The 3rd Edition

Guidelines for Conservation and Restoration of Seaweed Beds

(Isoyake Recovery Guidelines／Excerpted version)

March 2021

Fisheries Agency of JAPAN

The English translation of this excerpted version of the 3rd Edition Guidelines for Conservation and Restoration of Seaweed Beds (Isoyake Recovery Guidelines) includes only a portion of the content found in the original document. For further detailed information, please refer to the original document.

Preface

Japan, being an island nation surrounded by the sea, has long benefited from the bounty of marine products. Seaweed beds play an important role in providing these products. They serve as spawning grounds for marine organisms and as habitats for juvenile fish, and also function as feeding grounds for aquatic organisms that eat seaweed, such as abalone and turban shells, and for important predatory organisms, thereby contributing to the proliferation of fishery resources.

In order to ensure a stable and broad supply of marine products, the Fisheries Agency of JAPAN has been implementing measures to improve the growth environment for marine organisms in accordance with the Basic Plan for Fisheries and the Long-Term Plan for the Development of Fishing Ports and Fishing Grounds and seaweed beds are a crucial component of such environments. However, the expansion of "*isoyake*" (the large-scale decline and disappearance of such seaweed beds) has had a significant impact on the fishing industry. In recent years, blue carbon (carbon captured and stored by marine organisms) has been gaining attention as a way to fix carbon dioxide (CO_2), and seaweed beds are expected to play a role in this regard. To facilitate the widespread implementation of *isoyake* countermeasures by fishermen and other stakeholders, the Fisheries Agency of JAPAN has previously formulated the *Isoyake* Recovery Guidelines (2007) and the Revised *Isoyake* Recovery Guidelines (2015).

To date, *isoyake* countermeasures utilizing programs such as the Fisheries Multifunctional Measures Project have been implemented in various regions across Japan, and there have been numerous cases where seaweed beds have successfully recovered. However, in many cases, the recovery has been on a small scale, or the seaweed beds have reverted to an *isoyake* state after a temporary recovery. As such, maintaining and expanding the restored seaweed beds remains a challenge. Factors contributing to this challenge include difficulties in establishing a sustainable system for implementing *isoyake* countermeasures and the increasing complexity of obstacles to seaweed bed recovery due to recent changes in the marine environment. For instance, rising seawater temperatures have led to the disappearance of traditional seaweed bed component species, while the expanded distribution of herbivorous organisms has reduced the effectiveness of conventional *isoyake* countermeasures. In such cases, it is crucial to reassess the current situation, as the primary obstacles to seaweed bed recovery may have changed or increased, and, depending on the situation, effectively combining multiple countermeasure techniques may help to achieve seaweed bed recovery.

In revising the *Isoyake* Recovery Guidelines this time, we have worked to address the numerous issues surrounding seaweed beds, drawing on valuable advice from experts across various fields, including Associate Professor Daisuke Fujita of Tokyo University of Marine Science and Technology. Particular emphasis has been placed on enabling the implementation of *isoyake* countermeasures that respond to recent changes in the marine environment and on fostering sustainable activities. To this end, the guidelines include explanations accompanied by practical examples. Specifically, in addition to strengthening measures against herbivorous fish, which have had a growing impact on seaweed beds in recent years, the guidelines also present numerous case studies of countermeasures from various regions. Furthermore, new technologies that utilize ICT (information and communication technology), such as UAVs (drones), to improve the efficiency of assessing the current state of seaweed beds are also introduced.

We hope that these revised *Isoyake* Recovery Guidelines will be actively utilized by everyone across the country working on *isoyake* countermeasures, leading to the resolution of *isoyake* in their respective areas. Ultimately, we wish for significant recovery and maintenance of seaweed beds across Japan, contributing to the enhancement of fishery resources.

March 2021

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Introduction

Isoyake is a phenomenon in which seaweed beds decline and remain in a barren state without recovery. When seaweed beds deteriorate, it reduces the number of commercially valuable fish and shellfish, leading to poor growth and reduced yields, which significantly impacts coastal fisheries. Japan is a nation surrounded by the sea on all sides and is heavily reliant on seaweed and rocky shore resources. As such, Japan recognized this phenomenon over a century ago, and was the first country in the world to address the issue through efforts to restore depleted seaweed beds, such as stone placement, shoreline cleaning, and fertilization, have been implemented. These efforts were more effective in the past, during cooler climates that preserved nature, and when moderate fishing was practiced.

However, over the past quarter-century, the effects of global warming have become increasingly evident, with rising seawater temperatures not only expanding the decline of seaweed beds but also altering the distribution of marine species. Additionally, frequent and intensified storms and floods have prompted the construction of revetments and wave-dissipation structures, as well as river basin management, which have significantly transformed coastal environments. Furthermore, overfishing driven by health trends and increased inbound tourism demand has weakened coastal ecosystems. Meanwhile, the decline in the number of fishermen, their aging population, and the shift toward part-time fishing have led to a shortage of individuals responsible for managing and restoring seaweed beds. Countermeasures reliant on administrative bodies and construction efforts have, in some cases, inadvertently increased herbivorous species and made seaweed bed management more challenging.

The *Isoyake* Recovery Guidelines were compiled by bringing together the wisdom and techniques of our predecessors to enable fishermen themselves to take the lead in planning and implementing the restoration of seaweed beds. It has been 14 years since the first edition (2007) and 6 years since the revised edition (2015), during this time there have been significant changes in the circumstances surrounding seaweed beds. The spread of drones and underwater drones has brought significant improvements to methods for monitoring seaweed beds. In 2009, the Environmental Ecosystem Conservation Activity Support Promotion Project was launched, followed in 2013 by its successor, the Fisheries Multifunctional Measures Project. These initiatives established a globally unique public subsidy system to support activities by fishermen, including seaweed bed restoration and monitoring. The tsunami and nuclear accident caused by the 2011 Great East Japan Earthquake dealt a major blow to coastal communities and the fishing industry. However, in some affected coastal areas, the original seaweed beds temporarily recovered, highlighting the importance of water circulation and nutrient salts supply. In 2009, the United Nations named ocean carbon storage of carbon dioxide (CO_2) related to global warming as "blue carbon," thereby bringing global recognition to the importance of seaweed beds in mitigating climate change. This has also rapidly increased interest in knowledge and countermeasures for historic Japanese *isoyake*. Domestically within Japan as well, there has been a reevaluation of the role of food chain dynamics in regulating herbivorous organisms, which had previously been overlooked, and there are growing expectations for the recovery and maintenance of seaweed beds in fishing grounds that have been abandoned due to the declining number of fishermen. Additionally, with the marine plastic pollution becoming increasingly serious, careful consideration must now be given to the materials and management of tools that are used in seaweed bed restoration.

Under these circumstances, in favorable marine areas, seaweed beds must be steadily restored and expanded to increase rocky shore resources. Meanwhile, in more challenging marine areas, it will be necessary to adapt to *isoyake* through a "coexisting with *isoyake*" approach. We hope this guideline will serve as a valuable compass, leading to the recovery of as many seaweed beds as possible and to the restoration of vibrant coastal areas.

March 2021

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: Indicates items included in the excerpted English translation

Chapter 1: Purpose of these Guidelines

In addition to providing a habitat for fish and shellfish and a nursery for spawning and juvenile fish, seaweed beds play a major role in absorbing and fixing nutrients salts and carbon dioxide (CO_2) in the ocean and supplying oxygen. However, due to recent environmental changes caused by climate change, as shown in Figure 1-1, the balance between the productivity of the seaweed that constitutes seaweed beds and the grazing pressure from herbivorous organisms has been disrupted, resulting in *isoyake,* primarily caused by herbivores, becoming a nationwide issue. In response to this, fishermen have led efforts to restore and conserve seaweed beds, but fishermen's aging populations and labor shortages have made it increasingly difficult to implement traditional countermeasures. Therefore, to maintain and preserve healthy seaweed beds and promote effective *isoyake* countermeasures, these guidelines have been revised to make them more practical by reviewing countermeasure technologies and developing advanced countermeasure techniques using ICT (information and communication technology) as exemplified by drone-based image acquisition.

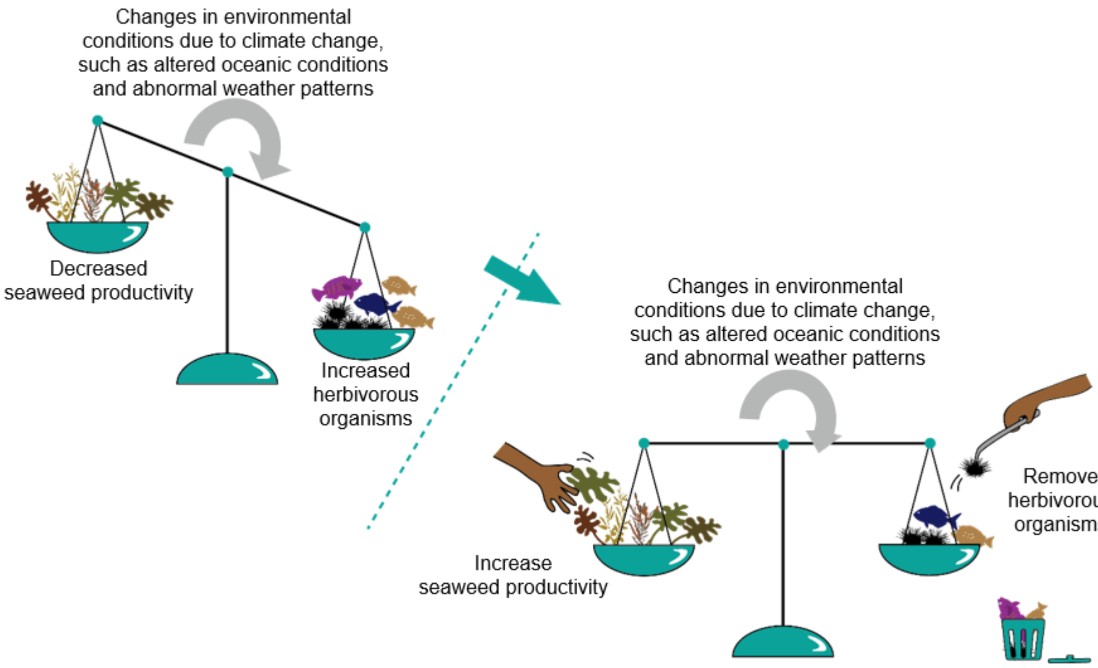


Figure 1-1: Conceptual approach to *isoyake* countermeasures

In addition, in recent years, the factors causing *isoyake* have become more complex, and due to the unstable environmental conditions, even if seaweed beds restored, often revert to an *isoyake* state. In response, these guidelines not only outline *isoyake* countermeasure techniques, but also explain fundamental approaches for sustaining *isoyake* countermeasures and methods for establishing frameworks that support these activities. Additionally, it introduces case studies of these initiatives.

Chapter 2: What Are Seaweed Beds?

2.1 Classification of Seaweed Beds

The term "seaweed beds" refers to areas in coastal shallow waters where seaweeds or seagrasses grow abundantly, or to communities comprising these plants and the animals within their habitats. Based on the types of seaweed they contain, seaweed beds can be classified into the following categories: *kombu* beds, *arame* and *kajime* beds, *wakame* beds, sargassum beds, gelidiaceae beds, and zostera beds (Table 2-1-1). Note that this guideline targets kombu beds, arame and kajime beds, wakame beds, and sargassum beds distributed in rocky reef areas.

Table 2-1-1: Major types of seaweed beds, their component species, and distribution areas

Major types of seaweed beds	Component species	Major distribution areas
Kombu beds	Kelp species such as *Saccharina japonica* (along with its variants *Saccharina japonica* var. *religiosa, Saccharina japonica* var. *ochotensis,* and *Saccharina japonica* var. *diabolica*), *Saccharina sculpera, Saccharina longissima* and *Saccharina angustata*	Rocky reef areas from the coasts of Hokkaido to Miyagi Prefecture (Pacific coast) and to Aomori Prefecture (Sea of Japan coast)
Arame / *kajime* beds	*Eisenia bicyclis, Eisenia nipponica, Ecklonia cava* (along with its variants *Ecklonia cava* var. *kurome* and *Ecklonia cava* var. *stolonifera)*, and *Ecklonia radicosa* (a warm water kelp species belonging to the same family as *Eisenia* and *Ecklonia*)	Arame beds: Rocky reef areas from Iwate Prefecture to eastern Kochi Prefecture, and from Kyoto Prefecture to Nagasaki Prefecture Kajime beds: Rocky reef areas from Chiba Prefecture to Miyazaki Prefecture, and from Shimane Prefecture to Kagoshima Prefecture
Wakame beds	*Undaria pinnatifida* (including *Undaria undarioides* and *Undaria peterseniana*)	Coastal rocky reefs throughout Japan, excluding the Sea of Okhotsk and Okinawa Prefecture
Sargassum beds	*Sargassum fulvellum* species such as *Sargassum horneri, Sargassum patens,* and *Sargassum macrocarpum*	Coastal rocky reefs throughout Japan
Gelidiaceae beds	*Gelidiaceae* family seaweeds including *Gelidium elegans Kützing*, *Gelidium pacificum Okamura*, *Ptilophora subcostata* , and *Pterocladiella tenuis*	Coastal rocky reefs throughout Japan, excluding the Sea of Okhotsk and eastern Hokkaido
Zostera beds	Marine flowering (seed-bearing) plants, such as *Zostera marina, Zostera japonica*, and *Zostera caulescens*	Coastal sandy-muddy areas throughout Japan (some species, such as *Phyllospadix iwatensis* and *Phyllospadix japonicus*, inhabit rocky reefs)

In addition, there are other types of seaweed beds, such as ulva (aosa*)* beds, which consist of green algae like sea lettuce (*aosa*) and green laver (*aonori*). These seaweed beds are often composed of multiple species, depending on the marine area and water depth.

The seaweeds that constitute Japan's seaweed beds can be classified into subarctic, temperate, and subtropical species, depending on the marine area where they grow (Tokuda, 1987). Subarctic seaweeds include kelp species and rockweeds, which grow in regions influenced by the Oyashio Current. Temperate seaweeds, such as *Eisenia bicyclis*, *Ecklonia cava*, *Undaria pinnatifida*, and many *Sargassum fulvellum* species, thrive in areas influenced by the Kuroshio and Tsushima Warm Currents. Subtropical seaweeds include some *Sargassum fulvellum* species that grow in areas strongly affected by the Kuroshio Current. These are referred to as southern *Sargassum fulvellum* species and include *Sargassum alternato-pinnatum*, *Sargassum assimile*, *Sargassum carpophyllum*, *Sargassum ilicifolium (Sargassum duplicatum)*, *Sargasso tenuiolium*, and *Sargassum crispifolium* (Tanaka, 2006; Kiriyama et al., 2012; Nagasaki Fisheries Department, 2018). Among these, *Sargassum alternato-pinnatum* and *Sargassum crispifolium* are primarily distributed in Kyushu and are therefore more precisely classified as temperate species (Terada & Shimabukuro, 2010).

Figure 2-1-1: Representative seaweed species comprising
kombu beds and *arame* / *kajime* beds

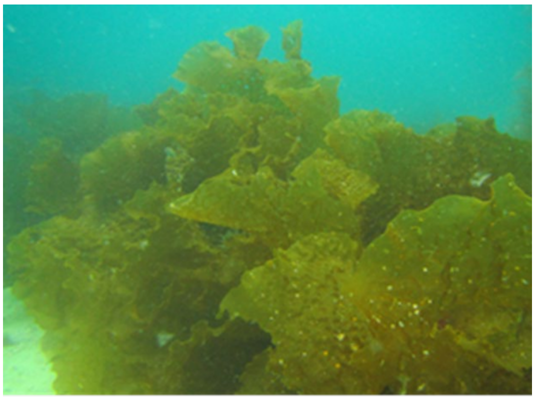
Saccharina japonica
Leaf length: 1.5–3 m, leaf width: 20–40 cm. Leaf thickness: 1–5 mm. The middle section is broad. Biennial.

Saccharina japonica var. *religiosa*
Found in shallow areas; leaf length: 0.4–1 m, leaf width: 5–10 cm. In deeper areas, leaf length: 1.5 m, leaf width: 15 cm. Annual.

Saccharina japonica var. *ochotensis*
Stem length: 5–9 cm, leaf length: 1.5–2.5 m. The middle section is narrower than that of *Saccharina japonica*. Biennial.

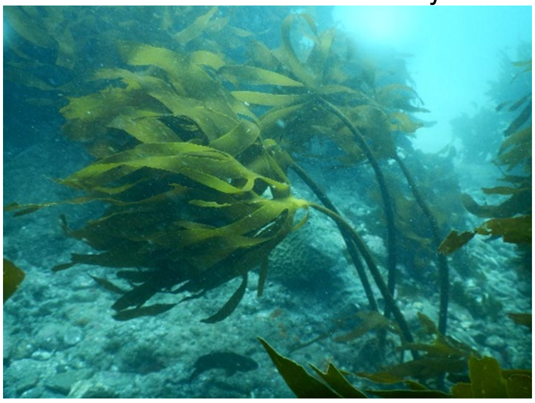
Eisenia bicyclis
Stem length: 1–1.5 m, occasionally exceeding 2 m. Central leaf length: 15–25 cm, leaf width: 5–10 cm. Perennial.

Eisenia nipponica
Near low tides; leaf length: 0.4–1 m, width: 5–10 cm. In deeper areas, total length exceeds 1.5 m, with a width of 8–15 cm. Perennial.

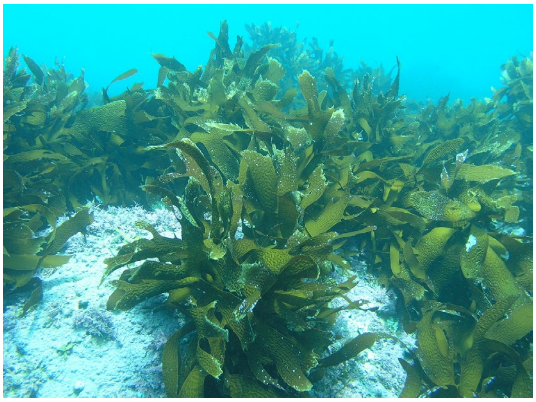


Ecklonia radicosa
Total length: 1.5–3 m, leaf width: 20–40 cm. Annual. The holdfast also matures.

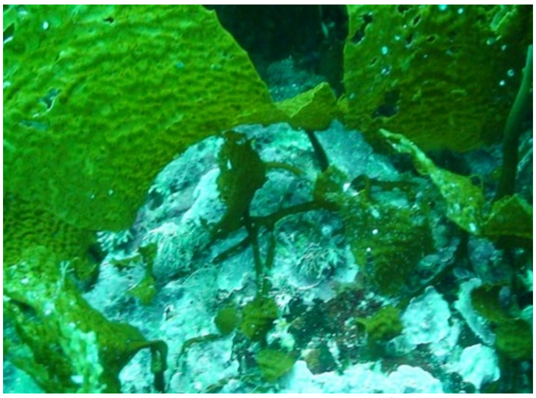
Figure 2-1-2: Representative seaweed species comprising
arame / kajime beds and *wakame* beds



Ecklonia cava
Stem length: 60–100 cm, central leaf length: 20–30 cm, leaf segment width: 5–6 cm. Grows on the Pacific side. Perennial.



Ecklonia cava var. *kurome*
Stem length: 3–50 cm, central leaf length: 15–50 cm, leaf segment width: 3–10 cm. Distributed in the Seto Inland Sea and parts of the Sea of Japan and Pacific coasts. Perennial.



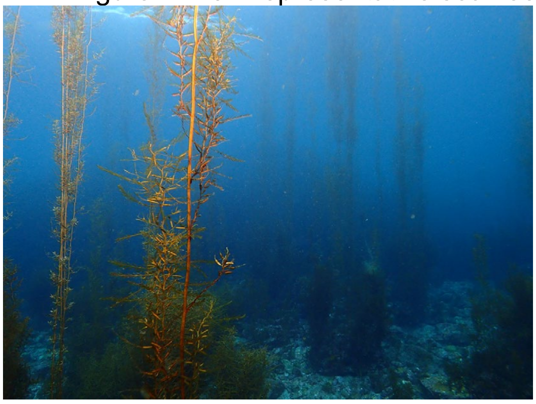
Ecklonia cava var. *stolonifera*
Stem length: 5–9 cm, leaf length: 1.5–2.5 m. Native to the Sea of Japan. Includes both a type that produces new shoots via creeping stolons (asexual reproduction) and a non-creeping type (similar to *Ecklonia kurome*). Perennial.

Undaria pinnatifida
Leaf length: 0.5–1.5 m, occasionally exceeding 2 m. Pinnate leaf segments form, with the midrib extending to the tip. Develops spore-bearing leaves (known as *mekabu*) upon maturity. Annual.

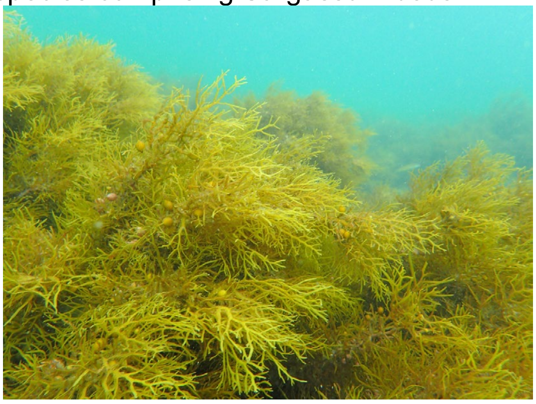
Undaria peterseniana
Total length: 1–3.5 m. Found in deep waters from northern Honshu to Kyushu. Lacks the pinnate leaf segments and midrib or spore-bearing leaves seen in *Undaria pinnatifida*, with sori forming on the leaf surface upon maturity. Annual.

Undaria undarioides
Total length: 1 m. Found sporadically from central Honshu to Kyushu. Midrib develops at the base of the thallus. Lacks pinnate leaf segments and spore-bearing leaves, forming sori instead. Often an intermediate form between *Undaria pinnatifida* and other types. Annual.

Figure 2-1-3: Representative seaweed species comprising Sargassum beds



Sargassum horneri
Total length: 1–10 m, occasionally exceeding 20 m. Holdfast is disc-like, with main branches growing directly. Air bladders are cylindrical. Edible. Annual.



Sargassum patens
Total length: 1–2 m. Difficult to distinguish between branches and leaves. Holdfast is disc-shaped. Air bladders are spindle-shaped. Perennial.

Sargassum macrocarpum
Total length: 1–4 m. Holdfast is conical. Characterized by large, serrated leaves. Air bladders are spindle-shaped with crown leaves. Perennial.

Sargassum fusiforme
Total length: 1–2 m. Grows in intertidal zones; lies flat at low tide and stands upright when submerged. Edible. Perennial.

Sargassum fulvellum
Total length: 1–2 m. Holdfast is disc-like. Produces few branches and resembles Canadian goldenrod (*Solidago canadensis*). Edible. Annual or biennial.

Sargassum piluliferum
Total length: 3–5 m. Holdfast is disc-shaped. Air bladders are spherical with rounded ends. A representative species of spring seaweed beds. Perennial.

2.2 Roles of Seaweed Beds

Seaweed beds serve as habitats for commercially valuable fish and shellfish, as well as for a wide variety of other marine organisms. They also function as sites of primary production in coastal ecosystems. Furthermore, seaweed beds have an ecologically critical function in environmental conservation (Table 2-2-1) and provide humans with pleasant landscapes and opportunities for environmental education.

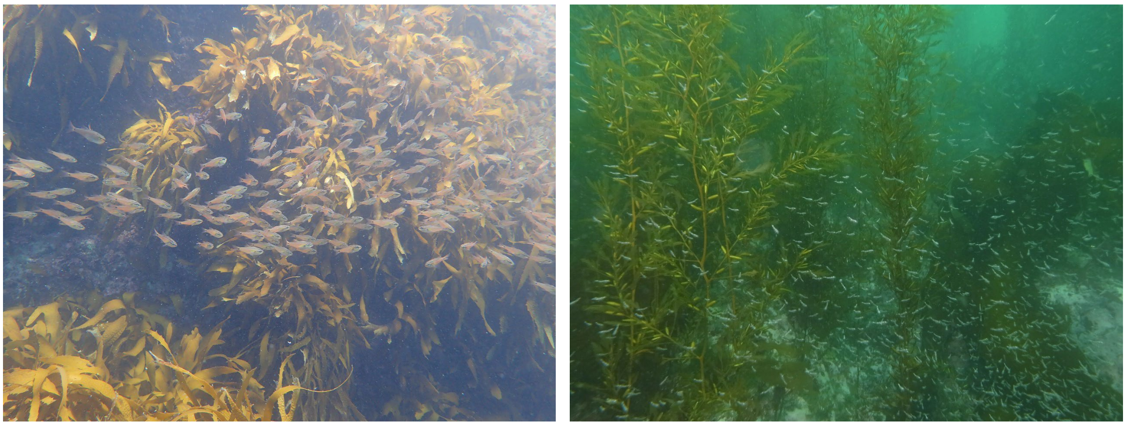
Table 2-2-1: Functions of Seaweed Beds (Fujita, 2001)

Function	Description
① Primary production	Captures solar energy and fixes carbon
② Nutrient absorption	Absorbs, retains, and recycles nutrient salts (nitrogen, phosphorus, and trace elements)
③ Food supply	Provides food for consumers and decomposers
④ Environment creation	Creates substrate for attachment, small spaces, and concealed environments with specific coloration
⑤ Environmental mitigation	Moderates physical environments such as light and water flow
⑥ Organism selection	Selects and limits organisms through dominant species' structure, distribution, and chemical signals
⑦ Environmental export	Supplies drift algae, floating algae, and washed-up algae

1) Habitat space

Because seaweed beds form a three-dimensional structure in the water, they provide habitats (Figure 2-2-1(1), left) and hiding places for fish and invertebrates, while also serving as a protective and nurturing place for juvenile fish. Microalgae and other organisms attach to the leaves of seaweed bed species, which then become food for invertebrates such as mysidaceas, gammarids, and shellfish (Figure 2-2-1(1), right). These invertebrates, in turn, attract fish and shellfish that use the beds as feeding grounds. For fish and squid, seaweed beds also serve as spawning grounds (Figure 2-2-1(2), left). When parts of the seaweed drift away, they become floating algae, providing habitats and feeding grounds for juvenile fish such as Japanese amberjack and crustaceans like Asian blue crab (*gazami* crabs). Detached leaf fragments that settle on the seafloor drift along and serve as food for rocky shore resources like abalone, turban snails, and sea urchins (Figure 2-2-1(2), right). Gelidiaceae beds yield high-quality raw materials for agar, contributing not only to fisheries but also to the fields of medicine and biotechnology.

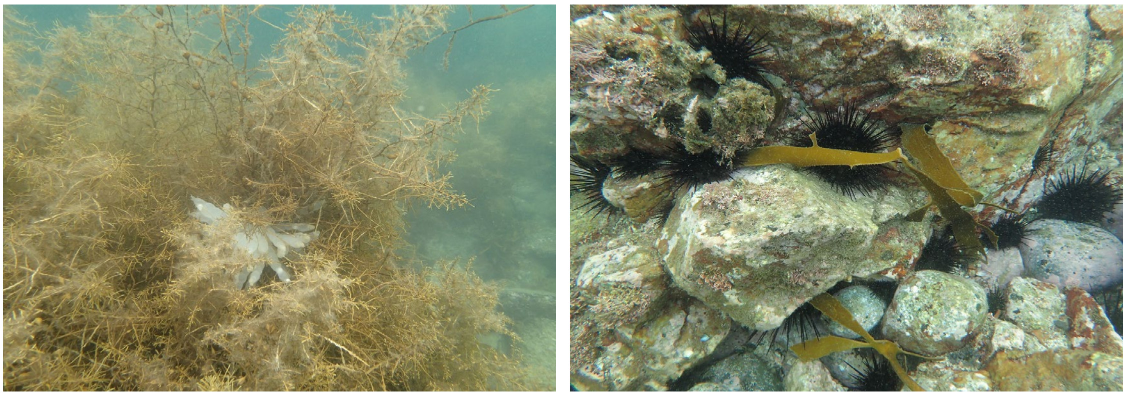
Figure 2-2-1(1): Organisms utilizing seaweed beds



Fish aggregating in *arame* beds

Mysidaceas aggregating in sargassum beds

Figure 2-2-1(2): Organisms utilizing seaweed beds



Egg mass of bigfin reef squid laid in a sargassum beds

Sea urchins feeding on detached seaweed fragments drifting along the seafloor

2) Sites of Primary Production and Environmental Conservation

Seaweed absorbs nutrients such as nitrogen and phosphorus throughout their growth, helping to prevent eutrophication in coastal areas. The development of seaweed beds can reduce wave energy. Through photosynthesis, seaweeds absorb dissolved carbon dioxide (CO_2) and release oxygen into the water. Thus, seaweed beds are recognized as part of the "blue carbon ecosystem" with the potential to reduce CO_2 levels. To assess these functions, it is essential to comprehend the area and production volume of seaweed beds.

3) Sites for Scenic Beauty and Environmental Education

Seaweed beds contribute to the appeal of underwater parks (for diving), underwater viewing facilities, and fishing parks, making them valuable resources for the tourism and leisure industries. They also serve as venues for public outreach and environmental education, helping citizens, children, and students understand the ecological importance of seaweed beds and the need for *isoyake* countermeasures.

Chapter 3: What is *Isoyake*?

3.1 Definition of *Isoyake*

Isoyake is defined as "a phenomenon in which seaweed communities (seaweed beds) in shallow bedrock and stony beds significantly decrease or disappear, resulting in a poorly vegetated state beyond the range of seasonal and slight yearly fluctuations" (Fujita, 2002). When *isoyake* occurs, seaweed bed recovery can take many years, leading to reduced rocky shore resources and poor growth, which significantly impacts coastal fisheries. The causes, landscapes, impacts, and recovery periods of *isoyake* vary depending on the topography, oceanographic characteristics, species composition, and the history and current state of coastal use and development in each region. Figure 3-1-1 illustrates various *isoyake* landscapes observed across Japan.

Figure 3-1-1: Various *isoyake* landscapes (Fujita, 2002)


Top left: Grazing damage by sea urchins (Hokkaido)
Top right: Grazing damage by sea urchins (Shizuoka Prefecture)
Middle left: Grazing damage by herbivorous fish (Shizuoka Prefecture)
Middle right: Withering due to high water temperatures (Toyama Prefecture)
Bottom left: Typhoon disturbance (Oita Prefecture)
Bottom right: Sedimentation of fine mud (Toyama Prefecture)

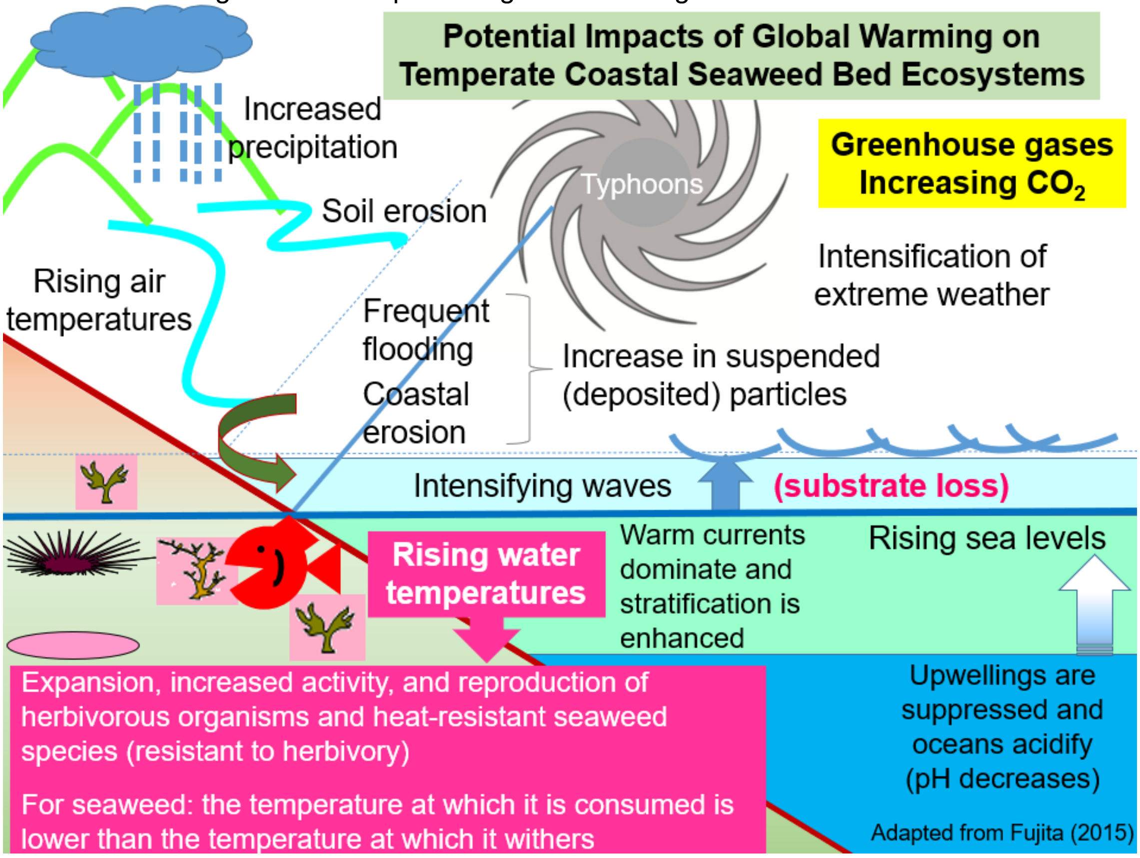
3.2 Causes of the Occurrence and Persistence of *Isoyake* and Global Warming

Seaweed decline occurs due to one or a combination of the following: (1) grazing by herbivorous organisms, (2) withering, (3) failure to germinate, and (4) being washed away. Even in healthy seaweed beds, seaweed is subject to some degree of grazing, withering, and variability in germination, while stormy conditions can also cause seaweed to detach or break apart from rocks. When these impacts exceed normal levels, persist over time, or are accompanied by factors that inhibit recovery, *isoyake* occurs. So what, specifically, leads to such conditions?

In northern Japan, herbivorous organisms primarily include sea urchins and small conches, while in southern Japan, herbivorous fish are also significant contributors. Grazing damage caused by these herbivores becomes pronounced under certain conditions: when water temperatures rise and intensify feeding activities; when the availability of detached seaweed leaves drifting along the seafloor decreases, leading herbivores to consume growing seaweed; when the seabed becomes increasingly calm due to the construction of wave-dissipation structures and the expansion of aquaculture; when herbivorous organisms tend to colonize stone placement areas and concrete blocks; and when overfishing exacerbates the problem by removing predator species, which allows herbivore populations to grow unchecked and for their grazing behavior to intensify.

Seaweed withers when prolonged high water temperatures (often accompanied by oligotrophic conditions in general marine waters) or low salinity persist and physiological disorder does not recover. Failure to germinate can result from grazing or physiological disorder, but it is often due to sediment buildup, which hinders seaweed attachment and growth or buries the thallus. Increased sediment is linked to intensified storms caused by nearshore warming. As precipitation increases, so does the risk of soil erosion and flooding, which leads to a rise in suspended particles and sediment accumulation in marine environments. The increase in sediment is also attributed to the calm conditions in coastal areas caused by the increase in the number of revetments and wave-dissipation structures. As storms intensify, the resulting stronger wave action leads to more frequent seaweed drift. In short, as shown in Figure 3-2-1, recent global warming has contributed to the decline of seaweed through all four of the previously mentioned mechanisms. Moreover, while rapid increases in seawater temperature can directly cause seaweed to wither, in many cases, herbivorous organisms consume the seaweed at lower temperatures (e.g., 27°C) before it reaches the critical withering temperature (e.g., 30°C).

Figure 3-2-1: Impacts of global warming on seaweed beds



3.7 Early Research on *Isoyake*

In Japan, seaweed has long been widely utilized as a food, fertilizer, and adhesive material, leading to considerable interest in fluctuations in seaweed abundance. For instance, fertilizer records from the late 18th century in Tsushima, Nagasaki Prefecture, note consecutive years of poor yields for seaweed-based fertilizer. Similarly, travel accounts from the southern Pacific coast of Hokkaido describe a scarcity of *kombu* kelp in one year but an abundance of juvenile kelp (first-year algae bodies), raising hopes for a better harvest the following year.

The first academic introduction of *isoyake* in Japan was in 1885, when the Shizuoka

Prefecture Industry Department submitted an inquiry to the Japan Fisheries Association under the title "*Iso-no-yake*" on the topic of "Questions on the Causes of and Preventing the Withering of *Gelidiaceae.*" At the time, *Gelidiaceae*, the raw material for agar, was the most important rocky shore resource in the country. Prominent figures such as Shinnosuke Matsubara, who conducted Japan's first nationwide fisheries survey, and Kintaro Okamura, a pioneer in Japanese phycology, actively discussed the decline of *Gelidiaceae* beds. Subsequently, Kamakichi Kishinouye and Katsuya Tago, trailblazers in abalone research, reported on the decline of *arame* and *kajime* beds and the corresponding reduction in abalone, which fed on them. Additionally, Kichisaburo Yendo, one of the leading phycologists alongside Okamura, reported on the decline of *kombu* kelp beds.

Among them, Kichisaburo Yendo (1874–1921) authored the textbook Studies of Marine Vegetation (1911), in which he discussed *isoyake* as part of a "Theory on the Decline of Seaweed." He was the first to introduce the concept of *isoyake* to an international audience. Additionally, he documented what is believed to be the world's oldest record of *kombu* kelp bed decline, dating back to the 1830s, in the Shimokita Peninsula.

Yendo, in his first report on *isoyake* titled Seaweed *Isoyake* Survey Report (1903), stated: "In certain specific coastal areas, all or part of the seaweed in those regions has withered and it has become barren. As a result, not only does valuable seaweed decrease, but the harvest of organisms dependent on them, such as abalone and rocky shore fish, decreases, leading to the impoverishment of fishing villages. This phenomenon often occurs along the east coast of Izu, calling this phenomenon as *isoyake* or *isogare* and has now become somewhat of a common term." He surveyed three regions: the eastern coast of the Izu Peninsula, Shima, and Awa, attributing the cause of *isoyake* to the impact of freshwater inflows as a result of runoff from deforestation in nearby mountains. However, he did not actually conduct any direct measurements of the changes in salinity associated with freshwater inflows. Instead, he based his conclusions on a German paper discussing the relationship between salinity gradients in canals and vegetation patterns. In recent times, the damage to seaweed beds from freshwater inflows is more commonly attributed to increased turbidity in seawater and sediment deposition on the seafloor, rather than to changes in salinity.

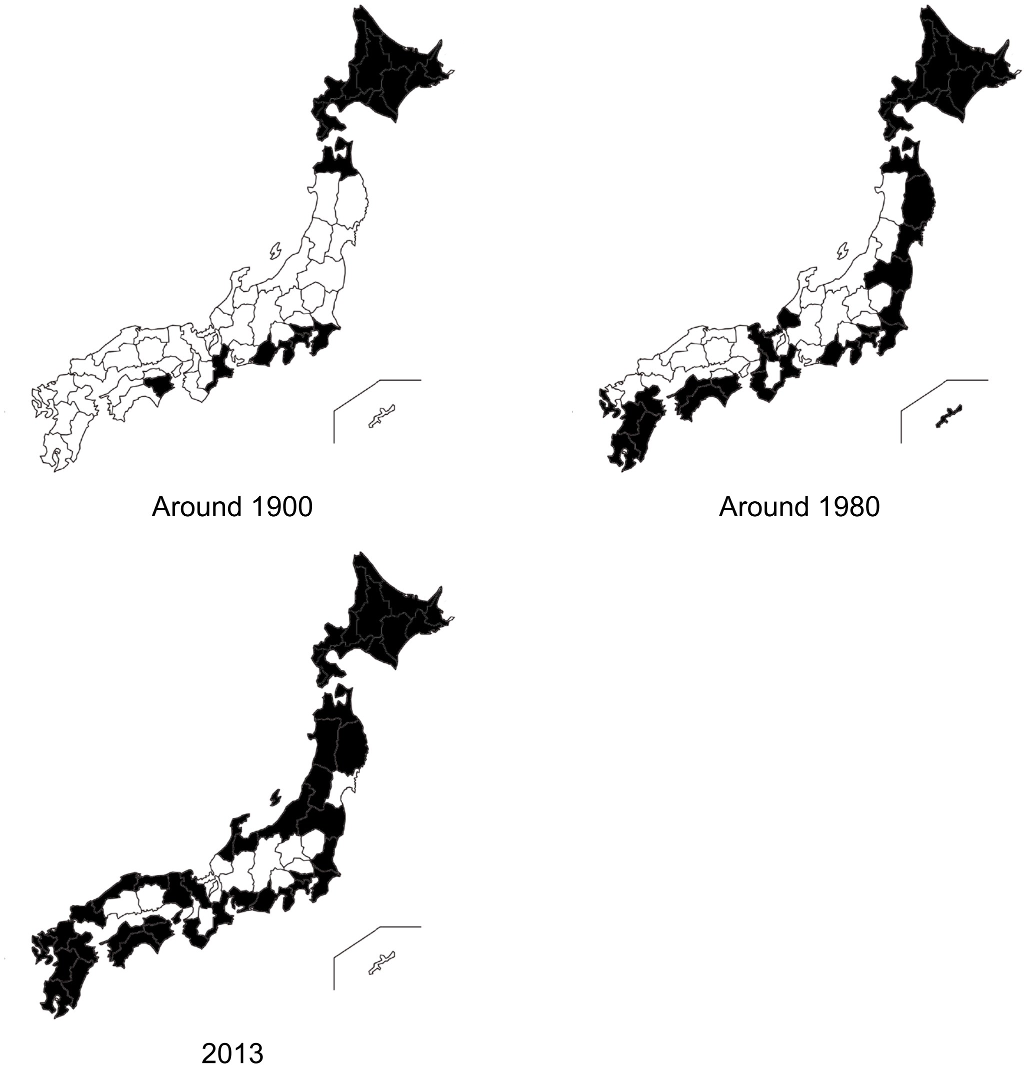
As described above, awareness of *isoyake* in Japan began to increase during the mid-Meiji era (1889-1904). Figure 3-7-1 illustrates the prefectures where the decline and continued deterioration of seaweed beds were observed around the early 20th century (around 1900), the late 20th century (around 1980), and around 2013.

Around 1990, the total area of seaweed beds along Japan's coast was approx. 200,000 hectares, representing a decrease of approx. 6,400 hectares compared to roughly 13 years earlier (Environmental Agency, Nature Conservation Bureau, 1994). The breakdown of the causes for this decline included direct modifications such as land reclamation (1,942 ha, 30 prefectures), *isoyake* (1,016 ha, 9 prefectures), overfishing (31 ha, 1 prefecture), changes in oceanographic conditions (1,117 ha, 16 prefectures), and unknown causes (2,801 ha, 17 prefectures). While most of the loss attributed to direct modifications was not caused by *isoyake*, the distinctions between the remaining four categories are highly ambiguous. It should also be noted that this survey excluded areas deeper than 20 meters, certain islands, and seaweed beds smaller than 1 hectare.

In recent years, *isoyake* has been reported in nearly all prefectures. Since the 1990s, as much as 8,000 hectares of seaweed beds in a single area of Omaezaki City, Shizuoka Prefecture, have disappeared due to *isoyake*, indicating a rapid expansion of the phenomenon. Since the beginning of the 21st century, attempts have been made to utilize satellite imagery and other technologies to monitor *isoyake*. However, the total area of seaweed beds and *isoyake* has not been consistently surveyed using the same scope and criteria as before, making it unclear how much the *isoyake*-affected areas have expanded. As a rough estimate, a 2008 study based on data from approximately 42% of coastal areas suggested that the total area of seaweed beds had decreased by 22% compared to around 1990 (Marine Ecology Research Institute, 2009).

As previously mentioned, recent cases of *isoyake* are caused by one or a combination of the following: 1) grazing by herbivorous organisms, 2) withering, 3) failure to germinate, or 4) being washed away. Table 3-7-1 summarizes these and other factors that have historically been considered to contribute to *isoyake* in Japan. In earlier times, factors such as the inflow of wastewater from mines, overharvesting of seaweed, and the accumulation of volcanic ash and debris near erupted volcanoes all had severe impacts on seaweed beds. Some of the factors listed in the table are not thoroughly understood, and others have gradually disappeared in Japan due to changing circumstances. However, they are intentionally included for reference.

Figure 3-7-1: Transitions in prefectures with seaweed bed decline
(adapted from Fujita, 2006)



This figure organizes the data by prefecture and does not indicate seaweed bed decline across entire coastal areas. The data for 2013 is based on survey results from the Fisheries Agency (2013).

Table 3-7-1: Factors behind the occurrence or continuation of *isoyake* in Japan

Factor	Example of factor	Remarks
1. Changes in oceanographic conditions	Dominance and approach of the Kuroshio and Tsushima Currents, offshore movement of the first Oyashio branch, approach of drift ice	High water temperatures in winter or summer can cause problems, with summer conditions often accompanied by oligotrophication. Drift ice ashore has greater effect on "*isosoji*" (removal of unwanted seaweed).
2. Nutrient deficiency	Discontinuation of squid gut dumping, increase in erosion control dams, construction of coastal roads, reduction or blockage of stream and river water inflow	Nitrogen and phosphorus (and possibly iron?) deficiencies can affect seaweed growth, pigmentation, and maturity. Coastal and watershed modifications and the loss of nutrient salts feedback to coastal areas have widened the gap between eutrophic and oligotrophic regions, raising concerns about nutrient deficiency in areas subject to water quality regulations.
3. Impact of freshwater inflow	Deforestation (causing river floods and temporary dam releases), land development, heavy or prolonged rainfall, dam sediment discharge	In the past, low salinity was believed to cause die-offs of oceanic seaweed species. However, sediment deposition and water turbidity during runoff events have proven to be more significant issues. Runoff can actually sometimes have a positive effect by supplying nutrient salts.
4. Abnormal weather patterns	Typhoons, mild winters	The only widely acknowledged instance of a typhoon impacting a large area was the Kitty Typhoon (1949) in western Sagami Bay. Recently, typhoons have been linked to the loss of *arame* and *kajime* species.
5. Grazing damage by herbivorous organisms	Sea urchins, turban shells, sea hares, small conches, herbivorous fish (e.g., rabbitfish, parrotfish, drummer, scalpel sawtail)	While sea urchins and fish are primary concerns, other species like turban shells can occasionally cause problems in Gelidiaceae beds, and Walking Sea hares in *wakame* beds.
6. Occupation of seafloor substrate	Non-geniculate coralline algae, polychaetes, corals, sea anemones, Mutable mussel	Non-geniculate coralline algae, which thrive in areas with grazing, wave action, water turbidity, and sediment accumulation, often proliferate in regions with reduced seaweed. However, they are generally a result of *isoyake* rather than its cause. Increases in corals and sea anemones are particularly notable in southern Japan.
7. Burial of seafloor substrate	Volcanic ash, drifting sand, fine sediment	Damage from volcanic ash has historically affected areas like Mt. Komagatake and more recently Mt. Fugen and Miyakejima Island. Drifting sand and fine sediment are closely linked to recent coastal and river modifications.
8. Pollution	Discharges from mines, industry, and households; thermal discharge from power plants; river improvements; coastal roads, ports, and revetment work (especially land reclamation and offshore structure); field maintenance, agricultural chemicals	Although most domestic mines have now closed and coastal pollution has improved compared to Japan's high-growth period, the increase in coastal structures has led to calmer waters, sediment accumulation, and the settlement of herbivorous organisms.
9. Fisheries and aquaculture	Overuse of fishing grounds, excessive seaweed harvesting, fishing ground improvements, transplantation of sea urchins to different depths, excessive release of sea urchins and shellfish, aquaculture residues	Many *isoyake*-affected areas have experienced overharvesting of abalone, Gelidiaceae, and *kombu* kelp. Inappropriate fishing ground improvements and the transplantation of sea urchins for fattening have also contributed to sustaining and worsening *isoyake*.
10. Other	Hot spring discharges, reduction of submarine spring water due to groundwater use, bacterial proliferation, etc.	In addition to these examples, numerous unverified theories exist. For instance, in the South Pacific, viral infections in *kajime* have been reported in areas where this species has declined.

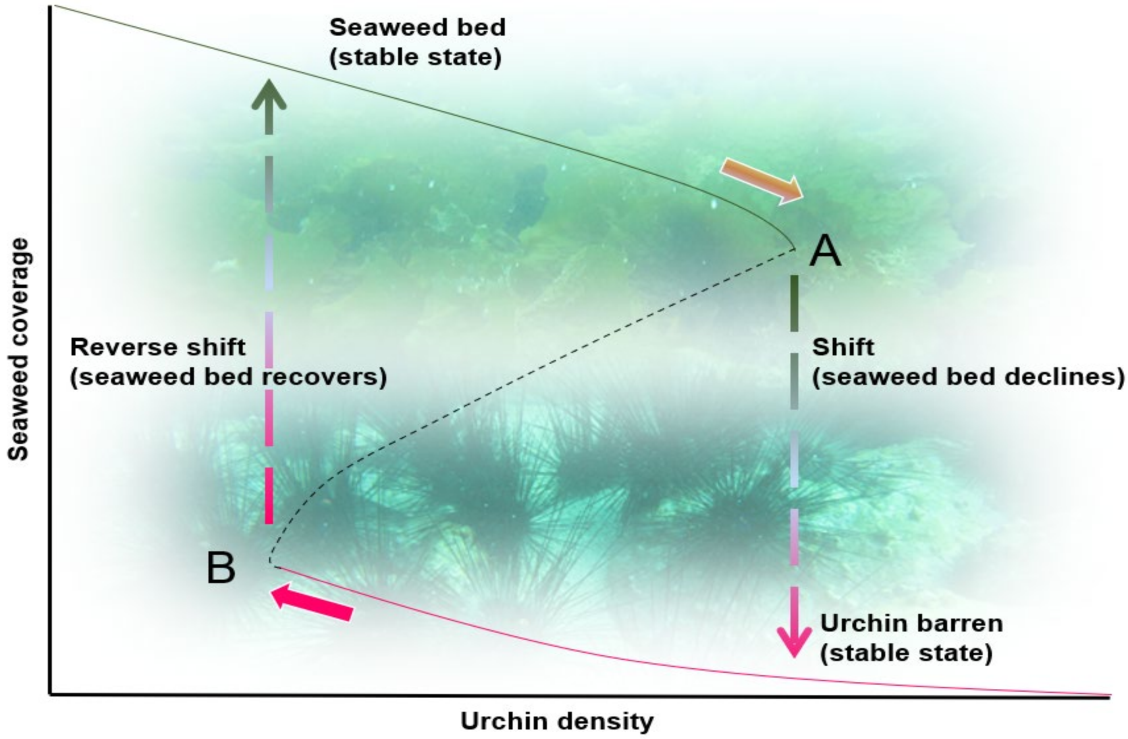
3.8 Herbivory-Induced Isoyake

In Japan, awareness of *isoyake* developed early, and sea urchin harvesting areas had long been known. However, the connection between sea urchins and *isoyake* received little attention. One of the earliest records comes from 1908, when Katsuya Tago, an engineer from the Ministry of Agriculture and Commerce, documented underwater observations in an *isoyake* area overrun with sea urchins in northern Ibaraki Prefecture. Another record, from 1932, describes sea urchins being purchased from fishermen in Rishiri Island's kelp fishing grounds (Hokkaido) as part of measures to address *kombu* kelp grazing damage.

Comprehensive experiments and observations on herbivory-induced *isoyake* began in earnest in the 1960s. This trend was particularly influenced by reports from the Kelp Habitat Improvement Project (KHIP) along the California coast, which detailed the decline of giant kelp forests due to an explosion in the population of sea urchins, and these findings sparked similar reports worldwide. In Japan as well, in the 1970s the Tohoku National Fisheries Research Institute implemented projects to create underwater forests as part of the "Comprehensive Research on the Development of Aquaculture Grounds in Shallow Waters" (1979), and research subsequently became active along the Pacific coast of the Tohoku region and the Sea of Japan coast in Hokkaido. In northern Japan, the large-scale decline of seaweed beds (particularly *kombu* kelp communities), is primarily caused by *kitamurasaki-uni* (*Mesocentrotus nudus*), while in southern Japan, it is primarily caused by species such as *murasaki-uni* (*Heliocidaris crassispina*), *gangaze* (*Diadema setosum*), and *naga-uni* (*Echinometra sp.A*).

Areas where high sea urchin densities result in barren zones are referred to as *urchin barrens*. Both urchin barrens and seaweed beds are considered opposing stable states in subtidal zones, and the relationship between urchin density and seaweed coverage is explained by a discontinuous phase shift (Figure 3-8-1) (Filbee-Dexter & Scheibling, 2014; Ling et al., 2014). The urchin density at which an urchin barren forms and the density at which seaweed beds recover differ significantly. This indicates that both seaweed beds and urchin barrens can exist under conditions of high or low urchin density, but once a seaweed bed declines and transitions to an urchin barren, it becomes difficult for the seaweed bed to recover.

Figure 3-8-1: Discontinuous phase shift representing the opposing stable states of seaweed beds and urchin barrens (thresholds a and b)



When urchin density exceeds threshold A, an urchin barren forms. Conversely, when urchin density falls below threshold B, the seaweed bed recovers. The difference in urchin density between thresholds A and B is approximately tenfold. (Adapted from Filbee-Dexter & Scheibling, 2014).

On the other hand, herbivorous fish such as rabbitfish, parrotfish, scalpel sawtail, and brassy chub originate from tropical and subtropical regions, with some species extending their distribution into temperate areas like Japan. The existence of herbivorous fish has been known since the time of Aristotle in the 4th century BCE in Europe. Similarly, along Japan's coasts – particularly in southern Japan – they have been recognized since at least the Edo period (1603-1868). For example, rabbitfish was known as a fish that could cause famine, and parrotfish was referred to as a seaweed-eating fish, indicating that these species have long been associated with consuming seaweed to some extent. Since around 1990, the decline of underwater forests of *arame* and *kajime* species, as well as *garamo* beds, has frequently been reported, particularly along the southern coast of Japan. The main cause of the decline in seaweed beds due to herbivorous fish is often attributed to rising coastal water temperatures. However, other factors also require consideration, including the increase in artificial coastlines, the disappearance of natural seaweed beds, the creation of artificial reefs and seaweed beds, the rise and fall of seaweed aquaculture, the decline in predators (such as piscivorous fish and bigfin reef squid), changes in the food culture and distribution of fresh fish in fishing villages, and thermal discharges from power plants.

In recent years, grazing damage to seaweed beds by herbivorous fish has gained global attention as a significant issue. It has become particularly severe in regions such as the western boundary currents of major oceans (e.g., the Kuroshio Current) along the western sides of continents, where rising water temperatures are evident. A similar issue is observed in the eastern Mediterranean, where herbivorous fish originating from the Red Sea have increased following the opening of the Suez Canal (Verges et al., 2014).

Many instances of *isoyake* eventually lead to the recovery of seaweed beds once the factors restricting seaweed growth are removed, although this may take time. Examples of *isoyake* caused by the approach of the Kuroshio Current, the accumulation of volcanic ash, or the inflow of mine wastewater illustrate this recovery process. In the cases of herbivory-induced *isoyake* discussed here, seaweed beds have recovered under conditions such as the experimental removal or culling of sea urchins (by hammering or spreading quicklime), population recovery of sea urchin predators like sea otters, or mass mortality of sea urchins during periods of high water temperatures. Currently, edible sea urchins from around the world are exported primarily to meet the demand in Japan, and in regions with high fishing pressure, large-scale *isoyake* has been resolved. However, when urchin barrens do not recover despite high fishing pressure, it may be due to the increase of non-edible sea urchins as a result of harvesting edible ones, and other contributing factors could include grazing damage by small conches or herbivorous fish, or the impact of fine sediment accumulation.

These guidelines propose the manual removal of herbivorous organisms, such as sea urchins and fish, as a method for addressing the factors hindering seaweed bed recovery. However, it is also important to consider the root causes of the increase in herbivorous organisms and to explore the use of predators to control their population density. For more details, refer to the Guide to Seaweed Bed Restoration Using Predators. Overseas, it is widely recognized that overfishing of sea urchin predators leads to large increases in sea urchin populations, which in turn cause *isoyake*. There are documented cases where establishing large-scale no-take zones has allowed predator populations to recover, resulting in a decline in sea urchins and the restoration of seaweed beds. In Japan, large-scale no-take zones like those overseas are difficult to establish due to the exclusive, localized management of fishing grounds by local fisheries cooperatives. However, even in protected areas voluntarily established by fisheries cooperatives, there are cases where the indirect effects of predation have helped to maintain seaweed beds within *isoyake* zones (see Column 3-8-2). In addition to traditional methods of fully managing the density of herbivorous organisms, it is also worth considering approaches that reduce or eliminate the need for management by protecting predators. Given the anticipated aging of fishermen, the decline in fishing village populations, and the stagnation of fish prices, predator-based methods for restoring seaweed beds are expected to gain traction as a labor-saving approach in the future.

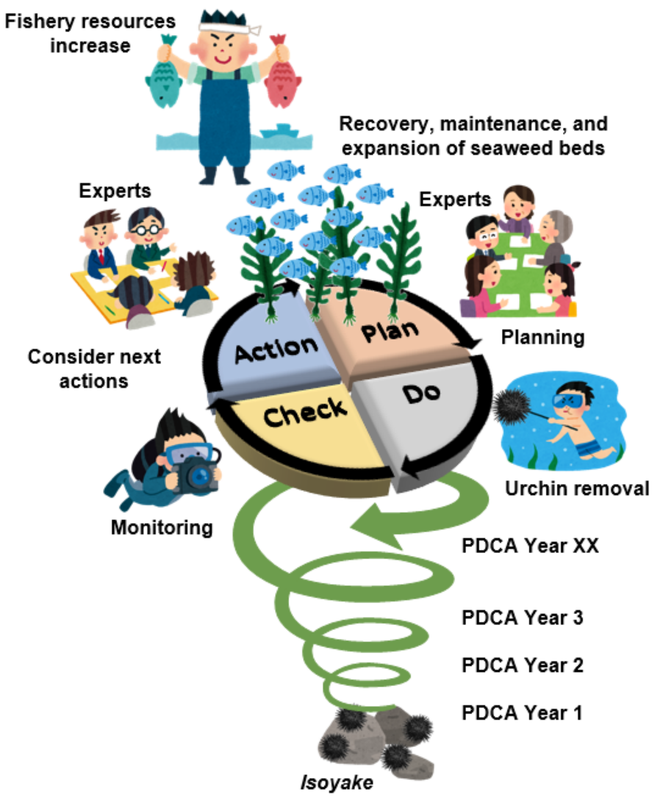
Chapter 6: Basic Approach to *Isoyake* Countermeasures and Planning/Design

6.1 Perspectives for Highly Effective *Isoyake* Countermeasures

As explained in Chapter 3, *isoyake* is a phenomenon caused by a complex interplay of multiple factors. Therefore, even when appropriate countermeasures are implemented, unexpected situations may arise, and as such it is important to approach countermeasures with the expectation that results may differ from initial predictions.

An effective approach to address this issue is to employ the PDCA cycle (adaptive management method). The PDCA cycle involves repeating four steps: Plan (planning), Do (execution), Check (evaluation), and Action (improvement), enabling continuous improvement and progress in addressing a problem. Applying this to *isoyake* countermeasures, the process involves assessing the current state of *isoyake* and developing specific plans based on the set goals (Plan), implementing the countermeasures according to the plan (Do), monitoring and evaluating the results of the activities (Check), revising the plan and establishing the next steps based on the evaluation (Action), and then run the PDCA cycle again. Restoring seaweed beds requires a certain amount of time. As shown in Figure 6-1-1, it is crucial to continuously follow the PDCA cycle in a spiral progression. This approach is key to effective *isoyake* countermeasures, ultimately leading to an increase in fishery resources.

Figure 6-1-1: Highly effective *isoyake* countermeasures by utilizing the PDCA cycle



In order to steadily run this PDCA cycle, at a minimum, the following points should be kept in mind.

① Clearly define goals

Setting specific goals is the most critical step in the PDCA cycle. Clearly defined goals enhance shared understanding and prevent the risk of losing sight of the objectives (see Section 6.2 of this chapter).

② Regularly monitor the condition of seaweed beds and *isoyake*

Observe the areas where *isoyake* countermeasures have been implemented, as well as the surrounding areas, during daily trips to and from fishing grounds. Pay attention to factors such as the growth condition of seaweed, signs of grazing damage, spawning of fish and shellfish, floating seaweed, washed-up seaweed, and water temperature readings on fish finders. Record observations as necessary.

③ Record the results

Keeping notes of daily observations and monitoring results (e.g., the number of sea urchins removed or graphs showing year-on-year changes in seaweed coverage) allows for a detailed analysis of the effectiveness of *isoyake* countermeasures and the recovery process of seaweed beds. By comparing these records with previous countermeasures, subsequent activities can be improved and implemented, leading to the maintenance and expansion of their effectiveness.

④ Develop human resources

A core leader is essential for any activity organization. Leaders should possess the passion and initiative to tackle new and unfamiliar challenges, along with strong execution, information-gathering, and communication skills. Additionally, it is vital to establish a system within the organization and among stakeholders that facilitates the development of the next generation of leaders.

⑤ Establish a Supportive Management System for Leaders

Government authorities, local researchers, and experts (supporters) must develop a management system that provides support to leaders. It is essential to continuously work on strengthening the organizational structure to ensure sustained effectiveness.

6.2 Developing Plans

1) Clearly define goals

Goals should include long-term goals as well as the short- and medium-term goals needed to achieve them, with clear timelines for their attainment. For long-term goals, identify the specific issues caused by *isoyake* and establish the ideal state of the seaweed beds as the target.

For short-term (immediate) and medium-term goals, set specific and achievable numerical targets (such as seaweed coverage or seaweed bed area), to help achieve the long-term objectives. For instance, in the Fisheries Multifunctional Measures Project (hereafter, Fisheries Multifunctional Project), the five-year target is to increase the "target biomass" by more than 20%, with the outcome indicator being "an increase in biomass within the target area." In this context, "target biomass" refers to seaweed, and biomass is measured in terms of seaweed coverage or the area of seaweed beds.

When setting seaweed coverage or seaweed bed area as target values, it can be challenging to feel a sense of accomplishment from activities alone. Therefore, it is helpful to establish additional indicator values separated from the target. For example, if the goal is to increase seaweed coverage by 5% or more annually, and the activity involves removing sea urchins, using the annual number of sea urchins removed as an indicator makes it easier to assess progress. Setting indicators that enhance the motivation of team members is also effective for sustaining activities.

2) Target seaweed beds

Targets should be seaweed beds that previously existed in *isoyake*-affected areas or those seaweed beds that are currently present nearby. Environmental changes, such as river and coastal development or rising water temperatures and sea levels due to climate change, may make it difficult to restore previously existing seaweed beds. Therefore, it is important not to focus solely on *isoyake*-affected areas. Instead, consider nearby healthy seaweed beds and current marine usage, and determine the target seaweed beds with input from research institutions and experts.

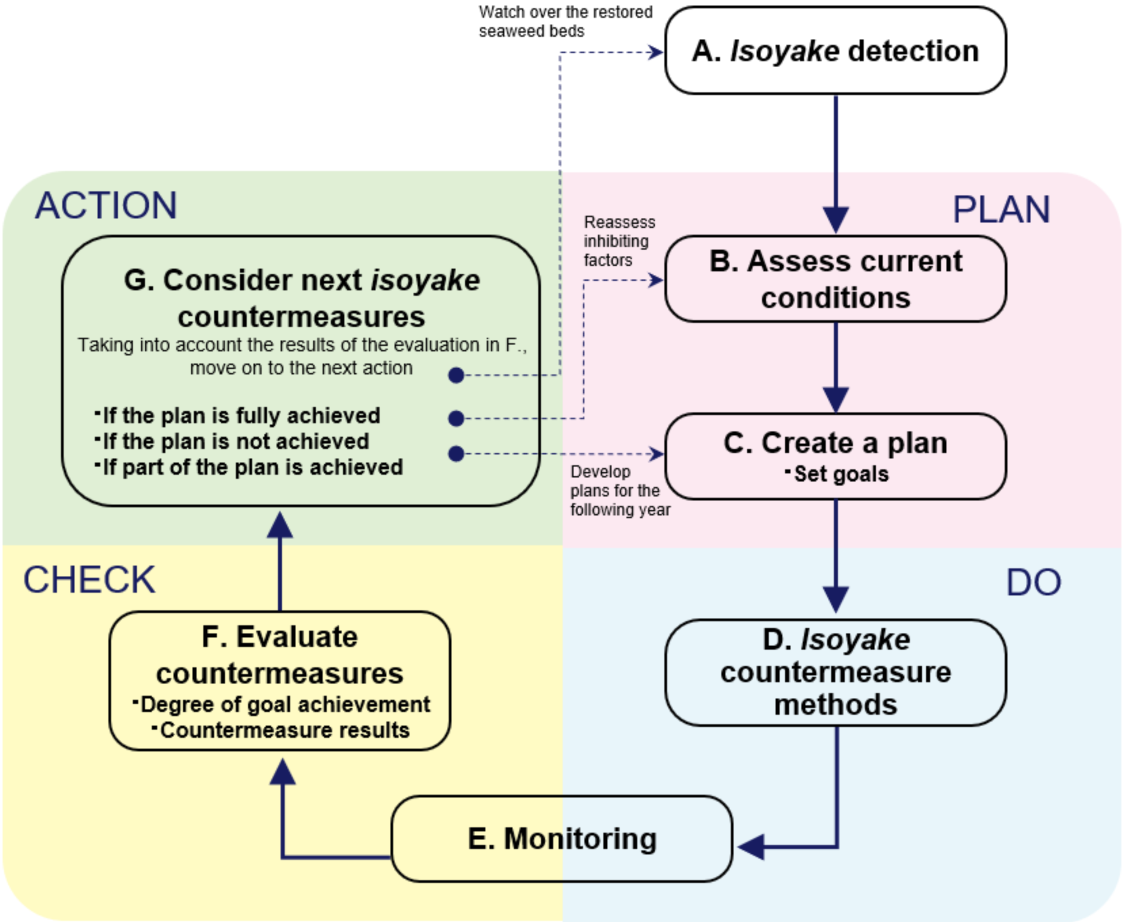
3) Implementation site

Select a site within *isoyake*-affected areas that is as close as possible to natural seaweed beds, ensuring it is safe and practical to conduct activities. Utilizing online map resources can be helpful when choosing a location (see Chapter 7, B1). It is important not to focus solely on *isoyake*-affected areas but also to consider nearby healthy seaweed beds and current marine usage.

4) Implementation flow for *isoyake* countermeasures

Isoyake countermeasures involve continuously following the PDCA cycle. Each year, tasks from steps A to G in the PDCA cycle flow are carried out (see Figure 6-2-2, the following page, and Chapter 7). Specific countermeasure techniques are introduced in Chapter 7 (D1-D9). Choose and combine appropriate methods based on the actual conditions of the target marine area.

Figure 6-2-2: *Isoyake* countermeasure flow utilizing the PDCA cycle



A. *Isoyake* detection

Regularly observe the condition of seaweed beds to detect *isoyake* by noting changes in the seafloor landscape (e.g., exposed rock surfaces or grazing damage) and sudden fluctuations in the harvest of abalone and other species.

B. Assess current conditions (identify inhibiting factors)

When *isoyake* is detected, conduct surveys to identify the factors inhibiting the formation of seaweed beds. If these factors cannot be determined, it may be necessary to perform simple experimental investigations.

C. Consider countermeasures and create a plan

Once inhibiting factors are identified, stakeholders should discuss and develop plans, including action policies, activities, and schedules. Planning should thoroughly address goal setting, role allocation, work safety, activity schedules, required costs, and coordination with stakeholders.

D. Implement countermeasures

Steadily implement the planned activities. As necessary, effectively combine multiple countermeasure methods. For *isoyake* countermeasures targeting grazing damage, the combination of "removing herbivorous organisms" and "supplying seaweed propagules" has proven to be highly effective. As sea-based work involves risks, ensure safety by carefully monitoring weather and sea conditions.

E. Monitoring

After implementing *isoyake* countermeasures, regularly monitor the countermeasure sites and surrounding areas to track changes. Consult with experts (supporters) to determine appropriate monitoring items and methods.

F. Evaluate countermeasures

Based on the monitoring results, consult with experts (supporters) to assess whether the goals have been achieved and whether the implemented countermeasures were effective. Share the results with activity members and other stakeholders.

G. Consider next *isoyake* countermeasures

If the goals have been achieved (e.g., the seaweed beds have recovered), then monitor the restored seaweed beds while planning *isoyake* countermeasures for other areas. If the countermeasures have shown effectiveness, plan for their continued implementation in the next cycle. However, if the countermeasures were ineffective, analyze the reasons for failure and revise the plan and implementation framework accordingly.

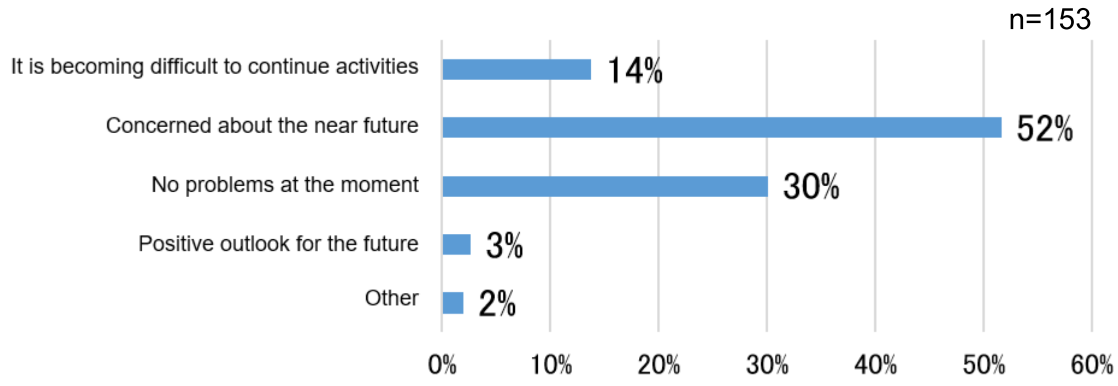
6.3 Building Frameworks

1) Establish an implementation framework

To effectively carry out *isoyake* countermeasures, it is essential to convene discussion councils, foster consensus among stakeholders from various perspectives, and ensure the sustainable implementation of activities.

A recent public opinion survey on environmental changes (National Institute for Environmental Studies, 2016) revealed that 59% of respondents believed that "the environment is deteriorating," and 90% expressed "were concerned" about climate change and global warming. With growing awareness of environmental issues among local residents, participation in seaweed bed conservation activities (including *isoyake* countermeasures) has become increasingly noticeable across Japan. On the other hand, fishermen, who have played a central role thus far, are worried about challenges such as aging and a lack of successors (Figure 6-3-1). Moving forward, it will be crucial to actively involve not only fishermen, government authorities, and experts (supporters) but also local residents and NPOs to establish frameworks that enable the entire community to work together. The development of such initiatives could also promote urban-fishing village exchanges and revitalize fishing villages (Figure 6-3-2, Table 6-3-1).

Figure 6-3-1: Status of implementation frameworks



Note: Results of a survey conducted on activity organizations involved in seaweed bed conservation activities under the Fisheries Multifunctional Measures Project (Fisheries Agency of JAPAN, 2020)

Figure 6-3-2: Ideal implementation framework for *isoyake* countermeasures

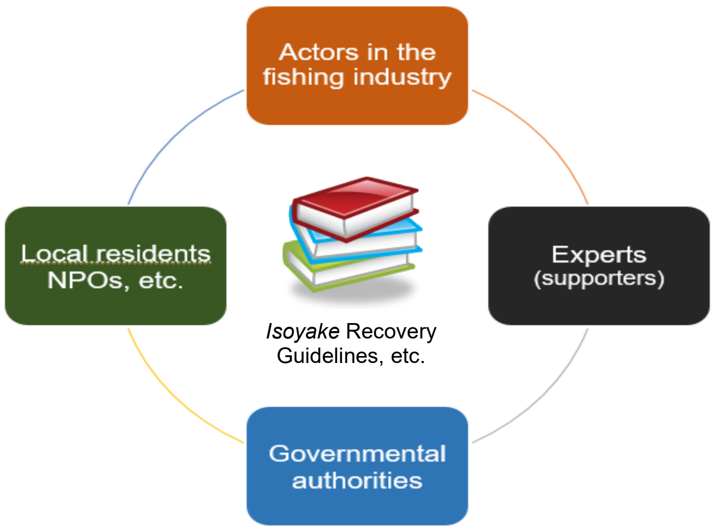


Table 6-3-1: Role allocation among organizations

Fishermen	Local Residents / NPOs, etc.
・ Conduct current condition surveys and monitoring ・ Planning ・ Implement *isoyake* countermeasures ・ Prepare activity reports and organizing reporting meetings ・ Share information (via social media)	・ Assist with implementing countermeasures ・ Participate in reporting meetings
Experts (Supporters) / Researchers	**Government Officials**
・ Provide information on seaweed beds and *isoyake* ・ Advise on plan development ・ Offer guidance on surveys ・ Technical support for countermeasure methods ・ Participate in reporting meetings	・ Provide information on seaweed beds and *isoyake* ・ Financial support ・ Advise on plan development ・ Support leader development

To effectively implement the PDCA cycle in *isoyake* countermeasures, the cooperation of experts (supporters) with specialized knowledge and problem-solving skills is indispensable. Ideally, experts (supporters) should be well-acquainted with the actual conditions of the target marine area, have extensive practical experience in seaweed bed restoration, and be capable of providing advice at each stage of the PDCA cycle.

In the Fisheries Multifunctional Project, experts (supporters) are directly sent to the sites to provide technical guidance and support for monitoring activities, targeting organizations engaged in seaweed bed conservation activities and related efforts. It is important to effectively utilize this support system provided by experts (supporters) to implement *isoyake* countermeasures.

The Fisheries Multifunctional Project information site, *Hitoumi.jp*, features a dedicated page for individual support.

https://www.hitoumi.jp/support/support.php

2) Sharing Information

Organizational capacity is strengthened by sharing the knowledge and techniques that leaders acquire through training sessions and similar opportunities with the entire group. Additionally, sharing the knowledge and experience of veteran fishermen can help streamline the planning process. Advice from experienced experts (supporters) can also provide solutions to challenges and troubles encountered during activities.

To promote information sharing, it is important not only to maintain regular communication among members but also to actively gather new information through interactions with fisheries research institutions, the National Council on *Isoyake* Countermeasures (Fisheries Agency of JAPAN), the Workshop on Measures to Demonstrate the Multifunctional Role of Fisheries (Fisheries Agency of JAPAN), or organizations implementing exemplary initiatives.

The collected information should be introduced in a format that is both "easy to use on-site" and "simple to manage and configure." Additionally, social media should be utilized (albeit with caution regarding copyright issues) to store and disseminate the information.

Information on initiatives across the country is available on the Fisheries Multifunctional Project information site *Hitoumi.jp*:

The National Initiatives page on the Fisheries Multifunctional Project information site, *Hitoumi.jp:*
https://www.hitoumi.jp/torikumi/

3) Integrating tangible installations and intangible countermeasures

Factors inhibiting the formation of seaweed beds include not only herbivorous organisms but also the burial of rocky substrates and the accumulation of fine sediment. To address these issues, blocks or seaweed bed reefs (or algae reefs) are sometimes installed (see Chapter 7, D5, D6, D8). Additionally, substrates can be set up to facilitate the attachment of seaweed propagules, and nutrients salts can be added to promote growth (see Chapter 7, D4, D7). Many of these methods have been developed through seaweed bed creation initiatives. However, rising seawater temperatures and increased activity of herbivorous organisms have made it difficult to achieve and sustain their effectiveness. Therefore, the Fisheries Agency of JAPAN has formulated plans from a broad perspective, integrating tangible installations and intangible countermeasures to promote integrated seaweed bed conservation and creation measures (Seaweed Bed and Tidal Flat Vision, Fisheries Agency, 2016).

As an example of integrating tangible installations and intangible countermeasures, this approach would involve installing seaweed bed reefs in areas where seaweed propagules (spores, seeds, etc.) released from natural seaweed beds are carried by ocean currents over a wide area, thereby creating new seaweed beds. At the same time, intangible countermeasures, such as sea urchin removal, would be implemented to ensure the maintenance of these beds (see Figures 6-3-3, 6-3-4, 6-3-5, and 6-3-6). To achieve such integration, it is essential to establish the aforementioned framework and facilitate effective information sharing, effectively incorporating both aspects into a cohesive plan.

In Mie Prefecture, the *Seaweed Bed Creation Guidebook 2013 (Revised Edition)* was created, along with the establishment of the *Mie Prefecture Tidal Flat and Seaweed Bed Coastal Fishing Ground Conservation Council Guidelines*. Through roundtable discussion meetings, the prefecture has been systematically addressing each district’s progress, from planning and design to construction, monitoring, and post-project evaluation, while facilitating discussions and exchanging opinions to ensure efficient and effective project implementation.

Figure 6-3-3: Image of integrating tangible and intangible measures (example 1)

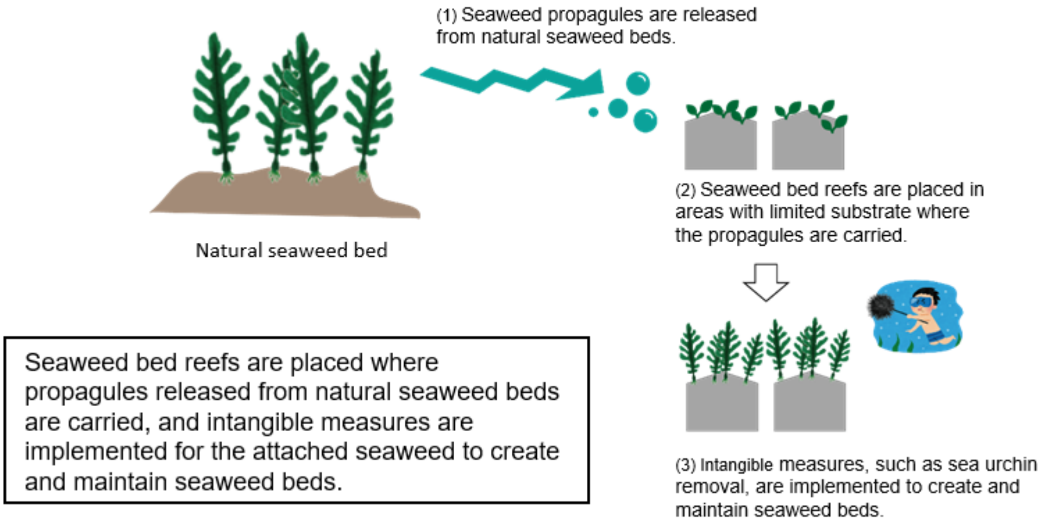


Figure 6-3-4: Image of integrating tangible and intangible measures (example 2)

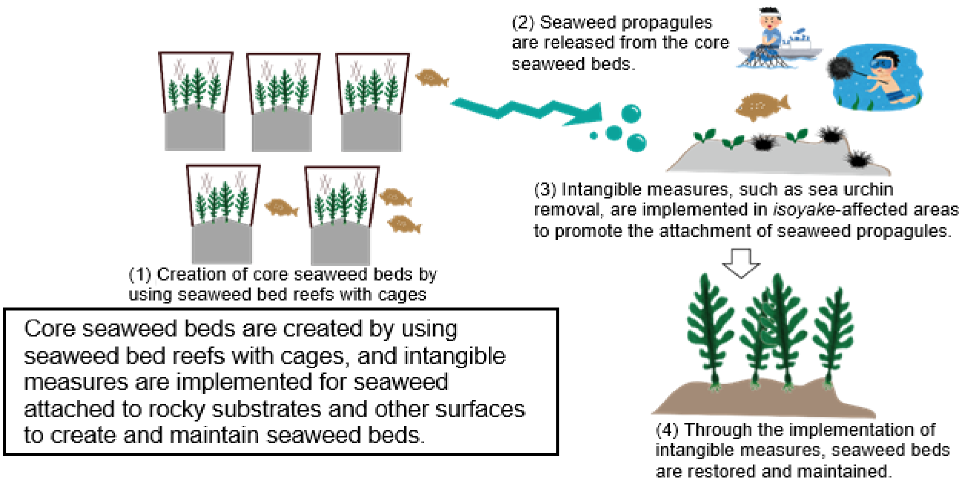


Figure 6-3-5: Image of integrating tangible and intangible measures (example 3)

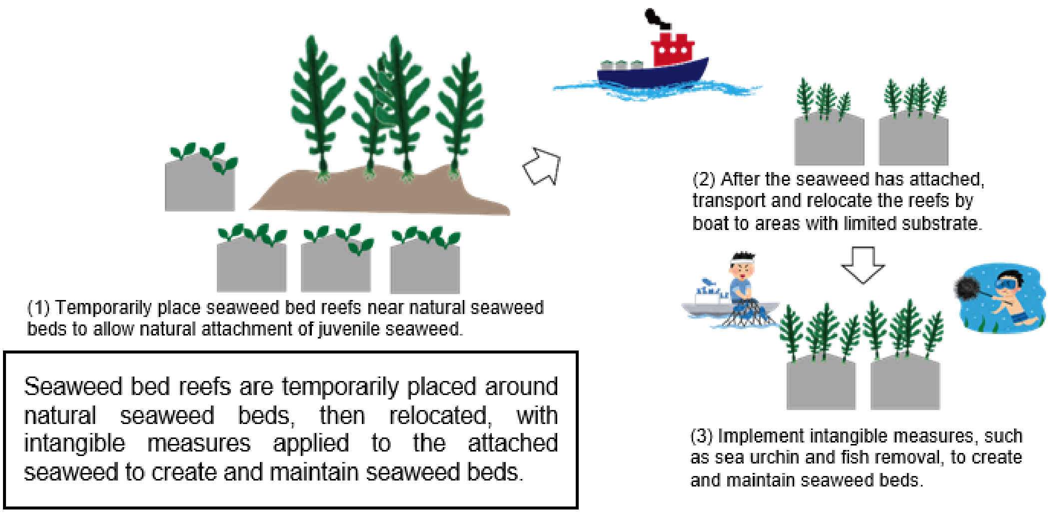
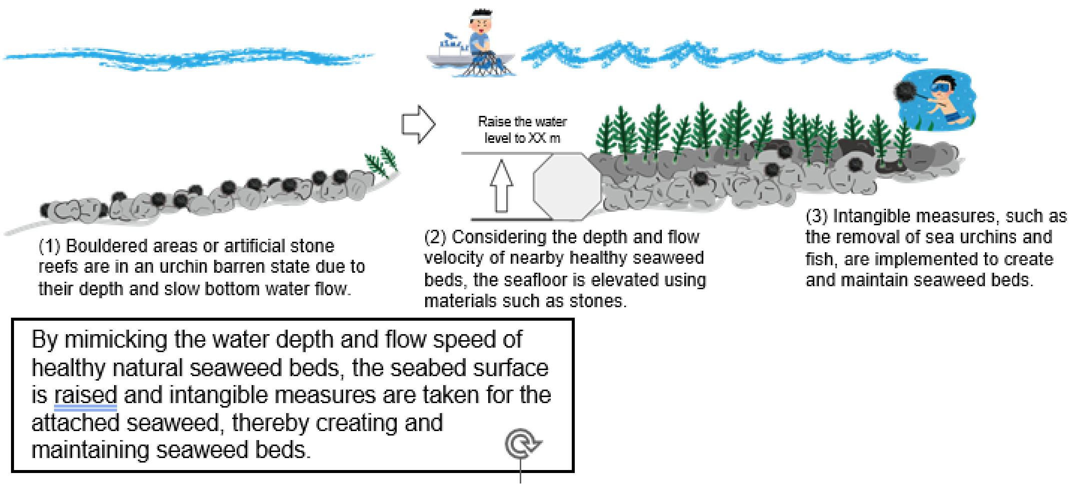


Figure 6-3-6: Image of integrating tangible and intangible measures (example 4)



6.4 Maintenance and Management

Even after seaweed beds have been restored through the PDCA cycle, it is essential to monitor (and manage) them to ensure their continued functionality. For instance, small-scale seaweed beds that emerge in widespread *isoyake*-affected areas are at risk of reverting to *isoyake* due to the presence of many herbivorous organisms nearby. Once a seaweed bed has been restored, the goal should be to maintain it and enhance rocky shore resources. It is crucial to avoid neglecting follow-up on restored seaweed beds, even when attention is focused on implementing *isoyake* countermeasures in other locations or when the importance of maintenance is not fully recognized.

In the Fisheries Multifunctional Project, areas designated for seaweed bed conservation and restoration activities over a five-year period are defined as "agreement areas" (measured in hectares), while the specific area where *isoyake* countermeasures and related activities are implemented referred to as the "activity areas" (≤ agreement area). Regular monitoring involves assessing the effectiveness of countermeasures within the activity area and annually evaluating the environmental and resource conditions of the entire agreement area. Within the agreement areas, monitoring points are established at sites where seaweed beds have been restored through countermeasures, allowing for continuous monitoring and the implementation of appropriate measures to prevent reversion to *isoyake*. Refer to the case studies in Chapter 8 for further guidance.

6.5 Post-Implementation Evaluation and Consideration of Future *Isoyake* Countermeasures

Post-activity evaluation involves assessing the processes and outcomes of the activities through records and monitoring, which corresponds to the Check (evaluation) stage of the PDCA cycle. Based on this evaluation, planning and advancing the next *isoyake* countermeasures align with the Action (improvement) stage of the PDCA cycle. In conducting post-activity evaluations and planning the next countermeasures, attention should be paid to the following points.

- Verify that the numerical targets set in advance have been achieved, and share the evaluation results with the activity members so that information is disseminated.
- Since *isoyake* countermeasures require sustained long-term efforts, compile the evaluation results into a report.
- Use the evaluation results as a basis for planning the next countermeasures to ensure the continuity of activities.
- Post-activity evaluations and the planning of subsequent countermeasures should be primarily carried out by fishermen and local governments, with advice from experts (supporters) as needed.