Ecology and restoration techniques for *Sargassum* beds in Japan

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SUMMARY: In a number of coastal areas of Japan, many naturally occurring *Sargassum* beds have been severely damaged or reduced due to land reclamation and water pollution. In order to achieve sustainable coastal development, *Sargassum* bed restoration has been emphasized as a conservation method. New techniques for restoration include: 1) periodic re-transplanting, supported by artificial production of young plants, is effective to form suitable seascapes in severely polluted and sparsely vegetated areas; 2) transplanting or seeding on artificially provided hard substrata are effective in extending nursery and fishing grounds around existing natural beds; and, 3) restoration of shallow and gently sloping sea bed is effective in creating maintenance-free beds along developed coastlines.

KEY WORDS: ecology, maintenance-free, restoration techniques, *Sargassum* beds, transplantation

INTRODUCTION

The brown macroalga, *Sargassum* forms the most dominant and important seaweed beds around Japan. However, the area of natural *Sargassum* beds has been decreasing for many reasons and restoration is becoming an urgent problem. In this presentation, the ecological aspects of naturally occurring *Sargassum* beds and new techniques for their restoration are reviewed from the point of view of environmental conservation and coastal management.

ECOLOGICAL ASPECTS OF SARGASSUM BEDS

Sargassum beds are abundant on rocky bottoms along coastal areas of Japan affected by warm currents, particularly the Tsushima Warm Current in the Japan Sea and Seto Inland Sea, southwestern Japan.¹⁾ The area of *Sargassum* beds has been estimated as 54,000ha.²⁾ The vertical distribution patterns of *Sargassum* were found to vary with water depth and intensity of wave action. On the coast of western Kyushu Is. facing the Eastern China Sea, several species of *Sargassum* plants are found attached to rocky substrata.³⁾ On the coast of central Honshu Is., facing the Pacific Ocean, the dominate

seaweed species changed from shallow to deep water, e.g. several species of *Sargassum* - *Eisenia bicyclis* - *Ecklonia cava*.⁴⁾ On the coast of central Honshu Is., facing the Sea of Japan, the dominant species were several *Sargassum* - Sea grass and coralline red algae - *Ecklonia kurome*.⁵⁾ On the coast of western Honshu Is., facing the Seto Inland Sea, the dominant species were changed in order *Sargassum* - *Ecklonia kurome* found at relatively shallow depth.⁶⁾

Sargassum beds are found on deeper and more stable substrata than *Laminaria* beds⁷⁾ and shallower and less stable substrata than *Eisenia* / *Ecklonia* beds.⁸⁾ The structure of the animal community, e.g. the interaction between the resident fishes and their food sources, associated with *Sargassum* beds were studied using a basket quadrat and dredges.⁹⁾ The abundance and species composition of resident fish were assessed in the artificial *Sargassum* bed using several fishing methods.¹⁰⁾ Captured fish were classified into the same three groups as from natural *Sargassum* beds, e.g. migratory fish, aborigines and rocky reef fish groups.¹⁰⁾ The biomass of phytal animals in the *Sargassum* beds varied according to the plant size, density and species diversity of the natural and artificial beds.¹¹⁾

DECREASE OF *SARGASSUM* BEDS

Since the 1960's, more than 100,000ha of coastal land has been reclaimed to increase new commercial and industrial areas. This resulted in a sacrifice of the coastal ecosystem, and a decrease in a natural *Sargassum* beds.¹²⁾ The ratio of natural sea coast decreased rapidly to 55% for the whole Japanese seacoast line, to over 80% in the Tokyo, Osaka and Hiroshima Bay regions.¹³⁾ Since the 1970's, barren grounds, called "Isoyake" areas in Japanese, have arisen in many coastal areas. "Isoyake" areas are considered to be a form of "deforestation" of the sea, caused by intensive grazing by herbivorous animals.¹⁴⁾ In these areas, *Sargassum* beds have declined and have not recovered naturally.

In the 1970's, technical studies on the restoration of rich *Sargassum* beds in "Isoyake" areas were initiated.¹⁵⁾ In the 1980's, technical studies investigated the re-establishment of natural coastal ecosystems to compensate for *Sargassum* beds destroyed or reduced through construction of reclaimed land. In the 1990's, artificial *Sargassum* bed creation was adopted by most coastal developmental projects, e.g. ports, fishing ports, breakwaters, formation of new agricultural land and new fisheries grounds. Recently, *Sargassum* bed restoration became an important aspect of environmental conservation and coastal zone management.¹⁵⁾

NEW TECHNIQUES FOR RESTORATION

Techniques for *Sargassum* bed restoration have been developed by application of the principles of seaweed cultivation using ropes and culture nets from the sea-surface to the sea-bottom.¹⁶⁾ The principal purposes related to *Sargassum* bed restoration in Japan have been classified into three categories,¹⁷⁾ e.g. 1) Cultivation of human food; 2) Propagation of benthic fishery resources; and 3) Increasing fish resources in a management-free style.

1) PERIODIC RE-TRANSPLANTING

Periodic re-transplanting, supported by artificial production of young plants, is effective to form a suitable seascape in severely polluted and sparsely vegetated areas. A germination rate of >80% and healthy growth in outdoor cultivation of *S. horneri* embryos was observed after storage at 5 °C for one year.¹⁸⁾ Healthy, rapid

growth and maturation of adventive embryos from *S. macrocarpum* was observed in outdoor culture tanks.¹⁹⁾

'Nursery substratum' made from concrete plate fragments were useful for transplanting artificially seeded *Sargassum* juveniles onto rocky bottoms and coastal structures.²⁰⁾ 'Seaweed transplanting plates' made from concrete plate fixed by stainless bolts were useful for re-transplanting of both artificially seeded young plants and mature mother plants which had been artificially attached.²¹⁾

2) PROVISION OF SUBSTRATA

Transplants on to artificially provided growing substrata is an effective method to extend nursery and fishing grounds around natural beds. The complete growth cycle (germination, growth, reproduction and death) of transplanted perennial *Sargassum* plants was observed on concrete blocks set on to a sandy bottom around a natural *Sargassum* bed.²²⁾ Experimental and ecological information has been obtained on the effect of the shape²³⁾ and time (season) of placement²⁴⁾ of artificial substrata and the effect of harvest¹¹⁾ on community organization on subtidal concrete blocks set around natural *Sargassum* beds.

3) RESTORATION OF SHALLOW BOTTOM

Restoration of shallow and gently sloping bottom substrata is effective in the creation of maintenance-free beds along developed coastlines. The technical points of management-free techniques for *Sargassum* bed creation are as follows: understanding the principal limiting factors to the local distribution of natural *Sargassum* plants, and reduction of a limiting factor at the actual site by coastal engineering. In such techniques, transplantation of plants is not required. Transplantation may be undertaken to accelerate growth of the *Sargassum* population.¹⁷⁾

However, information required for the establishment of "management-free techniques" for restoration of *Sargassum* beds, based on controlling ecological succession, is sparse. Experimental structures were placed at 8 depths on the sandy sea bottom off the western Seto Inland Sea.²⁵⁾ The blocks were structured as in a "stair reef" design with 6 heights above the sandy substratum.¹⁵⁾ The succession of algal vegetation at each depth was affected due to subtle differences in light intensity (depth) and sand action (height from sandy

bottom).¹⁵⁾ It has been suggested that *Sargassum* beds in various phases of establishment would be useful for restoration since their succession might be manipulated using the “stair reef” of various heights above a sandy substratum.¹⁵⁾

Gently sloping, shallow sea bottoms should be created to promote ecological succession on new substrata. Over the long term, *Sargassum* beds on artificial rocky structures and sea grass beds on sandy bottoms develop to form natural habitats which continue in to a maintenance-free state.²⁶⁾

A FORM OF COASTAL ZONE MANAGEMENT

Off the southwest coast of Hokkaido Is., northern Japan, barren grounds have been caused by intensive sea urchin grazing.²⁷⁾ Two methods of restoration were proposed in the “Isoyake” area: 1) seasonal control of excess grazing pressure using fences and, 2) adjustment of depth using blocks and stone to remove urchins by increasing the current velocity by waves.²⁷⁾ Off the south-west coast of Japan, “Isoyake” caused by sea urchin and herbivorous fish has become remarkably widespread,²⁸⁻³⁰⁾ even artificially established kelp beds were destroyed.³¹⁾ Restoration of *Laminaria* beds by systematic fishing of sea urchins is possible permission. Management of fishing grounds should be attempted in order to restore damaged seaweed beds.

It is important to make joint plans for coastal environment restoration within specific site, e.g. 1) restoration of shallow sea beds; 2) increase transparency by water quality purification; 3) fishing ground management; 4) undersea “green zone” management by the various environment industries (Fig.1).

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Fig1. Joint efforts for *Sargassum* bed restoration.³²⁾

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