

The Decline of *Ecklonia cava* in Kochi, Japan and the Challenge in Marine Afforestation

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Abstract

In the coastal waters of Kochi, *Ecklonia cava* formed dense beds until the 1980's. However, these beds have declined rapidly since the 1990's. The reasons for the decline of *E. cava* are the rise in seawater temperature along with grazing by sea urchins and marine herbivorous fish. Many researchers have conducted marine afforestation of *E. cava* beds. There are three main afforestation methods. The first is transplantation using adult plants or young plants cultured from fertilized eggs in indoor tanks. The second is to use a spore bag. The last method is to use a net cage for protection from grazing by herbivorous fish. Marine afforestation of *E. cava* using the spore bag method was tried at an *Isoyake* (barren ground) area in autumn. Many young sporophytes appeared around the spore bags in the following spring. However, several years later these plants completely disappeared due to grazing by marine herbivorous fish and sea urchins. In another afforestation attempt using a net cage, most of the *E. cava* were destroyed by high temperatures during summer, even though they were protected from fish. Although some afforestation attempts failed, others succeeded. Namely that is the afforestation using artificial reefs with seedlings. This results in constant growth and reproduction of *E. cava*. *E. cava* beds, which though small are similar to natural beds, have been formed around the artificial reefs now. This area maintains low seawater temperature and the grazing pressure from sea urchins and marine herbivorous fish is also low. Thus, it is important to select a suitable site for marine afforestation of *Ecklonia cava* beds.

Key words: *Ecklonia cava*, marine afforestation, marine herbivorous fish, seawater temperature, sea urchin

Introduction

Ecklonia cava Kjellman is a large perennial alga of Laminariales, Phaeophyta, distributed along the temperate region from central to southern Japan (Terawaki 1993). Sporophytes of *E. cava* form dense kelp beds called "marine forest" on the rocky bottoms along coastal areas (Kida and Maegawa 1983), and are one of the main primary producers in coastal ecosystems (Yokohama *et al.* 1987). The kelp forest plays an important role as a nursery and breeding space for commercial fish, shellfish and other animals (Ohno 1985). Furthermore, commercial shellfish such as abalones and turban shells feed on blades of *E. cava* (Nonaka and Iwahashi 1969). Therefore, kelp forest including *E. cava* has both ecological and economic importance in Japan.

Recently, it has been reported that marine plant

communities, including kelp forest, have disappeared or decreased along the Japanese coast (Environmental Agency of Japan 1994). In order to maintain high productivity and habitats for animals that kelp forest supply, many researchers have conducted marine afforestation.

In this paper we introduce the decline of *E. cava* beds in Kochi, Japan, the reasons for the decline and the challenges in marine afforestation.

1. Distribution Changes in *Ecklonia cava* Beds in Kochi

The chronological change in the distribution of *Ecklonia cava* beds in Kochi, Japan is shown in Fig.1. *E. cava* beds in the 1970's tended to decline compared with the past. Those in the 1980's recovered and were the largest beds in the past reports. However, every *E.*

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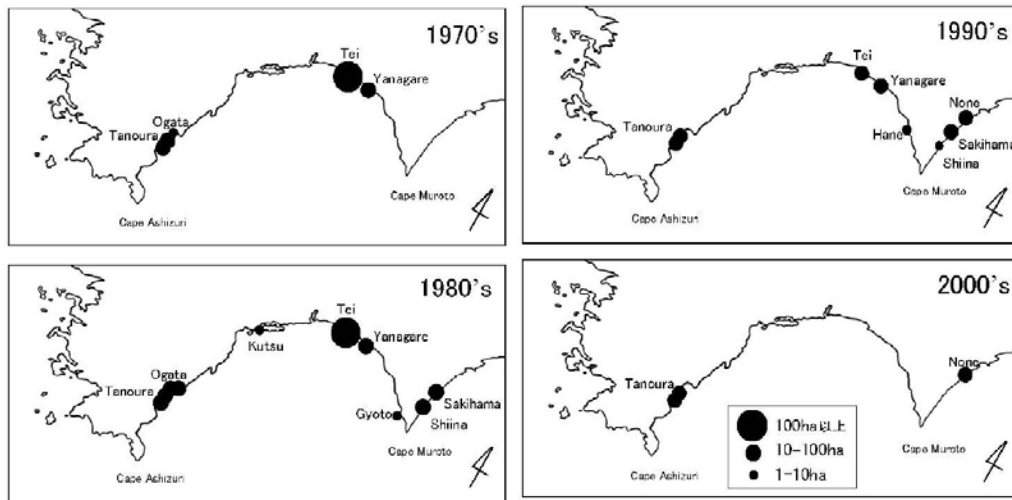


Fig. 1 The chronological change in the distribution of *Ecklonia cava* bed in Kochi, Japan (Hiraoka *et al.* 2005)

cava bed from the 1990's rapidly declined and some beds disappeared. Especially, the largest *E. cava* beds at Tei (approximately 180ha in the 1980's) completely disappeared by 2000 (Serisawa *et al.* 2004). In the 2000's *E. cava* beds existed in only two areas, Tanoura and None. Thus, *E. cava* beds have dramatically declined and haven't recovered at all since the 1990's.

2. Reasons for the Decline of *Ecklonia cava*

One reason for the decline is the rise in seawater temperature along the coast of Kochi. Annual changes in deflection of seawater temperature from 1965 to 2002 are shown in Fig. 2. *E. cava* beds declined, when seawater temperature was comparatively high in the 1970's. On the other hand, *E. cava* beds recovered, when seawater temperature was low compared with the average. However, as seawater temperature has remained high since the 1990's, *E. cava* beds have declined consider-

ably. Therefore, the decline of *E. cava* is related to the rise in seawater temperature.

The second reason is sea urchin grazing. Since the 1990's violent grazing by sea urchins has caused barren ground, known as *Isoyake* in Japanese (Fujita *et al.* 2008). *Isoyake* is the phenomenon where by seaweed markedly declines or disappears. Recently *Isoyake* area in Kochi has been expanded by sea urchin grazing (Taino 2008). Under these conditions, seaweeds, except for Coralline algae, are difficult to grow because of grazing pressure from sea urchins. Therefore, the occurrence of *Isoyake* area accelerates the decline of *E. cava* beds.

The third reason is grazing by marine herbivorous fish. Many researchers reported that marine herbivorous fish are violently damaging seaweed beds around the Japanese coast (Masuda *et al.* 2000, 2007, Hasegawa *et al.* 2003, Nimura *et al.* 2007). The main marine herbivorous fish in Kochi are *Siganus fuscescens*, *Calotomus japonicus* and *Prinurus scalprum*.

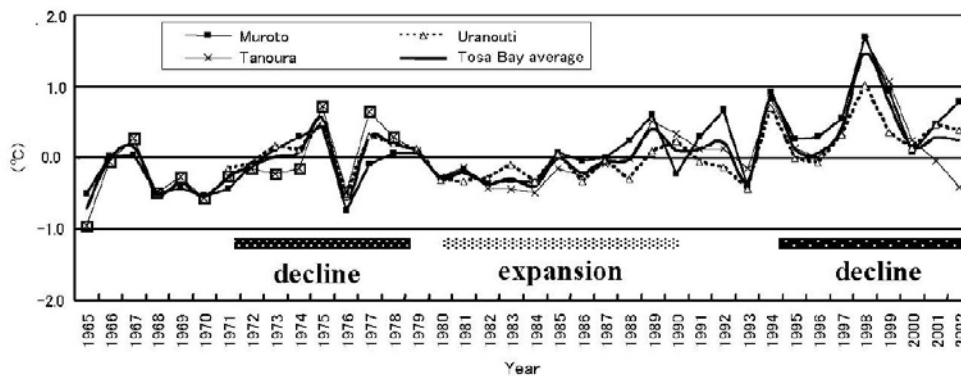


Fig. 2 Annual changes in deflection of seawater temperature from 1965 to 2002 (0 shows average of 1965-1998 (Ishikawa *et al.* 2004))

3. Marine Afforestation of *Ecklonia cava*

There are three main afforestation methods. The first is transplantation using adult plants and using young plants cultured from fertilized eggs in door tanks. The second method is to use a spore bag. The last method is to use a net cage for protection from herbivorous fish grazing.

Case 1: Using the spore bag method (Serisawa *et al.* 2005)

Spore bags including one or two mature *E. cava* were set in the autumns of 1999, 2001 and 2002 at different areas at depths of five to ten meters in the central part of Tosa Bay. In each area, many young plants (10-100 ind./m²) appeared around the spore bags and on the rocky grounds in the following spring. However, several plants were damaged due to herbivorous fish grazing in 2003. And, *E. cava* had completely disappeared by 2005. Now complete *Isoyake* area due to sea urchin grazing has developed at this site.

Case2: Using the net cage method (Tanaka 2008)

Plants that were cultured from seedlings for four months were transplanted to an artificial reef in May 2005 at the western coast of Kochi. Two sets of 25 plants were placed in cages and outside of cages, respectively (Fig. 4). Three months later, all *E. cava* plants outside the cages had been grazed by herbivorous fish (Fig. 5). In the cages, the growth of the blades stopped during summer and the leading edge of the blades was bleached and dissolved (Fig. 6). Seawater temperatures in summer ranged from 24°C to 28°C. The photosynthetic activity of *E. cava* is lower than their respiration activity at temperatures over 28°C (Serisawa 1999). Thus, this species cannot grow under these conditions. Therefore, *E. cava* wasn't able to grow in a cage and declined at this study site. Furthermore, *E. cava* didn't mature in December, which would have been the maturation period. This study revealed that when marine afforestation of *E. cava* is conducted, it is necessary to research the seasonal changes in seawater temperature.

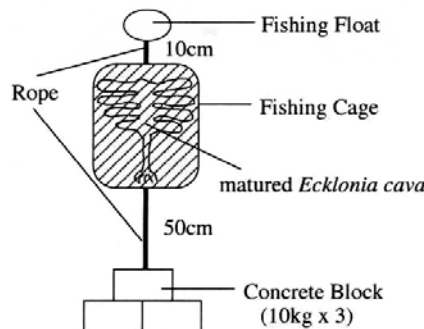


Fig. 3 Schematic of a spore bag used in this experiment (Serisawa *et al.* 2005)

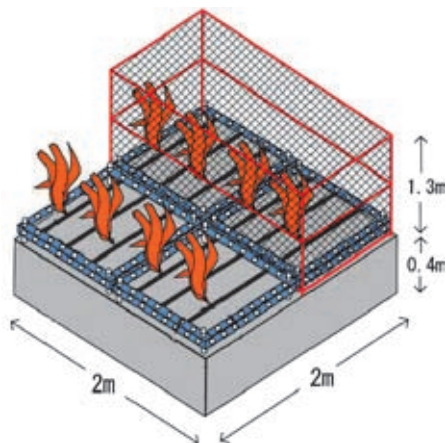


Fig. 4 A schematic diagram of the experimental setup (Tanaka 2008)



Fig. 5 Signs of grazing on the tips



Fig. 6 Photographs showing the experimental site with cage

A: survival state of the transplanted *Ecklonia cava*; B: bleaching of the leading edge of the blade; C: dissolving of the leading edge of the blade.

Case3: Transplantation using seedlings at artificial reefs (Serisawa *et al.* 2007)

Seedlings, which were cultured for six months, were attached to artificial reefs that had been placed on a breakwater at a four-meter depth in April 2003 in central Tosa Bay (Fig. 7). Four months later in August, transplanted *E. cava* grew well even though summer and matured in December. Juvenile plants appeared around the reefs and the lateral surface of the breakwater from February to March of the following year (Fig. 8). The densities of *E. cava* at the bottom (1, 5 and 10m from the artificial reef) were 36, 12 and 4 ind/m², respectively and those at the lateral surface (2.5 and 3.5m from the reef) of the breakwater were 104 and 56 ind/m², respectively. Sixteen months later in August 2005, *E. cava* beds expanded because juvenile plants grew to become the adult plants. About four years later in March 2007, it was observed that *E. cava* beds had continued to expand (Fig. 9). At this study site, grazing by sea urchins and marine herbivorous fish was observed. However, *E. cava* beds maintained their community without declining or disappearing. Thus, *E. cava* beds which are small yet similar to natural beds have now formed. This area maintains low seawater temperatures and low grazing pressure thanks to the influence of inner water. Therefore, it is important to select suitable a site for marine afforestation of *E. cava* beds.

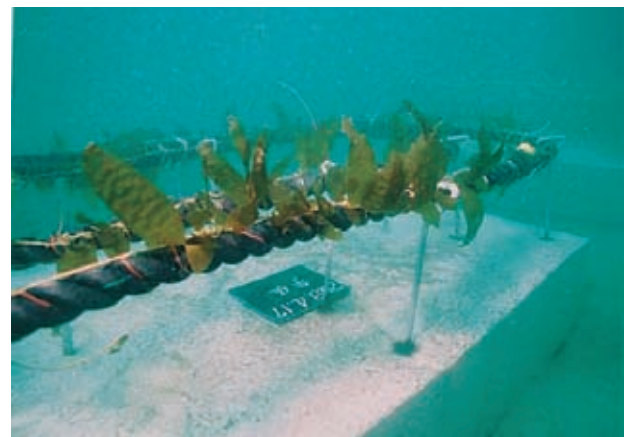


Fig. 7 Seedlings on an artificial reef in April 2003



Fig. 8 Young sporophytes growing on the lateral surface of a breakwater in March 2004

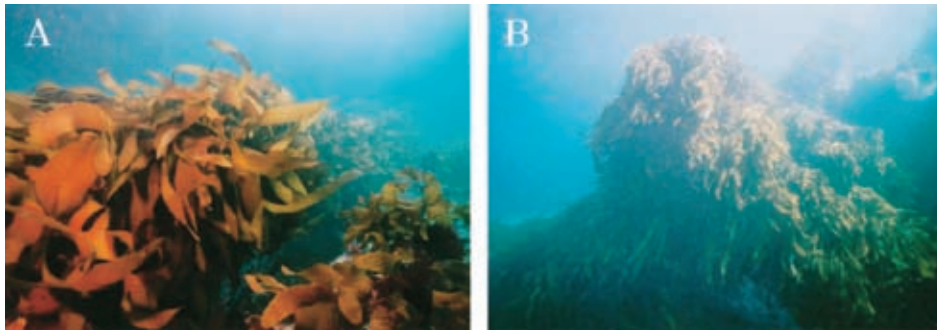


Fig. 9 Photographs showing *Ecklonia cava* in March 2007

A: the artificial reef with well-grown fronds; B: the lateral surface of the break-water with well-grown fronds

Conclusion

Ecklonia cava beds have economic and ecological importance in Japan. Furthermore, many marine afforestation efforts of *E. cava* were conducted. We introduced some challenges in the marine afforestation of this species. And then, only one afforestation attempt namely transplantation using seedlings, succeeded from among the three methods. However, there is no problem with the marine afforestation methods. Thus, it is important to select a suitable site for marine afforestation of *E. cava*. It is difficult to afforest *E. cava* in Kochi, even if these plants grew in the past. However, we should persist in researching suitable sites for successful afforestation.

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