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Introduction of Isoyake Recovery Guideline (Fisheries Agency, Japan)

Hisami KUWAHARA [*1], Osamu HASHIMOTO [*2], Akito SATO [*2] and Daisuke FUJITA [*3]

Abstract : Reduction of seaweed beds called 'isoyake' has become a serious problem in most of coastal prefectures in Japan. To restore seaweed beds, Fisheries Agency carried out a national project in cooperation with 16 prefectures and 19 specialists from fiscal 2004 to 2006. Isoyake Recovery Guideline was published in February 2007. Main users are fishermen who should be at the core of the restoration. Main theme is the control of intensive grazing by sea urchins and herbivorous fishes. Major topics are as follows.: (i) adaptive management to lead to successful reforestation through adaptive learning and feedback, (ii) flow chart for selecting techniques through 6 simplified categories which minimize trial and error, (iii) organized cooperation to support fishermen by volunteers, citizens, enterprises, specialists and local governments, (iv) useful viewpoints for detecting decrease of seaweeds and finding critical factors in recovering seaweed beds, (v) explanation of each technique systematized as a flow chart, (vi) promotion of effective use of herbivores to remove them from the habitat and so on.

Key words : guideline, barren ground, isoyake, adaptive management, herbivorous fish, sea urchins

Isoyake recovery project

Seaweed beds provide marine life with food sources and habitat, including breeding and nursery grounds, thus they are important communities to maintain fishery resources. However, reduction of seaweed beds called 'isoyake' has become a serious problem in most coastal prefectures in Japan. It is said that the area of seaweed beds that have disappeared are more than thousand hectares.

To restore seaweed beds, Fisheries Agency carried out a national project in cooperation with 16 prefectures and 19 specialists from fiscal 2004 to 2006. This project reviewed restoration attempts for isoyake reported in previous literatures, and tested them with some newly developed techniques in the field. In addition, various issues on isoyake were discussed at 2 national conferences and 2 local committees in a year. As a summary of the review and these meetings, the Isoyake Recovery Guideline was published in February 2007 (Fisheries Agency, 2007).

Concept of guideline

It has long been said that there are various factors causing isoyake including elevation of water temperature, and decrease of nutrients. (Kuwahara *et al.*, 2006a). According to the questionnaire survey to local government in 2005, reduction of seaweeds was reported from most of the coastal prefectures and overgrazing by herbivores (sea urchins and/or herbivorous fishes) is the most common causative agent of isoyake (Kuwahara *et al.*, 2006b). Therefore, the major theme of the guideline is how to control grazing by herbivores.

Fig. 1 illustrates the situation of isoyake in Japan. When grazing on seaweeds by herbivores exceeds the growth of seaweeds, the balance will incline clockwise leading to isoyake. The clockwise

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*1 National Research Institute of Fishery Engineering, Fisheries Research Agency, 7620-7 Hasaki, Kamisu, Ibaraki 314-0804, Japan
*2 Fisheries Agency, 1-2-1 Kasumigaseki, Chiyoda, Tokyo 100-8907, Japan
*3 Tokyo University of Marine Science and Technology, 4-5-7 Konan, Minato, Tokyo 108-8477, Japan

movement of the balance may be strengthened by other changes in backgrounds such as global warming and anthropogenic destruction of marine resources. In the unbalanced situations, disappearance of seaweeds and the consequent barren state will enlarge and maintain for a long time. Though the algal growth and grazing should be rebalanced essentially by improving the background conditions, we have few specific methods for the improvement at present. Therefore, though restoration of seaweed beds should be started from accessible areal size such as 100m × 100m, this guideline shows the effective and efficient methods to recover seaweed beds by decreasing herbivores and by increasing seaweed production.

Adaptive management in recovery from isoyake

In this guideline, adaptive management is introduced. This approach consists of eight sections from A to H (Fig. 2). In section A, the occurrence of the isoyake is detected and diagnosed. If the character of isoyake is enumerated, we proceed to Section B where the factor(s) inhibiting seaweed bed formation is identified using simple experiments or surveys in the field. In section C, the goal of the recovery is set with the reference of records of seaweed bed distributions in the past. In section D, methods to remove or alleviate the inhibiting factor identified in section B are examined. In section E, some practical techniques are selected. with the aid of a systematic flow chart of techniques. In section F, restoration is carried out using the technique on the target barren ground. The techniques should be selected considering social contexts in the fishermen's community because of easiness to repeat. After the action, as denoted in section G in Fig. 2, it is necessary to monitor the successional changes on the treated barren ground. Results obtained from monitoring are assessed through section H where the data is compared with the goal of the plans in section C. If the achievement of the goal is confirmed, the new goal should be aimed by starting from section C. If the goal has not been achieved yet, restarting from section B is needed to clarify the reason of the failure. After the reason was clarified, the new approach can be started.

Cycles of trials and monitoring to establish the adaptive learning and feedback control in the restoration of seaweed beds, and they give us valuable information on further management for rocky shore ecosystems.

Flow chart of processes in isoyake recovery

Fig. 3 shows a flow chart of processes sections from A to H. This flow chart helps us to find techniques to minimize the cost and labor of

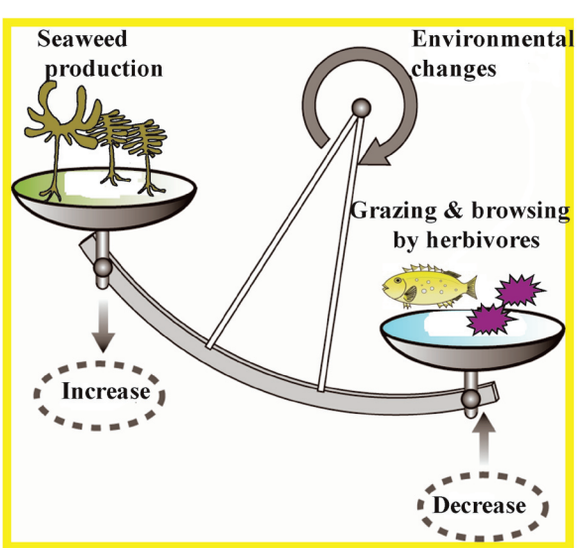


Fig. 1. Situation of isoyake in Japan.

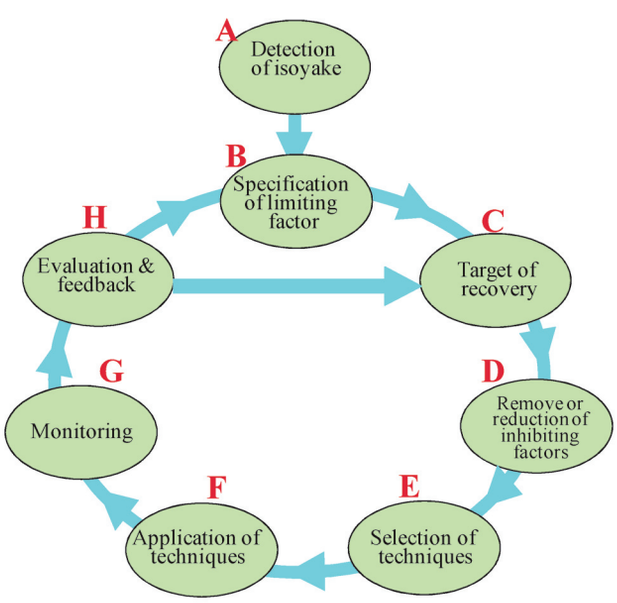


Fig. 2. Adaptive management in isoyake recovery

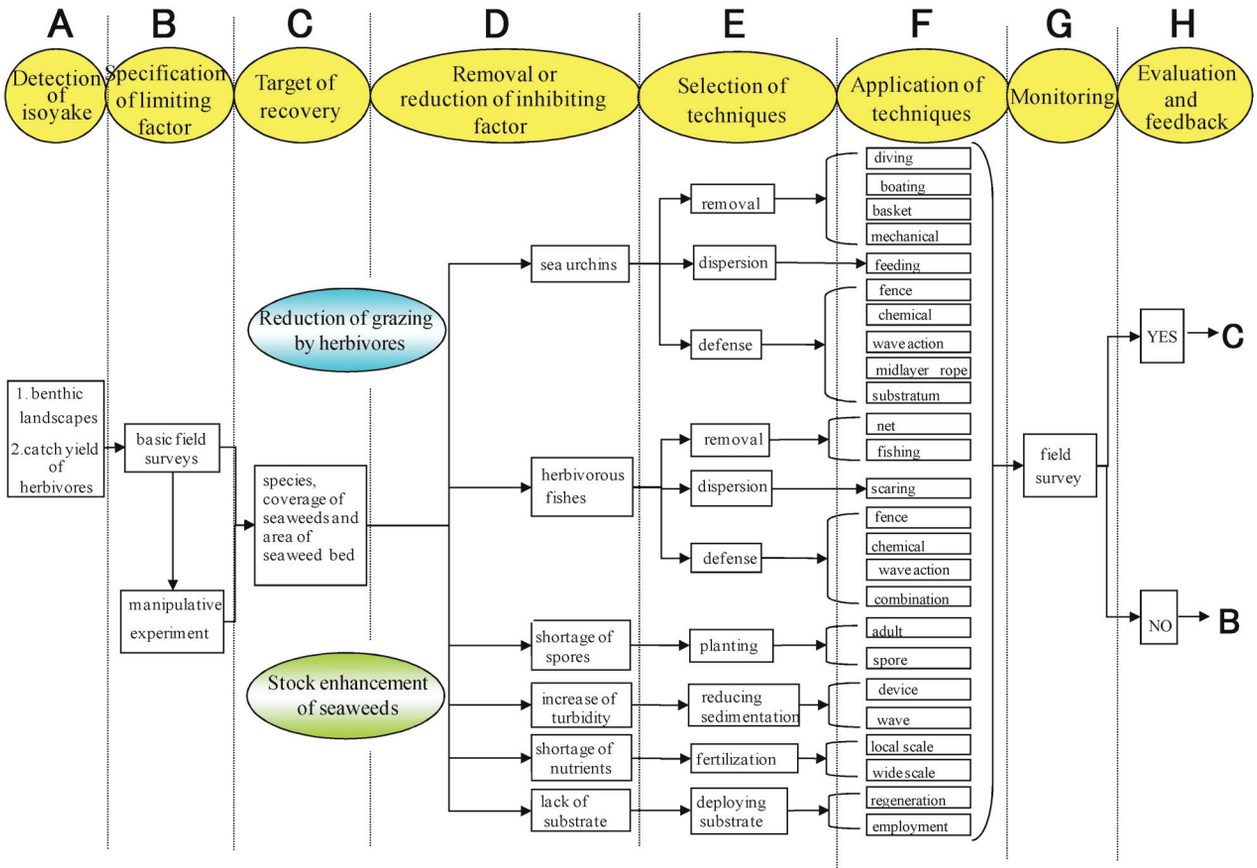


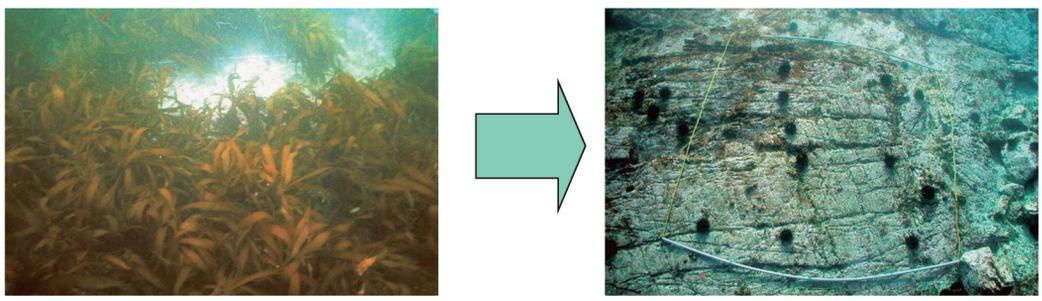
Fig. 3. Flow chart of processes in isoyake recovery

required for trial and error. The techniques were categorized into 25 groups according to their characteristics;. These techniques were extracted from a database with more than 1000 papers in domestic journals on restoration of seaweed beds published from 1970 to 2005 (Kuwahara *et al.,* 2006c). The flow chart is composed of two main branches; reduction of grazing by herbivores and stock enhancement of seaweeds. The former main branch was divided into two branches, for sea urchins and for herbivorous fishes, which are comprised of 10 and 7 techniques, respectively. In each branch, the techniques are categorized into 3 groups, removal, dispersion and defense. The latter main branch is composed of 8 techniques categorized into 4 groups, planting, reducing sedimentation, fertilization and deploying substrates.

Detection of isoyake

Fig. 4 shows section A that proposes two diagnostic methods for isoyake. The first method is the detection from benthic seascapes recorded at the fixed monitoring site every year. The pair of photos (Fig. 4a, b) taken in Ofunato district, Iwate Prefecture, is an example that shows isoyake caused by sea urchins. Photos taken on the sea area will give us valuable information about not only the presence or absence of isoyake but the process of deterioration of the seaweed bed. The second method is the use of statistical data of seaweed and/or and the related herbivores. The figure (Fig. 4c) shows the relationship between catch yields of a canopy forming kelp, *Eisenia arborea* and abalones (*Haliotis* spp.) in Hainan district, Shizuoka Prefecture. Catch yields of *E. arborea* decreased in the 1990's and followed by the depletion in catch yields of abalone. However, each fluctuation cannot

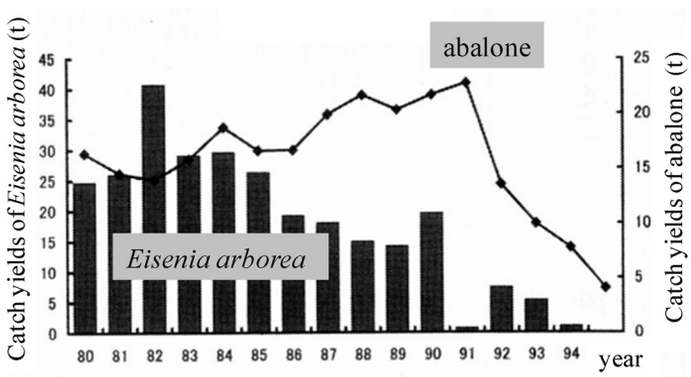
1. Using data of benthic landscapes (Ofunato district in Iwate Prefecture)



a) *Eisenia bicyclis* bed before deforestation (October, 2001)

b) Persistence of urchin barren (October, 2003)

2. Using statistic of catch amount (Hainan district in Shizuoka Prefecture)



c) Relationship between *Eisenia arborea* and abalone

Fig. 4. Two methods for detection of isoyake

be easily reverted as shown in the Fig. 4c.

Specification of limiting factor for reforestation

In section B, the factors inhibiting growth of seaweeds should be specified. At first, basic field surveys should be carried out using cross-shore observations and the profile of sea bottom, characteristics of sediment, spatial distribution, species composition, coverage of seaweeds and density of herbivores (the top figure of Fig. 5). Through the survey, the limiting factor can be speculated. Otherwise manipulative experiments should be planned. The bottom figure of Fig. 5 shows an example of a cage experiment. Two groups of seaweeds are transplanted on the experimental barren ground; one is protected from grazing by herbivores with the cage, the other is exposed to the grazers. If seaweeds in the cage remain while seaweeds outside disappear, grazing

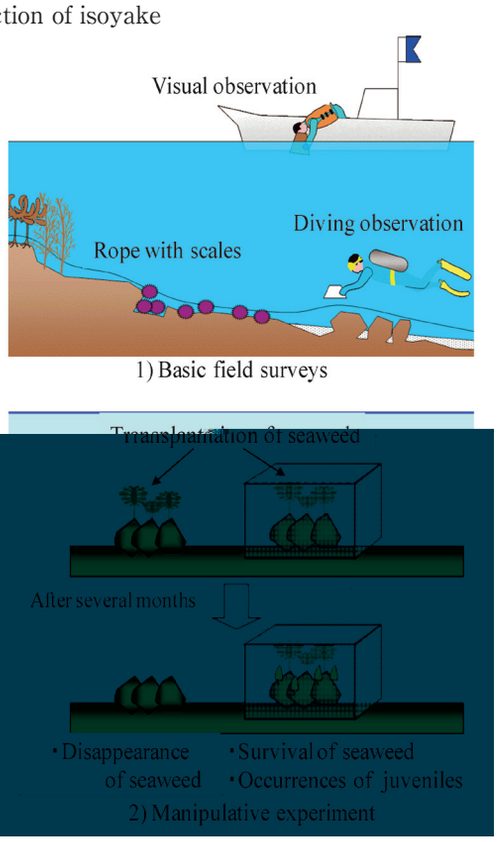


Fig. 5. Specification of limiting factors

by herbivores can be one of the inhibiting factors. In addition, this experiment provides us some other useful information. If seaweeds never deteriorate after transplantation, one can infer that ambient water conditions including nutrients and light have hardly affect growth of the seaweeds. Furthermore, if juveniles of the target seaweed appear within the cage, supply of seaweed spores can be confirmed. It is important to find out the limiting factors for seaweeds before one decides immediate countermeasures for isoyake.

Techniques to control grazing by sea urchins

Fig. 6 shows techniques to control the density (hence grazing pressure) of sea urchins. These techniques are categorized into 3 groups, removal, defense and dispersion.

Removal includes capture by divers, collecting from boat, baskets and pump. Removal by diving is the most efficient among the 4 techniques, but it also requires much labor and cost. Removal by boating and basket needs skill and is difficult to remove sea urchins hiding under stones. Removal by pump is to be developed because of its easiness for handling and low cost.

Defenses include rope, fence, increase of flow velocity and improvement of substrata. The suspended rope is effective along exposed coasts because sea urchins are shaken off by wave action. For enclosure, fence such as loosely folded or buoyed gill nets are used. Furthermore, changing their position is also the way that destabilize footholds for sea urchins. But biofouling and destruction by

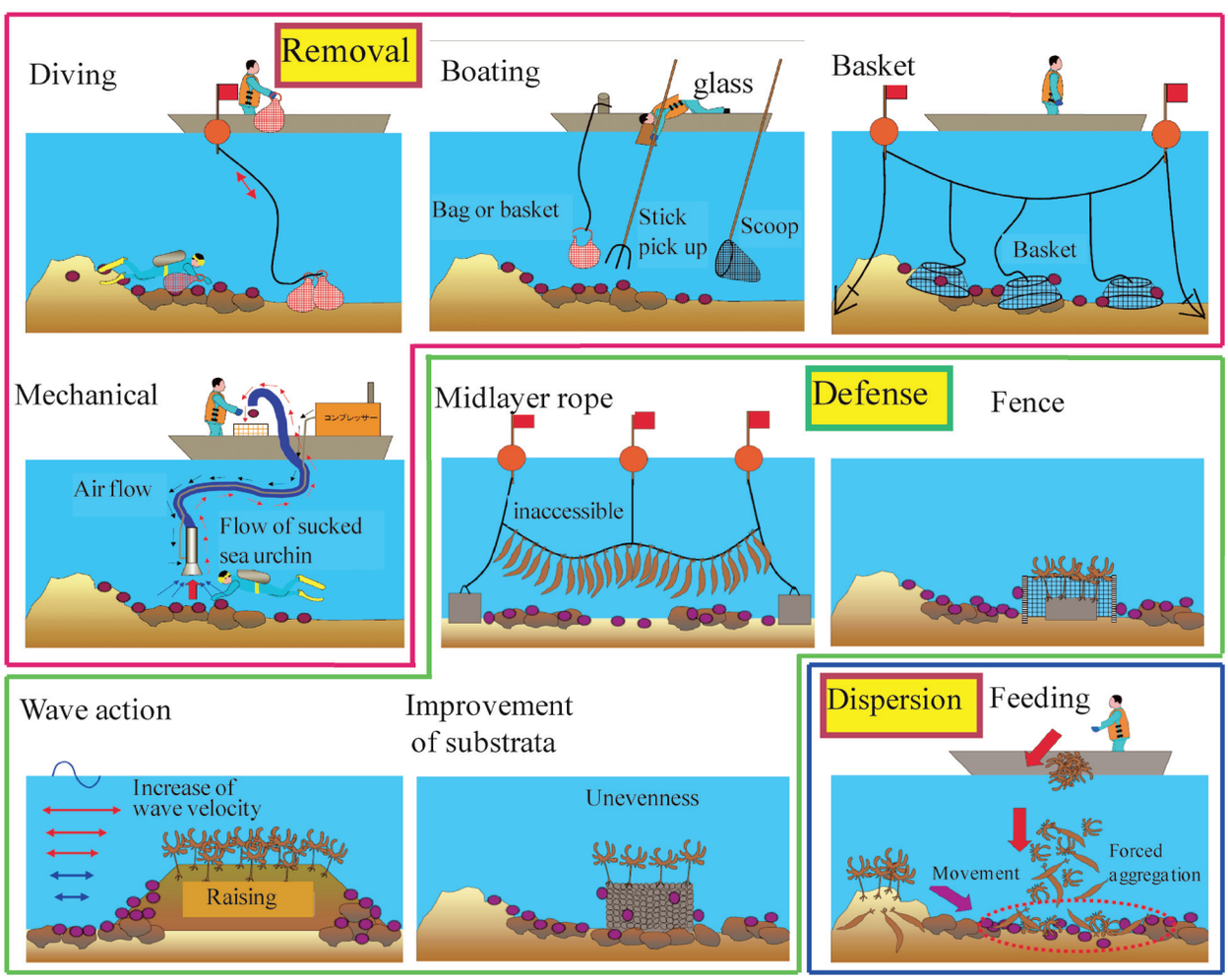


Fig. 6. Techniques to control density of sea urchins

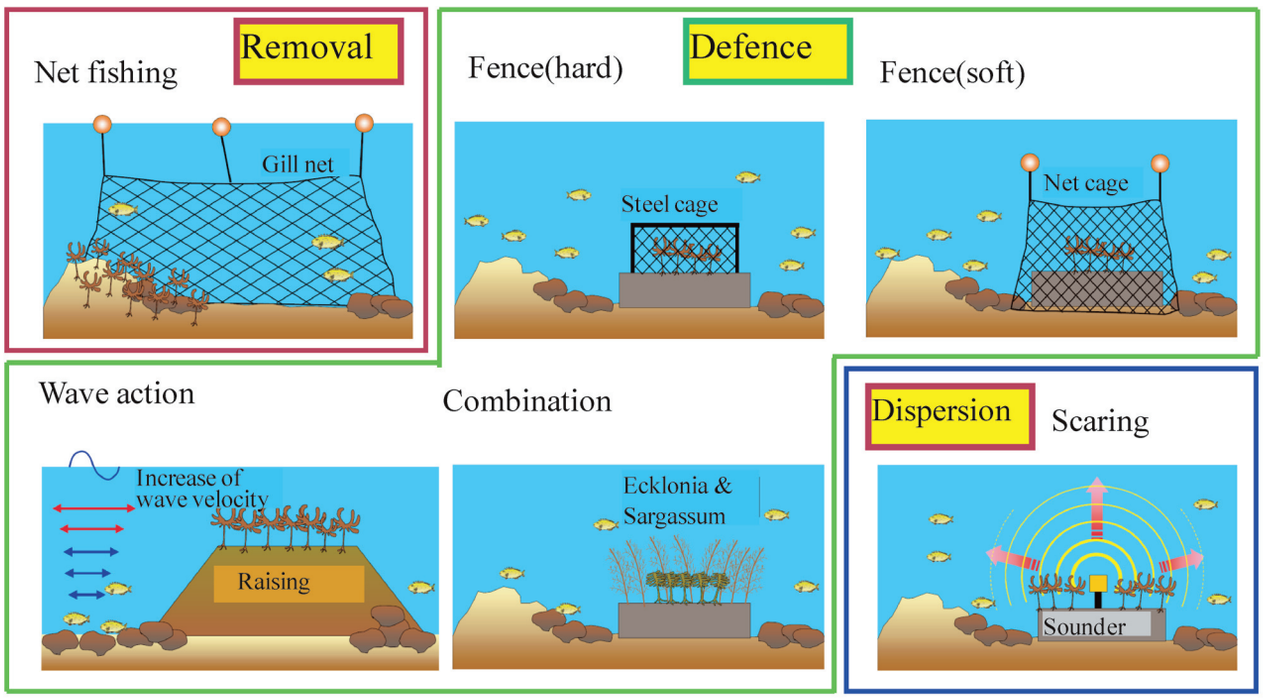


Fig. 7. Techniques to control grazing by herbivorous fishes

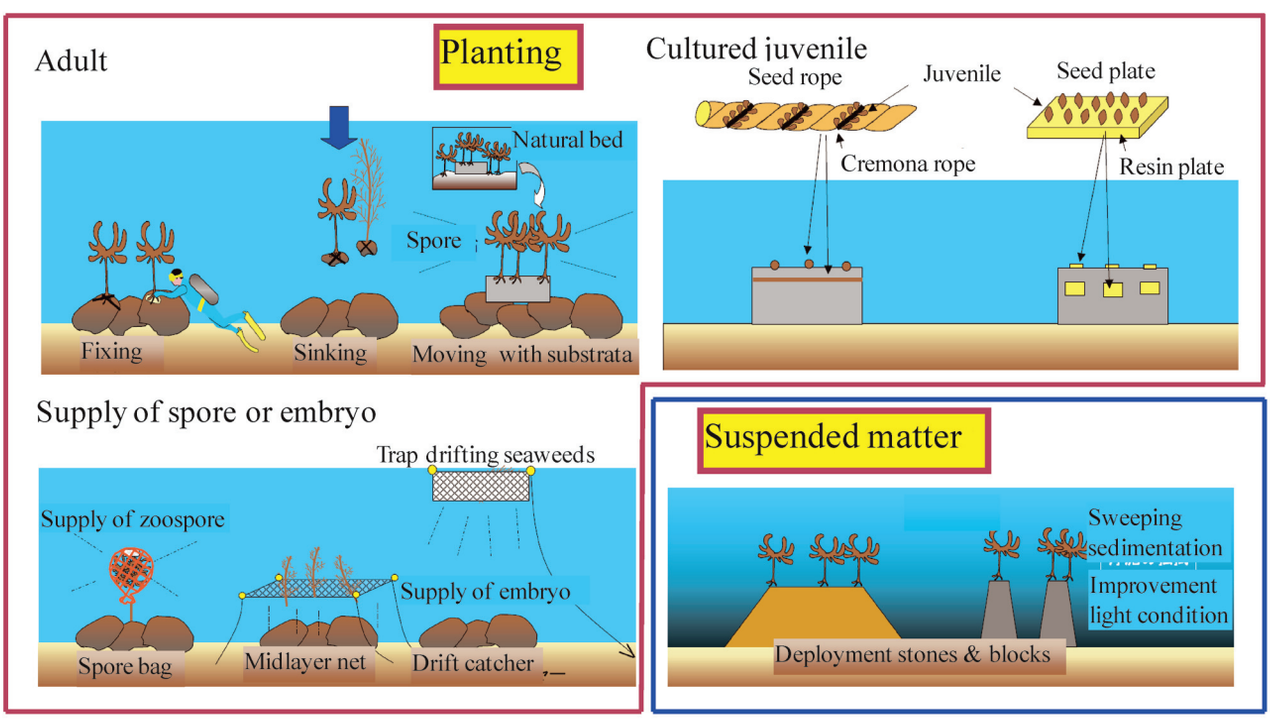


Fig. 8. Techniques for stock enhancement of seaweeds

waves disable long-term use of this method. The elevation of the bottom level using blocks or stones enhances the wave action on them. Enhanced wave motions suppress feeding activity of sea urchins and help seaweed grow. The relationship between the wave action and feeding activity of sea urchins is discussed by Kawamata in this issue. The improvement of substrata is a way to modify

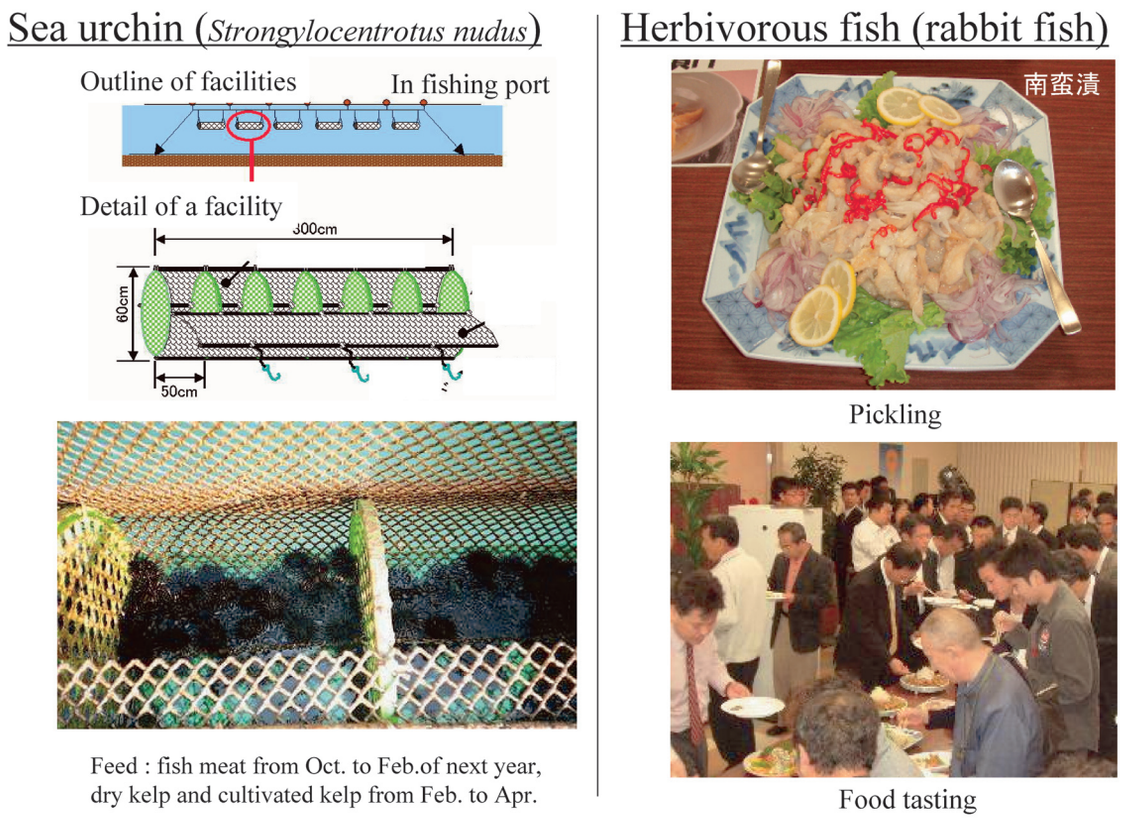


Fig. 9. Examples of effective use of herbivores

the surface microtopography of stones or blocks to increase the refuge of seaweed juveniles.

Dispersion is used to decrease the density of sea urchins by loosening their aggregations by feeding harvested seaweeds.

Techniques to control grazing by herbivorous fishes

Fig. 7 shows techniques to control grazing by herbivorous fish. Removal includes capturing with gill net, fixed shore net and fishing. Herbivorous fishes have often been recorded among the by-catch in net fishing (Akiyama, 2007). Recently, the active removal of herbivorous fishes has been started by fishing. Defenses include fences, increase of flow velocity and combination. Seaweeds in the fence are protected from browsing by fishes. However, the seaweed beds cannot extend out of the fence. Therefore, further improvement is needed to enable seaweeds to grow outside the fence. The combination is a trial to transplant the target on seaweed species with other species. According to information from divers, herbivorous fishes feed much more on seaweeds in uni-algal population than in multispecies communities. Studies about selectivity on seaweed species in herbivorous fishes were started recently. Dispersion is a method that keeps fish away from the seaweed bed by generating blast noises in the water. Wakayama Prefecture Fisheries Experiment Station is developing this method (Yamauchi *et al.*, 2006). Browsing by herbivorous fish has been known for more than a century but has become serious only recently in Japan. Ecological information is not enough to develop effective control of herbivorous fishes. The latest information on herbivorous fishes is shown by Yamaguchi in this issue.

Techniques for stock enhancement of seaweeds

Fig. 8 shows techniques for stock enhancement of seaweeds. Planting includes transplantation of adult seaweeds, supply of spores and embryos and

Fig. 10. Examples of the activity by Shiriya Fisheries Cooperative in Aomori Prefecture.

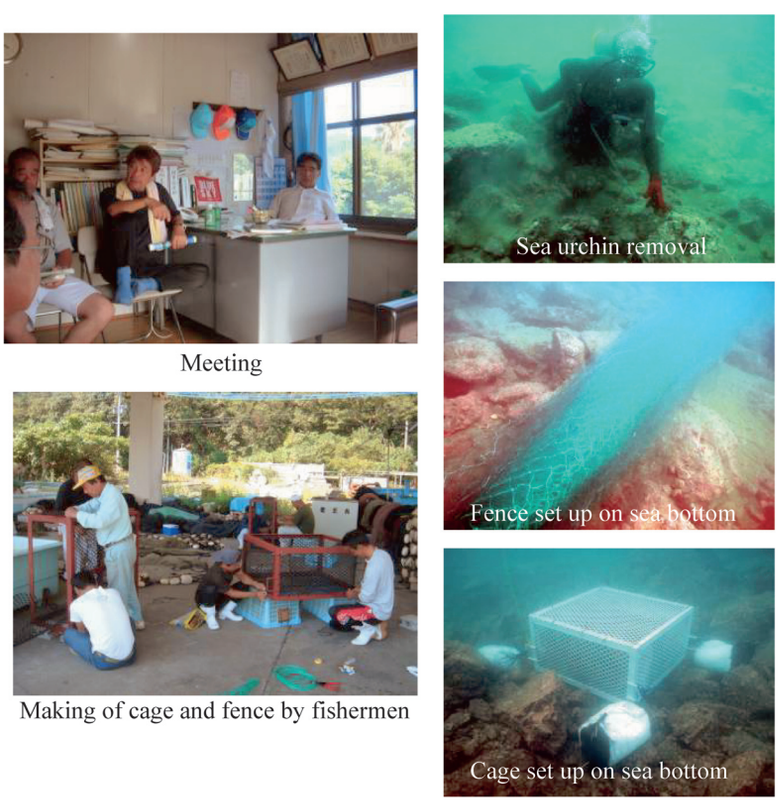


Fig. 11. Examples of the restoration activity by Nagoya Fisheries Cooperative in Oita Prefecture

cultured juveniles. In the transplantation of adult seaweeds, fixed adult seaweeds with adhesive anchors on the bottom. The simpler method is to throw adult seaweeds with weights from the sea surface. Cultured juveniles are transplanted with ropes or plates where embryos of seaweed grow. Supply of spores or embryos includes mesh bag with adult seaweeds, middle layer net with seaweeds and catcher of drifting seaweeds floated near the sea surface. This method is explained by Yatsuya in this issue. The influence of sedimentation and/or suspended particles has been reported in some bay and inland waters, and is becoming more serious recently. Removal of suspended particles may be needed to decrease light attenuation in the water, but the sources and pass way of the particles should be clarified to reduce the inflow.

Effective use of herbivores

Utilization of herbivores caught by fishermen is very important for the effective and sustainable management of the wild and restored seaweed beds. The left of Fig. 9 is an example of simple pen-culture in a fishing port for sea urchins removed from urchin barrens. This example has been carried out at Setana district in Hokkaido. At the beginning of the culture, sea urchins are fed with meat of fish *Pleurogrammus azonus* caught abundantly in this region, and then cultivated kelps are given to enhance their flavor. Sea urchins reared in this method mature faster than wild individuals; therefore their gonads can be sold at a good price early in the season.

In Japan, custom of eating herbivorous fishes are limited to local areas. The right of Fig. 9 shows a party for sampling the taste of rabbit fish *Siganus fuscescens*. In general, rabbit fish is disliked because of the distinctive smell of the fish meat and a toxic spine in their dorsal fins. However, the dishes of rabbit fish had good evaluation when cooked well without damaging the viscera in the sampling party. To popularize the taste for its commercialization, more sampling parties should be organized.

Practice of Isoyake recovery guideline

Our project team travelled all over the country to inform people about the guideline and to encourage them to practice the procedures given in the guideline. The core of this activity is giving adequate technical support to fishermen who are trying to start restoration of seaweed beds in isoyake area. This activity has been carried out in about 15 areas, where fishermen positively work on recovery from isoyake. In each area, a local consultation group was organized to decide the plan. In this group, practitioners of local government and scientific experts were included. We started new attempts in which that fishermen work together with people from other sectors such as universities and high schools. This practice is explained by Taino in this issue.

Fig. 10 shows an example of the activity by Shiriya Fisheries Cooperative in Aomori Prefecture. In this area, 1-3 hectares per year of kelp (*Saccharina japonica*) beds have been recovered since professional divers employed by fisherman carried out removal of sea urchins. In 2008, fishermen manifested the removal of sea urchins for themselves. Therefore, they were trained to use dry suits and to practice removal of sea urchins. They managed to implement a large-scale sea urchin removal project.

Fig. 11 shows the case of Nagoya Fisheries Cooperative in Ohita Prefecture. Seaweed bed in this region has been heavily grazed by both sea urchins and herbivorous fish. The fishermen made cages to protect seaweed from fish grazing and fences to protect from herbivorous fish. In this area, there are a lot of fishermen divers because they use SCUBA diving gears in their daily jobs. Therefore, they could complete sea urchin removal by themselves and they set nets and cages on the sea bottom.

References

Fisheries Agency, 2007: Isoyake recovery guideline. 213 pp. (in Japanese)

Akiyama S. (2007) Discards in Large-Scale Set Net in Tateyama Bay, Nippon Suisan Gakkaishi, **73(6)**, 1103–1108.

Kuwahara H., Watanuki A., Aota T., Ando W., Kawai T., Terawaki T., Yokoyama J. and Fujita D (2006a) Trends in Literature on Seaweed Restoration Techniques on Barren Grounds in Japan, Fisheries Engineering, **43(1)**, 81–87.

Kuwahara H., Watanuki A., Aota T., Yokoyama J. and Fujita D (2006b) Results of Questionnaire on 'Isoyake' in Japan, Fisheries Engineering, **43(1)**, 99–107.

Kuwahara H., Watanuki A., Aota T., Ando W., Kawai T., Terawaki T., Yokoyama J. and Fujita D (2006c) Summary of Component Techniques in 'Isoyake' Recovery Technology, Fisheries Engineering, **43(1)**, 89–97.

Yamauchi M., Kimura H. and Fujita D (2006) Seasonal and Diurnal Feeding Patterns of the Herbivorous Fish Siganus fuscescens and Scaring by Optic and Auditory Stimuli, Fisheries Engineering, **43(1)**, 65–68.