature in Kochi's coastal areas.

2) *Isoyake* (barren ground)

In the 1990s and after, the phenomenon of *isoyake* caused by sea urchins has increased along the coastal areas of Kochi (Fig. 9). *Isoyake* refers to the phenomenon where algae communities greatly decline or disappear in the rocky and boulder areas of shallow water, thus bringing about a state of poor vegetation in the area. An increase in *isoyake* causes a decrease in marine resources, too, and seriously affects coastal fisheries. Expanding *isoyake* is considered to be one of the causes of decline in existing temperate *Sargassum* species. On the other hand, from the standpoint of tropical *Sargassum* species, the new comers, it can be supposed that the basic conditions for their growth have improved, thereby making it easier for them to establish themselves in these coastal waters. But no relationship has yet been found between *isoyake* and the increasing distribution of tropical *Sargassum* species, and we should continue our studies and investigations on this in the future.

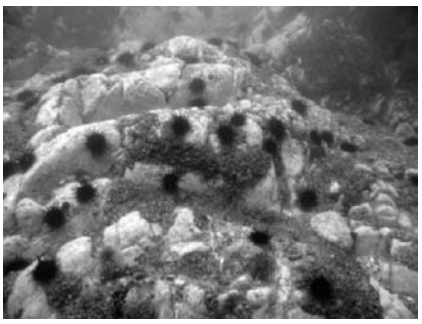

Fig 9. Phenomenon of *isoyake*.

Conclusion

Seaweed and seagrass beds have played an essential and important role, as the forests of the sea which support the ecosystem of the coastal areas. This is so not only in the coastal waters of Japan but also in those of the Philippines and Taiwan. Needless to say, the distribution of seaweed and seagrass beds is connected through the sea. In particular, the Kuroshio Current is like a great seawater river that runs through from the Japanese

archipelago to Taiwan and then to the Philippines, and we have benefited from it in a variety of forms from very early times. The recent phenomenon of global warming is causing unprecedented changes in the activities of this current. In this paper we have discussed the situation where many tropical seaweeds and seagrass have been seen in the coastal areas of Japan. These changes became apparent in the 1990s and after, and expansion in *isoyake* has been reported recently as if it went hand in hand with changes in the species composition of seaweed and seagrass beds. We believe that it will be an important task for us to precisely understand the situation of the dramatic changes that are now occurring around the Kuroshio Current, mainly in seaweed and seagrass beds, and to pursue the background and causality of these changes. In this regard, it is important in estimating the future effects of the changes on the coastal waters of Japan to study the ecology of seaweeds and seagrass in Taiwan and the Philippines, which are connected to Japan by the great river of the Kuroshio Current. The investigations should be continued at length in close cooperation with researchers in Taiwan and in the Philippines.

This paper is based on "Relationship between seaweed beds and seawater temperature in the Tosa Bay" in the *Aquabiology* 160, Vol.27, No.5, and our paper read at the XIXth International Seaweed Symposium, "Distribution changes and growth characteristics in low temperature of two species in Sargassum beds of Kochi prefecture, Japan."

References

Haraguchi H., Murase N., Mizukami Y., Noda M., Yoshida G. and Terawaki T. 2005 The optimal and maximum critical temperatures of nine species of Sargassaceae in the coastal waters of Yamaguchi Prefecture, Japan., *Jpn. J. Phycol*., **53**: 7-13.

Haraguchi H., Yamada C., Imoto Z., Ohno M. and Hiraoka M. 2006 Species composition of *Sargassum* beds on the coast of Ogisaki, Kochi, Southern Japan., *Bul. of Mari. Sci. Fish. Kochi Univ*., **24**: 1-9.

Hiraoka M., Ura Y. and Haraguchi H. 2005 Relationship between seaweed beds and seawater temperature in the Tosa Bay., *Aquabiology*, **160 (27)**: 485-493.

Noro T., 2004 Marine algae in the vicinity of biological institute on Kuroshio, Kochi Prefecture, Japan. *Kuroshio Biosphere*, **1**: 1-6.