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Management of kelp ecosystem in Japan

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Abstract: Among the countries with kelp habitats, Japan is unique because of the highest diversity of kelp species (38 species) as well as the long history of harvest for utilization as a food material (> 1000 years) and stock enhancement (ca. 300 years). Management of kelp ecosystem has been challenged by legal control of kelp fisheries, culture of kelps, deployment or improvement of substrata, and restoration of the deforested areas. In Japan, kelp is harvested manually from boat without diving by fishermen after permitted by prefecture. The legal system is outlined in national acts and prefectural laws; details are ruled by fisheries cooperatives. The amount of cultured kelps is now comparative to that of wild in quantity. Deployment of artificial substrata, although increased between 1960's and 1990's, has been shrunk because of too short functional longevity and impacts on other members of communities. Improvement of substrata has been practiced using mechanical gears. The most recent nationwide concern in kelp ecosystem is the restoration on deforested areas. Publish of a guideline (2007), a succeeding project and the commencement of a new support system (2009) refreshed the national policy of monitoring, maintenance and restoration of kelp and other macroalgal beds to be more practical and effective by centering fishermen themselves.

Résumé : *Gestion de l'écosystème des Laminariales au Japon.* Parmi les pays où l'on trouve des habitats à laminaires, le Japon est unique parce qu'il abrite la plus grande diversité d'espèces (38) et possède la plus longue histoire en matière de récolte des kelps pour un usage alimentaire (> 1000 ans) et d'amélioration des stocks (environ 300 ans). La gestion des écosystèmes à laminaires a dû répondre aux exigences de la réglementation de la pêche des laminaires, de leur culture, du déploiement ou de l'amélioration des substrats et de la restauration des zones dépeuplées. Au Japon, la récolte des kelps se fait manuellement, sans pratique de la plongée, et est soumise à autorisation préfectorale. Le système est régulé par des lois nationales et préfectorales et géré par les coopératives de pêcheurs. Aujourd'hui, la culture des kelps est comparable en quantité à celles récoltées. Le déploiement de substrats, en hausse entre 1960 et 1990, a depuis été réduit en raison d'une longévité fonctionnelle trop courte et de la faiblesse des impacts sur les communautés et les environnements. L'amélioration des substrats a été réalisée avec l'usage d'engins mécaniques. La plus récente préoccupation nationale, en ce qui concerne l'écosystème des kelps, est la restauration des zones dépeuplées. La publication d'un guide (2007), un projet réussi et l'introduction d'un système de soutien (2009) ont renouvelé la politique nationale de surveillance, d'entretien et de restauration des kelps et d'autres stocks de macro-algues. Elle a été rendue plus pratique et plus efficace en la confiant aux pêcheurs.

Keywords: Culture ● Home sea ● Kelp ● Legal control ● Stock enhancement ● Restoration

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Introduction

Kelp ecosystem is an important algal system on rocky shores in the high latitudes of both hemispheres as most of kelps are foundation species (Mann, 1982; Dayton, 1985; Steneck et al., 2002) which support a diversity of organisms (Graham et al., 2008). Among the countries with kelp habitats, Japan is unique because of the highest diversity of kelp species in the world (Kawashima, 1989) as well as the long history of harvest for utilization as a food material (Okazaki, 1971; Nishizawa, 2002). The recent checklist of Japanese seaweeds and kelps (Yoshida & Yoshinaga, 2010; Yotsukura, 2011) contains 38 species of kelps (most of them were illustrated and diagnosed in Kawashima, 1989). In the long history of Japan, kelps have been used as a kind of tax to government at least in 900's (Miyashita, 1974). In order to maintain the kelp resources, fishermen began stock enhancement by piling stones since early 1700's (Ueda et al., 1963), developing rules of harvest and developed a culture method of kelps in 1800s (Tazawa, 1990). In 1900's, stone piling and later deployment of concrete blocks as well as culture using ropes were developed to increase kelp production (Saito, 1962; Ueda et al., 1963; Hasegawa, 1971). After experiencing changes in coastal environments (thus reduction of kelp habitats) accompanied with high economic growth in late 1900's (Nature Conservation Bureau, 1995), depopulation and aging in fishing villages (Statistics Bureau, 2003), Fisheries Agency of Japan published a guideline (Fisheries Agency, 2007) to direct the way of restoration of kelp and other macroalgal beds. After the "Shogunate" closed and new government opened in 1867, hundreds of articles, documents and books have been published on the biology (e.g. Kawashima, 1989), ecology (e.g. Hasegawa, 1962), culture (e.g. Saito, 1962; Kawashima, 1993) and stock enhancement (National Association of Coastal Fisheries Development, 1982) of kelps in Japan. However, as most of these papers are written in Japanese, few have been read in foreign countries (using alphabetical languages). On the stock management of kelps, even outline has never been introduced. Therefore, the author briefly introduced how we have been trying to manage kelps ecosystem in Japan in the modern context and discussed the current problems.

Materials and Methods

Management of kelp ecosystem in Japan includes legal control of kelp fisheries, culture of kelps, deployment or improvement of substrata, and restoration of the deforested areas. Here I outlined each of these social systems and activities using selected papers, books or web pages written in English. Some information written in Japanese are also included when they are comprehensive, available commercially or on web sites. Statistical data were obtained from web sites in Japanese Ministry of Agriculture, Forestry and Fisheries (2011).

Figure 1 shows the distribution of major kelp groups in the generic level. Among commercially important kelps, *Saccharina* spp. and other cold temperate kelps are limited to Hokkaido and three prefectures in northernmost and northeastern Honshu (i.e. Pacific side), while *Undaria pinnatifida* (Harvey) Suringar 1872 (mainly warm temperate) occurred in all of 39 coastal prefectures except Okinawa (subtropical, Ryukyu Islands). In central to southern coastal prefectures, warm temperate kelps in genera *Ecklonia*, *Eisenia* or *Eckloniopsis* are harvested for local usage as food but seldom mentioned here because of its small amount.

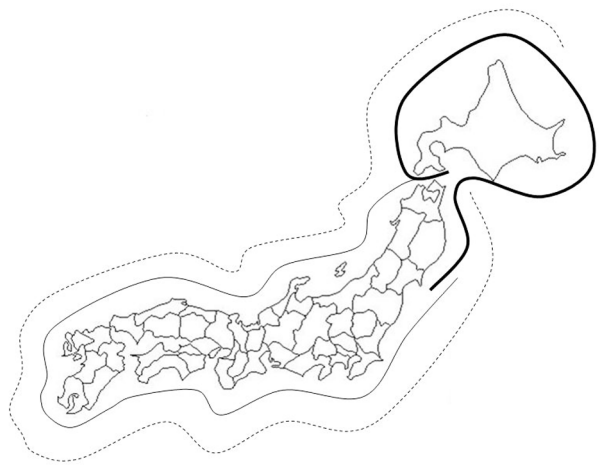

Figure 1. Map showing the distribution of commercial kelp in Japan, *Saccharina* spp. (thick), southern kelps *Ecklonia*, *Eisenia* and/or *Eckloniopsis* (narrow) and *Undaria pinnatifida* (dotted).

Figure 1. Carte de la distribution des kelps exploitées au Japon, *Saccharina* spp. (trait épais), kelps méridionales *Ecklonia*, *Eisenia* et/ou *Eckloniopsis* (trait fin) et *Undaria pinnatifida* (pointillés).

Results

Legal control of kelp fisheries

Early legal control of kelp fisheries in Hokkaido was summarized by Tazawa (1990). In Hokkaido, even in the age of "Shogunate" before 1867, poaching and underground dealings of kelp as well as over-harvest of yearling kelp were prohibited by local governors. After the "Shogunate" closed, coastal branches of Hokkaido prefectural governments in the new national government recommended the removal of a

rocky species of seagrass (*Phyllospadix iwatensis* Makino, 1931) as competitive weed in kelp beds and the appropriate selection of harvesting gears.

Now kelp fisheries are controlled in a unique legal system in Japan. The major laws are the Fishery Act (established in 1949) and the Act on the Protection of the Fisheries Resources (established in 1951); both of them have been revised several times to date (Ministry of Justice, 2011).

According to the Fishing Act, harvest of wild kelps needs a cooperative fishing right (for kelps and other macroalgae, class 1 among five classes), which is permitted to fisheries cooperatives (*i.e.*, not to individual fisherman nor to enterprise) by each prefectural governor. On the other hand, culture of kelps needs a demarcated fishing right (for kelp and other macroalgae, class 1 among five classes), which is permitted to individual fisherman by the governor of each prefecture but has to be renewed every 10 years. Further rules (e.g. target species, period of harvest, type of harvesting method) are given by prefectures and details are ruled, discussed and practiced by each fisheries cooperative (e.g. commencement time or its sign of harvest, daily or total amount limit, limitation of harvest ground, number of boat). Harvest of kelps and other fisheries resources by common people are prohibited and fishermen have the duty to maintain the stock under the Acts of the Protection of the Fisheries Resources. These acts and rules provide the fundamental legal frameworks for the kelp management in Japan. As the result, neither mechanical nor underwater diving kelp fisheries have been permitted all over the country. Only manual gears, such as hook with rod or rope, forked twister 'makka' with rod or rope, twister or sickle (Fig. 2 after Okazaki, 1971) are used by fishermen on boat or drift kelps are collected on shore.

In the fishery of *Saccharina longissima* (Miyabe) C.E. Lane, C. Mayes, Druehl & G.W. Saunders, 2006, a species with single blade, 7-8 m in length or more, Kawashima (1989) growing in northeastern Hokkaido, a hook with rod (Fig. 2A) is solely permitted. Abe (2010) pointed out that the hook with rod can harvest long blade but leave short blade near the bottom for further production (elongation and maturation). He also pointed out that the holdfast of which long blade is harvested in summer remains until autumn to winter and prevents the invasion of competitive small algae.

Kelp culture

To decrease the wild harvest, or to stabilize the production and income of fishermen, culture of kelp has been popularized in 1970's (Kawashima (1993) for *Saccharina* (as *Laminaria*), Ohno & Matsuoka (1993) for *Undaria pinnatifida* (Harvey) Suringar, 1873). No large-scale culture has been established for the other warm temperate kelps *Ecklonia, Eisenia* and *Eckloniopsis,* because of their long-lived perennial nature and local demand. Although the detailed explanation of culture methods is out of focus of this paper (see Nabata (2005) for the newest review), kelp culture has provided substantial contribution in the seaweed production industries in Japan. Figure 3 shows the recent production of seaweeds in Japan, including aquaculture and harvest of wild resources as averages between 2002 and 2006. In total seaweeds and only in *Porphyra* and kelps, production from aquaculture overwhelms the harvest of wild resources, although highly systematized and mechanized *Porphyra* culture (Oofusa, 1993) accounts for 63% among a total of ca. 600 thousand tons. Harvest and culture of commercial kelp (*Saccharina* spp. and *Undaria pinnatifida*) account for 15 and 18% of the total production, respectively. In perennial kelp *Saccharina* spp., establishment of forced culture technique shortened culture periods into less than 1 year (Hasegawa, 1971) and rapidly increased the culture production of kelps.

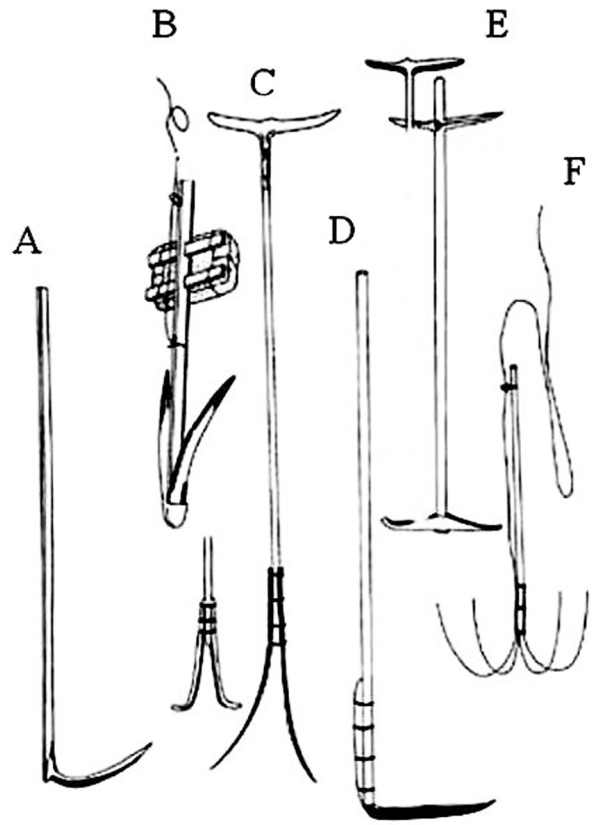

Figure 2. Gears for harvesting kelp in Japan, hooks with rod (A) or rope (B), forked twister with rod (C) or rope (F), sickle (D) and twister (E). Redrawn and retranslated after Okazaki (1971).

Figure 2. Engins de récolte des kelps, crochet avec tige (A) ou corde (B), fourche tordeuse à tige (C) ou corde (F), faucille (D) et tordeuse (E).

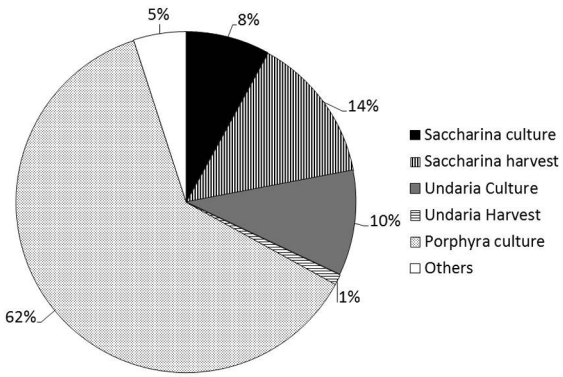

Figure 3. Production of seaweeds in Japan. Data are averaged between 2002 and 2006.

Figure 3. Production d'algues au Japon. Valeurs moyennes 2002-2006.

Now culture of *Saccharina japonica* (J.E. Areschoug) C.E. Lane, C. Mayes, Druehl & G.W. Saunders, 2006 extends southward beyond the southernmost boundaries of its wild population both on the Pacific and Sea of Japan sides, down to Kagoshima Prefecture of Kyushu (Matsuda, 2010). As the demand on *S. japonica* and its growth rate is large, kelp culture outside of its original distribution contribute to the supply of thinner but cheaper materials in the local areas. The cultured kelp is also used in improvement of sea urchin gonads or abalone meats.

Deployment and improvement of substrata

Deployment of artificial substrata has been another concern, which has much more longer history than culture. Among them, piling stones has been the most popular method since 1700's (Ueda et al., 1963) though it has not necessarily brought success in tock enhancement (Kinoshita, 1947). In addition, a variety of concrete blocks (Tokuda et al., 1994) have been deployed in the vicinities of kelp habitats since 1960's. As maintenance and enhancement of kelp stock are the duties of fishermen harvesting kelp. According to the Act on the Protection of the Fisheries Resources, deployment of stones and concrete blocks have been subsidized by national government (Fisheries Agency, Ministry of Agriculture, Forestry and Fisheries) (1/2) and prefecture (1/4); the rest (1/4) is paid by town/city and fisheries cooperative.

Although successful kelp growth has been often reported as shown in Tokuda et al. (1994), persistence of the established kelp beds has been actually limited on the blocks in spatial and temporal scales (Funano, 1981), particularly on the deforested bottoms (Fujita, 2010). In most studies on concrete blocks, monitoring periods (usually 3 years, only following the progressive succession to stable kelp forest phase) were not enough to follow the persistence of the established kelp beds, while the legally expected durable period (persistence of vegetation) of financially supported concrete block is 30 years. The deployment of hard materials contains high risks because improvement and removal is institutionally and financially difficult even when they reduce or lose the property as kelp substrata due to providing habitats for fouling organisms and/or herbivores (Fisheries Agency, 2007). Such hard techniques have been preferred by municipals, local construction companies and fisheries cooperatives rather than fishermen themselves because they have been highly dependent on this kind of subsidization.

In kelp habitat, improvement of substratum is necessary to control ecological succession to more unpalatable (i.e., left after grazing by herbivores) or long-lived seaweeds (e.g. *Sargassum*) rather than annual to biennial kelp. To clear these competitive 'weed algae' in fisheries ground, mechanical gears including wave-driven dragging of chains and bottom scrapers as well as backhoes (Fisheries Agency, 2007) have been used, though large scale treatments are highly expensive.

Restoration in deforested areas

The largest problem in the kelp ecosystem is "*isoyake*", which means persistence of barrens after deforestation (Fujita, 2010). "*Isoyake*" has not restricted to kelp system but other macroalgal systems on rocky coasts, including *Sargassum* and *Gelidium* systems, since the oldest record as early as 1830's in northeastern Honshu. Kelp reduced when thalli were fed by herbivores, withered in high water temperature/low nutrients, torn away by storm and/or recruitment was inhibited by the stagnation of waters and sedimentation. The resultant poor vegetated area often enlarged from offshore or appears in a zone between shallow and deep seaweed beds. The maintenance factor of barren state is not necessarily the initial factor of barren formation. Some occur naturally but the others are highly anthropological. "*Isoyake*" has increased during the 20th century; now most of coastal prefectures with and without kelp habitats have more or less "*isoyake*" areas (Fujita, 2010). The restoration of seaweed beds has often been unsuccessful because (1) drastic changes in coastal environments, (2) misunderstanding of "*isoyake*", (3) inappropriate selection of restoration method including deployment of substrata, (4) decrease of young fishermen, (5) limited information on planning and measures, (6) short of social support system, (7) limited commercial usages for priceless herbivores (Fujita, 2009).

In 2007, Fisheries Agency published *Isoyake Taisaku* (= Countermeasures to "Isoyake" Guideline (Fisheries Agency, 2007; Kuwahara et al., 2010) for promoting restoration of seaweeds. The principle of guideline is the

removal of factor(s) inhibiting formation of seaweed beds; the recommended actions include the adaptive management, introduction of small experiments before large scale projects and collaboration among fishermen, administrative, specialists and citizen. In the three-year project for extension (2007-2009), the policy and contents of the guideline has been popularized by local meetings in requested local fishing communities and practiced at experimental areas with the help of supporters (experienced specialists). In the restoration trials at the experimental areas, each practice was obliged to follow the steps of adaptive management shown in the guideline, to record the process and to announce the results for sharing information among participants and local residents. Introduction of a chief supporter (organizer, specialist, or professional diver) resulted in the successful recovery of algal communities in several urchin barrens (Taino, 2010; Watanuki et al., 2010). Now urchin barrens are highly recoverable to seaweed beds by removing sea urchins (Fujita et al., 2008), but further technical developments are needed to restore seaweed beds when barren state is maintained by other factors, *e.g*. feeding by herbivorous fish or high density of snails and sedimentation.

To develop restoration activities in nationwide scales, Fisheries Agency started a new project for supporting the conservation of environmental ecosystem in 2009 after two-year test periods (Fisheries Agency, 2009a & b). The new financial support system was established to keep monitoring, maintenance and restoration of seaweed beds. Other targets in the project are the maintenance of healthy tidal flats, coral reefs, shallow bottoms and reed (*Phragmites*) communities on the lakes. When admitted by the regional committee established in each prefecture, the proposed activity plans can be supported by a combined grant from town/city (1/4), prefecture (1/4) and nation (1/2) at least for five years (Fisheries Agency, 2009a). During the activities, applicants have the duty to monitor the seaweed beds in these target areas and record the process of selecting methods as well as results of their actions (Fisheries Agency, 2009b). Although level of skills and concerns varied in place to place, now more than 250 groups started action to restore healthy and functional ecosystems, among which 150 groups worked on seaweed beds, and 50 groups work for restoration of kelp beds. The subsidized restoration activities were removal of sea urchins, supply of fertile kelp or seedlings, fertilization and/or clearance of weeds on bedrocks (Fisheries Agency, 2009b). Methods for monitoring and maintenance of seaweed beds are introduced in Fujita et al. (2010). For example, usages of handy GPS, digital camera hanged from balloon or radio-controlled model helicopter, fish finder (echo sounder), side-scan sonar, aerial photograph and satellite photograph are explained for monitoring areal size of seaweed beds. In addition, examples of long-term monitoring, detecting factors to reduce beds and historical or new soft and improved hard techniques for maintenance and restoration are introduced.

Discussion

Among the management of kelp ecosystems in Japan, ruling of kelp fisheries and deployment of substrata have much longer history than the other activities such as improvement of substrata, culture of kelps and restoration of the deforested areas.

The present ruling systems, *i.e.,* national and prefectural laws as well as detailed rules by fisheries cooperatives have well protected the kelp resources even in the modern context. However, the limitation of handling commercial herbivores (e.g. sea urchins, gastropods) in the same act and local rules sometimes disturbs volunteer activities for restoration of kelp beds when local public officers hesitate to widen interpretation of the rules even in the necessary restoration programs (e.g. removal of sea urchins). Even when permitted, procedures are often complicated to introduce the volunteer divers so that restoration activities are often spatially and temporally limited. However, because of depopulation, aging and increasing of side job in the fishing villages, flexible application or renewal of these rules is needed for the extension of volunteer activities.

Deployment of substrata contains problems, because functional longevity of piled stones and concrete blocks are quite limited in deforested areas. In addition, deployed substrata such as concrete blocks sometimes provide a base for further deforestation because they are inhabited by herbivores. They also change the course and strength of water motion which is needed for the growth of seaweed. Water motion not only enhances nutrient uptake by seaweed, sand abrasion (clearance of rock surface) and turnover of stones (supplying uncovered surface) but prevents from sedimentation and heavy grazing (Fujita, 2009).

The largest problem is the difficulty in removal of concrete structures even when they lose the function or weaken the ambient water motion. The managers of these structures (town/city) have to return the subsidization to prefecture and nation and remove them by their own finance. Therefore, duty of maintenance or removal of these structures by the prospective manager (town/city or fisheries cooperative) should be informed adequately during the subsidization in the further project of deployment of substrata. As in mechanical improvement of kelp beds, maintenance of deployed substrata should be a key for further planning and economical evaluation of this kind of project.

As the figure 3 shows, production of kelp culture is comparative to harvest of wild kelps. There are some local problems on the kelp culture, for example, grazing by sea hare

Aplysia, nesting by epifauna such as amphipods and hydrozoa, decrease of healthy culture site and some diseases in seedling centers and on the sea (Nabata, 2005). However, the largest problem in kelp culture is the competition in price and quality with the imported products cultured in other Asian countries because the quality is being improved than before, particularly in *U. pinnatifida*. The ecological impacts by the resultant decrease of domestic kelp culture should be monitored because kelp populations in culture have ecological functions in the similar way as in wild kelp beds. Decrease of the temporal beds (*i.e.,* culture rafts) may induce the loss of habitats of related infauna and drift kelp expected as food for herbivores. Restoration of kelp and other beds are now extended in a nationwide project after publishing of "*Isoyake Taisaku*" Guideline (Fisheries Agency, 2007). The activity of Environmental and Ecosystem Conservation refreshed the national policy of monitoring, maintenance and restoration of seaweed beds. Some are also expected on the contribution to the culture of kelp by means of increasing food for commercial herbivores and maintenance of piled stones and concrete blocks. The largest characteristic is the system which is well systematized (Fisheries Agency, 2009b) and supported financially (Fisheries Agency, 2009a), academically (Fujita et al., 2006, 2008 & 2010) and technically (National Federation of Fisheries Cooperative, 2011). The problem in the project is the absence of budget for subsidization in some deficient prefectural governments.

In the management of kelp beds in Japan, setting of marine protected areas (MPA, see Yagi et al. (2010) for the current status in Japan) is not the core. As Japanese people have utilized a variety of marine resources, fish, shellfish, kelp and seaweeds in a balanced traditional way. Therefore, no-take conditions in MPA cannot maintain the balanced system as shown in the case of Hong Kong, China (Ang et al., 2010) where increased sea urchins collapsed *Sargassum* beds after setting MPA. Therefore, monitoring, manual maintenance and restoration of seaweed beds are the most reasonable way of management of seaweed-based ecosystems. We need to take care and manage seaweed beds (limited in coastal shallow waters accounting for only 0.5% of Japanese territory on land), located within the "*Sato-umi"* (Home Sea), "like gardens around our houses". Because of recent rapid anthropogenic changes in coastal areas and depopulation of fishing village, fishermen have to pay much more efforts to maintain the kelp communities for their sustainable fishery than before (Fisheries Agency, 2009a & b). Important are to sustain supports for the fishermen as well as the stop of further destructive changes on the coastal areas.

References

Abe E. 2010. *Stories on Kelp in Kushiro and Nemuro Regions,* Private publication, 70 pp.

Ang Jr P.O., So K.Y., Li T.W., Yeung F.F., Wong S.Y. & Woo C.K. 2010. Balance between harvesting pressure and protection: Implications for barren ground formation in Hong Kong. *Bulletin of Fisheries Research Agency*, **32**: 51-60.

Dayton P.K. 1985. Ecology of kelp communities. *Annual Review of Ecology and Systematics*, **16**: 215-245.

Fisheries Agency 2007. *Isoyake Taisaku Guideline*, 208 pp.

Fisheries Agency 2009a. *Environment and Ecosystem Conservation*, 8 pp.

Fisheries Agency 2009b. *Guideline of Environment and Ecosystem Conservation Activities*, 158 pp.

Fujita D. 2009. *Decline and restoration of Seaweed Beds*, Tokyo Fisheries Promotion Foundation: Tokyo. 55 p.

Fujita D. 2010. Current status and problems of isoyake in Japan, *Bulletin of Fisheries Research Agency*, **32**: 33-42.

Fujita D., Machiguchi Y. & Kuwahara H. 2008. *Recovery from sea urchin barrens - Ecology, fishery and utilization of sea urchins*, Seizando- Shoten, 296 pp.

Fujita D., Murase N. & Kuwahara H. 2010. *Monitoring and restoration of seaweed beds*, Seizando-Shoten, 260 pp.

Fujita D., Noda M. & Kuwahara H. 2006. *Marine Herbivorous Fish - Ecology, Fishery and Utilization.* Seizand-Shoten, 259 pp.

Funano T. 1981. Ecological and maricultural studies on *Laminaria japonica* growing on the shores of Date City, Hokkaido 2. Technical approaches to create laminarian forests by concrete blocks and cut stones. *Scientific Report of Hokkaido Fisheries Experiment Station,* **23**: 9-52.

Graham M.H., Halpern B.S. & Carr M.H. 2008. Diversity and dynamics of Californian subtidal kelp forests. In: *Food webs and the dynamics of marine benthic ecosystems* (T.R. McClanahan & G.R. Branch eds.), pp. 103-134. Oxford University Press: Oxford.

Hasegawa Y. 1962. An ecological study of *Laminaria angustata* Kjellman on the coast of Hidaka Prov. Hokkaido. *Bulletin of Hokkaido Regional Fisheries Research Laboratory,* **24**: 116-138.

Hasegawa Y. 1971. Forced cultivation of *Laminaria*. *Proceedings of the 7th International Seaweed Symposium*: pp. 391-393.

Kawashima S. 1989. *Illustrated book of Japanese Kelp*, Kitanihon Kaiyo Center, 215 pp.

Kawashima S. 1993. Cultivation of the brown alga, *Laminaria* 'Kombu', In: *Seaweed cultivation and marine ranching* (M. Ohno & A.T. Critchley eds), pp. 25-40. Japan International Cooperation Agency (JICA): Yokosuka.

Kinoshita T. 1947. *Studies on the stock enhancement of Kombu and Wakame.* Hoppo Syuppansha: Sapporo*,* 79 pp.

Kuwahara H., Hashimoto O., Sato A. & Fujita D. 2010. Introduction of Isoyake recovery Guideline (Fisheries Agency, Japan), *Bulletin of Fisheries Research Agency*, **32**: 51-60.

Mann K.H. 1982. *Ecology of coastal waters, a system approach*. Blackwell: Oxford. 322 pp.

Matsuda Y. 2010. *Aforestation in the Sea*. Midori-Shobo, 167 pp.

Ministry of Agriculture, Forestry and Fisheries 2011. Statistical Yearbook of Ministry of Agriculture, Forestry and Fisheries. http://www.maff.go.jp/j/tokei/ kouhyou/kensaku/ bunya6.

Ministry of Justice 2011. Japanese Law Translation. http://www.Japaneselaw translation.go.jp/

Miyashita A. 1974. *Seaweed*. Hosei University Press: Tokyo. 315 pp.

Nabata S. 2005. Kombu and Wakame. *Aquaculture System,* **3**: 35-56.

National Association of Coastal Fisheries Development 1982. *Guideline to create nursery.* Chikyusha, 252 pp.

National Federation of Fisheries Cooperatives 2011. Handbook of Environment and Ecosystem Conservation, 110 pp.

Nature Conservation Bureau 1994. The report of the marine biotic environment survey in the 4th national survey on the natural environment. Vol.2. Algal and Sea-grass Beds, 400 pp.

Nishizawa K. 2002. *Seaweeds. Kaiso Bountiful harvest from the seas.* Japan Seaweed Association. 106 pp.

Okazaki A. 1971. *Seaweeds and their Uses in Japan*. Tokai University Press, 165 pp.

Oofusa T. 1993. The cultivation of *Porphyra* 'Nori'. In: *Seaweed cultivation and marine ranching* (M. Ohno M. & A.T. Critchley eds). pp. 57-73. Japan International Cooperation Agency (JICA).

Ohno M. & Matsuoka M. 1993. Cultivation of Undaria 'Wakame'. In: *Seaweed cultivation and marine ranching* (M. Ohno M. & A.T. Critchley eds). pp. 41-49. Japan International Cooperation Agency (JICA).

Saito Y. 1962. Fundamental studies on the propagation of *Undaria pinnatifida* (Harv.) Sur. *Contributions of the Fisheries Laboratory Faculty of Agriculture University of Tokyo,* **3**: 1-101.

Statistics Bureau 2003. Households, Household Members and Persons Engaged in Marine Fisheries (1953-2003), http://www.stat.go.jp/data/chouki/zuhyou/07-39.xls

Steneck R.S., Graham M.H., **Bourque B.J., Corbett D., Erlandson J.M., Estes J.A. & Tegner M.J. 2002.** Kelp forest ecosystems: biodiversity, stability, resilience and their future. *Environmental Conservation*, **29**:436-459.

Taino S. 2010. Different effects on seaweed succession after sea urchin removal at several coastal waters in Tosa Bay, southern Japan, *Bulletin of Fisheries Research Agency*, **32**: 61-67.

Tazawa N. 1990. *History of kelp fisheries in Hokkaido*, Private publication, 414 pp.

Tokuda H., Kawashima S., Ohno M. & Ogawa H. 1994. *Seaweeds of Japan*, Midori Shobo, 194 pp.

Ueda S., Iwamoto K. & Miura A. 1963. *Fisheries Botany*, Koseisha-Koseikaku, 643 pp.

Watanuki A., Aota T., Otsuka E., Kawai T., Iwahashi Y., Kuwahara H. & Fujita D. 2010. Restoration of kelp beds on an urchin barren: Removal of sea urchins by citizen divers in southwestern Hokkaido. *Bulletin of Fisheries Research Agency*, **32**: 83-87.

Yagi N., Takagi A.P., Takada Y. & Kurokura H. 2010. Marine protected areas in Japan: Institutional background and management framework. *Marine Policy*, **34**: 1300-1306.

Yoshida T. & Yoshinaga K. 2010. Checklist of Marine Algae of Japan (Revised in 2010), *Japan Journal of Phycology*, **58**: 69-112.

Yotsukura N. 2011. The hierarchy of Laminariales in Japan, *Algal Resources*, **3**: 193-198.