R2 Seaweed and seagrass beds and the living things of the sea

What do seaweed and seagrass beds bring to the living things of the sea and to people, how much have they decreased, and what labour does it take to bring them back?

Readers	Local governments (fisheries and environment), fishery cooperatives, research institutions, investors and others without specialist knowledge, who want to check with figures how much seaweed and seagrass beds have decreased, how well the ways of protecting them and bringing them back work, and how much labour they take.
Takeaways	1. Seaweed and seagrass beds (shallow sea where seaweeds and seagrasses grow thickly) are a home and a spawning ground for fish and other animals and a place where young fish grow, and they are said to take up nitrogen and phosphorus and to store carbon (views are divided on the carbon of seaweed beds). The amount absorbed by seaweed and seagrass beds is, in the national government's model, about 0.03% of Japan's emissions. 2. The loss of seaweed and seagrass beds, compared nationwide by the same method, was about 3% in the roughly 13 years of about 1978–90. In the Seto Inland Sea that proportion was high, and eelgrass beds (beds in which eelgrass, a flowering seagrass, grows thickly on sandy or muddy bottoms) are said to have decreased by about 70% from 1960 to 1989–90 (this includes values whose original source cannot be checked). In recent years there are places in the Seto Inland Sea where eelgrass beds have come back, and the seaweed beds of rocky shores are said to be decreasing. 3. There are cases in which removing sea urchins, sowing seeds, transplanting and improving water quality have worked (most of them at one site). We find no record that checked the effect of parent seaweed (adult seaweed that releases the seeds) alone, or the area of beds that actually grew on substrates such as stones. Even among activities that received national support, the groups in which cover (the proportion of the seabed covered by seaweeds and the like) increased and the groups in which it decreased are almost half and half (not compared with places where no activity took place), and the income from J Blue Credits, which make the amount of CO2 taken up by seaweed and seagrass beds and the like saleable, is also small.
After reading	When you look at the area of seaweed and seagrass beds in your own region, check the method and the year of measurement, separate eelgrass beds from seaweed beds, and keep recording by the same method and in the same season.

November 2026 · English edition 1 (translation of the Japanese 1st edition) · SeatecHIROSHIMA Ltd.

This is an English translation. The Japanese edition is the authoritative text.

1. Key points

- Seaweed and seagrass beds (shallow sea where seaweeds and seagrasses grow thickly) are a home and a spawning ground for fish and other animals and a place where young fish grow, and they are said to take up nitrogen and phosphorus and to store carbon (views are divided on the carbon of seaweed beds). The

amount absorbed by seaweed and seagrass beds is, in the national government's model, about 0.03% of Japan's emissions. [S1, S2, S3]

- The loss of seaweed and seagrass beds, compared nationwide by the same method, was about 3% in the roughly 13 years of about 1978–90. In the Seto Inland Sea that proportion was high, and eelgrass beds (beds in which eelgrass, a flowering seagrass, grows thickly on sandy or muddy bottoms) are said to have decreased by about 70% from 1960 to 1989–90 (this includes values whose original source cannot be checked). In recent years there are places in the Seto Inland Sea where eelgrass beds have come back, and the seaweed beds of rocky shores are said to be decreasing. [S1, S4, S5, S6, S10]
- There are cases in which removing sea urchins, sowing seeds, transplanting and improving water quality have worked (most of them at one site). We find no record that checked the effect of parent seaweed (adult seaweed that releases the seeds) alone, or the area of beds that actually grew on substrates such as stones. Even among activities that received national support, the groups in which cover (the proportion of the seabed covered by seaweeds and the like) increased and the groups in which it decreased are almost half and half (not compared with places where no activity took place), and the income from J Blue Credits, which make the amount of CO2 taken up by seaweed and seagrass beds and the like saleable, is also small. [S1, S7, S8, S9, S13, S14, S16]

2. What is happening

World and Japan: the functions of seaweed and seagrass beds, and carbon

Seaweed and seagrass beds are places in shallow coastal sea where seaweeds and seagrasses grow thickly. The Fisheries Agency's guidelines on measures against barren ground (isoyake) (2021) divide them, by the species that form the bed, mainly into kombu kelp beds, arame and kajime kelp beds, wakame beds, Sargassum beds (beds of Sargassum species), tengusa (Gelidium) beds and eelgrass beds (there are also others, such as sea lettuce beds). Eelgrass beds form mainly on sandy or muddy bottoms (on rocky shores for some species, such as surfgrass), and the others mainly on rocky shores. What these guidelines cover is the four of rocky shores: kombu kelp beds, arame and kajime kelp beds, wakame beds and Sargassum beds. [S1] Seagrasses are plants that, like eelgrass, flower and multiply by seeds; seaweeds are algae such as kombu and wakame. [S10] Barren ground (isoyake) is a state in which the seaweed beds of rocky shores decline beyond their ordinary ups and downs and remain lost. [S1]

Seaweed and seagrass beds serve as a home and a hiding place for fish and other animals, a place where young fish grow, and a spawning ground for fish and squid, and they also take up nitrogen and phosphorus (the list of roles in the guidelines is a qualitative description). [S1] In an analysis of 160 peer-reviewed papers from around the world (more than 11,000 comparisons), in almost all structured habitats, such as communities of underwater grasses including seagrasses, mangroves (forests of tropical and subtropical seashores) and coral reefs, the density of juveniles (the young of fish and invertebrates) was higher than on flat seabed, and in some of them growth and survival were also higher. Among them, communities of underwater grasses and mangroves raised density and growth more than other habitats. However, evidence is said to be scarce for seaweed forests and the like, and for anything other than density (growth, survival, recruitment [the young growing up and joining the adult population] and so on) (abstract only checked). Comparisons from Japan are few, such as one site in Ibaraki Prefecture. In Japan, a study (2020) that examined a small eelgrass bed inside Hiraiso Port in Ibaraki Prefecture found that the number of fish species and the number of fish per net haul were significantly greater in the eelgrass bed than on the neighbouring sandy bottom (collected in the daytime from May to August 2014 by two people holding both ends of a small net, spreading it to a width of 4 m, and walking 20 m parallel to the shore pulling it through shallows up to 1 m deep. The net was hauled 5 times each month in the eelgrass bed

and on the sandy bottom (20 times each over 4 months), and the totals were 29 species and 1,126 individuals in the eelgrass bed and 20 species and 562 individuals on the sandy bottom. A survey of one site over 4 months). [S2]

For a nationwide value putting the function of taking up nitrogen and phosphorus into money, we found only an old trial calculation. A report of the Science Council of Japan (2004) cites, for reference, a trial calculation by the Mitsubishi Research Institute, and puts the value of water purification by seaweed and seagrass beds at 552.7 billion yen (390.4 billion yen for nitrogen and 162.3 billion yen for phosphorus). It is a trial calculation (the replacement cost method) that replaces the nitrogen and phosphorus taken up by seaweed and carried to the open ocean with the cost that would arise if they were recovered by sewerage; it is not an amount actually paid, and it is not stated whether it is a value per year. The report itself also cautions that this is no more than the monetary amount of part of the functions, and that the method too has many immature points. [S21]

In a table in the Fisheries Agency's guidelines on measures against barren ground (isoyake) (2021), among the seaweed beds of rocky shores, kombu kelp beds, arame kelp beds and Sargassum beds take up about 112–136 g of nitrogen per 1 m^2 per year (values from Fisheries Agency reports of 2003 and 2011; the places and the method of derivation are not stated in the guidelines. Eelgrass beds are not in the table). The guidelines replace this amount with the cost of treating the same amount of nitrogen at a sewage treatment plant (20.7 million yen per 1 t, which the Fisheries Agency derived from the fiscal 2009 edition of the annual report of the Tokyo Metropolitan sewerage works), and calculate on a trial basis about 23.12 million to 28.12 million yen per year per 1 ha (hectare; 10,000 m^2, an area 100 m square) (for phosphorus too, replacing it with 148.2 million yen per 1 t, about 10.34 million to 12.58 million yen per year per 1 ha). This too is a trial calculation by the replacement cost method, and is not an amount actually paid. Unlike the trial calculation in the Science Council report, it is a value applied to the whole of the amount taken up, not to the portion carried to the open ocean. The guidelines themselves also state that the trial calculations of the monetary amounts for nitrogen, phosphorus and CO2 need to be checked in further detail, also considering a quantitative assessment of the processes by which they are stored, for example by being carried to the deep sea. [S1] There are also sea areas where the function of removing nitrogen cannot be read as a benefit as it stands (see the "Region" section), and in such sea areas the monetary amount for nitrogen in neither the Science Council report's trial calculation nor the guidelines' trial calculation can be read as a benefit as it stands (this paper's interpretation). [S20]

The values for blue carbon (carbon stored by living things in the sea) differ greatly depending on whether they are the amount taken up or the amount that remains for a long time (Table 1). [S1, S3, S11, S12] Of the carbon taken up by photosynthesis, only part remains for a long time in the seabed or the deep sea. The statement of calculations of greenhouse gas emissions and removals that the national government submits to the United Nations (the inventory) converts the maximum standing stock of the beds (the maximum value, within one year, of the amount of seaweeds and seagrasses present in the beds) into production and multiplies it by the proportion of carbon (30%), and then multiplies by the proportion that remains for each of four pathways (the portion that accumulates in the seabed inside the bed, the portion carried to the deep sea, the hard-to-decompose fragments that accumulate in the seabed outside the bed, and the hard-to-decompose dissolved organic carbon), to obtain the amount that remains for 100 years or more (a model of the national government's own. The method was created in a research project of the Ministry of Agriculture, Forestry and Fisheries [2020–24], and not all of the results have been published as papers). [S1, S3]

Table 1 Carbon values for eelgrass beds (seagrass) (t-CO2 = weight converted to carbon dioxide. ha = hectare; 1 ha is 10,000 m^2, an area 100 m square. Per 1 ha per year)

Source	What amount it is	Value	Conditions and type of value
Fisheries Agency guidelines [S1]	Amount taken up by photosynthesis	12.6 (±8.9)	Nationwide. Production × proportion of carbon

Source	What amount it is	Value	Conditions and type of value
Kuwae et al. (2019) [S11]	Carbon that increases within the ecosystem	Mean 4.9 (the upper limit of 33.4 is the mean + 2 times the standard deviation)	Nationwide estimate. The production of the whole ecosystem, including microscopic algae, multiplied by the proportion that remains (mean 18.5%). The definition differs from that of the national coefficients
The national statement of greenhouse gas calculations (inventory, 2026) [S3]	Amount that remains for 100 years or more	2.2–5.9 (2.32 for the Seto Inland Sea)	Coefficients of the national government's own model. Not measured values
Duarte et al. (2005) [S11]	Amount buried in the seabed	About 3.0	Geometric mean of 5 reports (83 g of carbon per 1 m^2 per year. At least 3 of the 5 are studies that examined the Mediterranean seagrass Posidonia [a different species from eelgrass]). Not a value measured in Japan
IPCC (the United Nations' Intergovernmental Panel on Climate Change, 2014) [S12]	Amount that accumulates in the soil of beds restored by planting or sowing	About 1.6 (95% confidence interval about 0.7–2.6)	A default value common to the whole world. Based on 6 studies. Beds that came back naturally are 0

Note: The values of the IPCC and of Duarte et al. are converted to CO2 by multiplying the weight of carbon by about 3.67 (this paper). A confidence interval is the range of uncertainty of an estimate; a geometric mean is a mean obtained by multiplying the values together. The seagrass value of Duarte et al. rests on only 5 reports, and the burial amount for the world's seagrass beds given later by Fourqurean et al. (2012) also cites this estimate (it is not separate evidence).

Apart from the yearly amount, there are also estimates of the amount of carbon accumulated in the soil of the seabed (the stock). A study (2012) that compiled data from 946 seagrass beds around the world estimated the carbon accumulated in the soil to a depth of 1 m at about 140 t per 1 ha in weight of carbon (the median of 41 cores [columns of soil pulled out of the seabed with a tube] measured to a depth of 1 m, combined with 48 sites estimated from shallow measurements; the authors say that it is probably a conservative value). The deep cores are concentrated in Florida Bay in the United States, the western Mediterranean and Shark Bay in Australia, and data are said to be especially scarce for the western Pacific and elsewhere (Japan is not named). The IPCC default value is 108 t per 1 ha in weight of carbon (a value derived from the data of 89 sites of the same 2012 study, not an independent estimate. It is a value used only where the soil is dug out). Both are amounts accumulated, and are different figures from the yearly amounts in Table 1. [S11, S12]

The amount absorbed by the country as a whole is a small value. The national inventory puts the amount absorbed by seaweed and seagrass beds in fiscal 2024 at about 320,000 t-CO2, which is about 0.03% of Japan's total emissions (1,046 million t, excluding the portion for land use and forests) (this paper's calculation). It counts the whole of the natural beds by a model, and the portion that came back naturally is also included. [S3]

Seen worldwide too, the amount that can be absorbed and stored by restoring coastal ecosystems is a small value compared with the world's emissions (this paper's interpretation). The IPCC special report (2019, the ocean and cryosphere) stated that the restoration of mangroves, salt marshes (grassy wetlands that seawater enters), seagrass beds and the like could absorb and store around 0.5% per year of the world's current emissions (confidence is medium. Seaweed beds are not among the ecosystems given as examples). The same report states that protection and restoration also bring protection from storms, improvement of water quality, and

benefits to biodiversity and fisheries (confidence is high), and that the uncertainty in how the amount of carbon is measured needs to be reduced. [S12]

World and Japan: how the beds have decreased, and the causes

The world's seagrass beds for which there are records have been decreasing (about 29% of the area measured at 215 sites in 1879–2006). However, the beds examined are 10% or less of the world's, and are skewed towards certain regions. The decrease of "7% per year since 1990" in the abstract of this study is the median of the rates of decrease at the sites that are decreasing; it is not the annual rate of decrease of the beds of the whole world (the period is divided differently from "5% per year since 1980" in the main text). In a 2021 tabulation that added sites to this record (547 sites, 1880–2016) too, a net 19.1% of the whole of the beds examined had been lost (a proportion of the area examined. The area examined is about 10% of the seagrass beds known in the world, and is skewed by period and region. About half of the area lost is that of the beds at one site in the US state of Florida). The temperate North Pacific, which includes Japan, was almost flat in 1955–2013 (a net +0.6%) (data are especially scarce, and it is said that the flat trend may be only apparent). [S13]

The large seaweed forests of kombu and its relatives (kelp) have not decreased uniformly around the world. In a study (2016) that analysed by a model the records of 1,138 sites from 1952–2015, among the sea-area divisions with data, they decreased in 38%, increased in 27%, and showed no change in 35%, and the world average was a small decrease (a trend derived not from area but from records such as density and cover). The sea areas around Japan have no data in this analysis; the cold-temperate division of the Northwest Pacific is expressly marked as having no data, and the warm-temperate division is not mentioned. [S13]

The decrease measured by the same method for the whole of Japan exists for one round only. In the Environment Agency's 4th National Survey on the Natural Environment (fiscal 1989–91, mainly interviews), 6,403 ha (3.2% of the existing 201,212 ha) disappeared in the roughly 13 years from fiscal 1978 (newly formed beds are not counted, and places deeper than a water depth of 20 m, beds of less than 1 ha and some islands are not included). [S4, S1]

Most of the causes of the beds that disappeared nationwide in the period of the 4th survey are not known. The causes are those reported by the prefectures on the basis of interviews and the like (not confirmed causal relationships): direct alteration such as land reclamation was 28.1%, barren ground (isoyake) 14.7%, other changes in sea conditions 16.2%, unknown 40.6%, and overharvesting 0.4% (one sea area only, Soya). The analyst of the report, considering that barren ground and changes in sea conditions had a weak basis, regarded the 71.5% obtained by combining them with "unknown" as being in effect of unknown cause. [S4]

The nationwide figures after that differ in both method and scope. In the nationwide survey that the Ministry of the Environment carried out with satellite images in fiscal 2018–20, the beds excluding enclosed seas (Tokyo Bay, Ise Bay, the Seto Inland Sea, the Ariake Sea and Shimabara Bay, and the Yatsushiro Sea) were 164,340 ha (of which seaweed beds 122,570 ha, eelgrass beds 32,990 ha and surfgrass beds 8,780 ha. The conversion to ha is by this paper). The images were taken mainly in 2014–18, and the area shows the extent at that point in time; it does not show cover. The Ministry of the Environment states that the way the figures were produced differs from the past basic surveys, and the difference from the 201,212 ha of the 4th survey cannot be read as an amount of decrease. [S4]

"The nation's seaweed and seagrass beds have decreased to about half" is an estimate of the national inventory (328,129 ha in 1990 → 146,179 ha in 2024). It joins by a straight line the surveys of 1990 and 1999, which were mainly interviews, and the model values from 2018 onwards, and its 1990 value is about 1.6 times that of the 4th survey (this paper's calculation). The Port and Airport Research Institute, which made the model, also raises the possibility that part of the decrease is due to the difference in survey methods. What decreased was mainly the seaweeds of rocky shores, such as the arame type (61,593 ha → 5,065 ha), and the eelgrass type is almost flat at

26,379 ha → 25,279 ha (both 1990 → 2024. Among seagrasses too, the tachi-amamo [Zostera caulescens] type is estimated at about 10,200 ha → about 20 ha). However, the values by type are also of the same series, and change with the edition (in the institute's 2024 material, eelgrass is "expanding"). Fiscal 2021–24 is flat at about 142,000 to 146,000 ha. [S3]

As recent causes, the national government (the Fisheries Agency) gives high water temperature and grazing damage. The Vision for Seaweed and Seagrass Beds and Tidal Flats (2023; a document in which the national government sets out its thinking on protecting seaweed and seagrass beds and tidal flats) states that the beds have been lost through land reclamation and the like and, in addition, are decreasing in recent years because the dying back of standing seaweeds caused by the rise in seawater temperature, and grazing damage by sea urchins and by fish such as the brassy chub (noto-isuzumi), the rabbitfish (aigo) and the parrotfish (budai), have become more active and spread (it does not give figures or a ranking of the causes). [S6] In a Fisheries Agency questionnaire in 2020, 31 of the 39 coastal prefectures (a value from the figure) answered that the decline of the beds of rocky shores was continuing. Of the number of responses, the factors were grazing damage by sea urchins at 26%, and grazing damage by fish and the rise in seawater temperature at 21% each (the view of the officials in charge). [S1] The same Vision states that water quality itself has improved through reducing the pollutant load (the amount of pollution entering the sea), but that the environment in which living things grow has not necessarily improved. [S6]

Region (Hiroshima and the Seto Inland Sea)

The Seto Inland Sea was a sea area with a high proportion of beds lost by about 1990. In the 4th survey, ranks 1 to 4 and rank 6 among the 91 sea areas nationwide by proportion lost were on the coast of the Seto Inland Sea. The area lost in the Seto Inland Sea (from the Kii Channel to the Bungo Channel) was 20.8% of the national total (about 21% in the general summary), and 43% (general summary) to about 50% (analysis chapter) of it was due to land reclamation and the like (the values differ by chapter even within the same report). [S4] The licensed area of land reclamation in the Seto Inland Sea (the area for which reclamation was permitted, not the area actually reclaimed) was about 463 km^2 (1 km^2 is 100 ha) in 1898–2020, of which about half, 225 km^2, was the portion for 1950–73, and 1974–2020 was 137 km^2. The area reclaimed on top of seaweed and seagrass beds is not stated. [S5]

However, the figures for the large decrease of the past join together values obtained by different methods. The eelgrass beds of the Seto Inland Sea went from 22,635 ha in 1960 to 6,381 ha in 1989–90 (the Ministry of the Environment describes this as a loss of about 70%), but almost all of the decrease lies between the values for 1960 and 1971 (5,574 ha), whose original sources cannot be checked. [S5] The beds of Hiroshima Bay too, in the Hiroshima Bay Restoration Action Plan (second term, 2017) of the Hiroshima Bay Restoration Promotion Council, decreased from 959 ha in fiscal 1973 to 292 ha in fiscal 1990 (by calculation, about 667 ha disappeared. The northern part at the head of the bay went from 701 to 43 ha), and were 302.7 ha in fiscal 1998 (the only part that increased from fiscal 1990 to fiscal 1998 was the northern part [43 → 83.1 ha]; the southern part went from 249 to 219.6 ha). This "Hiroshima Bay" includes the Yamaguchi Prefecture side, and both its scope and its method (the old basic surveys, which were mainly interviews) differ from the divisions of the Ministry of the Environment's satellite survey (Table 2), so it cannot be compared with the values in Table 2. Values for this scope later than fiscal 1998 are not given. [S22]

The long series for Hiroshima Prefecture as a whole also joins together surveys with different methods. The prefecture's materials give 2,711 ha for 1973, 2,059 ha for 1989, 1,841.7 ha for 1998 (another prefectural material treats this as a value for fiscal 1995–96) and 2,519 ha for 2016, but the differences cannot be read as increases or decreases. The prefecture's plan (2016) states that, comparing 1978 and 1989 by bay and nada (open basin) (including the portions of neighbouring prefectures), there was no great change (Bisan-Seto decreased by about

10%), and that in 1989–98 there was a decrease of about 10% (the 1978 value is a calculated value obtained by adding the area lost to the 1989 area). [S14]

After about 1990, there are places that increased and places that decreased. In the 23 areas (not random) that the Ministry of the Environment compared in fiscal 2015–17 by the same interviews as in the past, eelgrass beds increased in 14 and decreased in 3 (6 unchanged), and seaweed beds increased in 10 and decreased in 11 (2 unchanged). In the three areas within Hiroshima Prefecture too, the beds had increased according to the interviews (1989–90 → fiscal 2016. Matsunaga Bay 75 → 125 ha, Mitsu Bay 628 → 843 ha, Nomi Island 231 → 261 ha. Mitsu Bay is almost entirely eelgrass beds, 623 → 838 ha). However, the satellite values for the same year were 129 ha for Matsunaga Bay, 941 ha for Mitsu Bay and 133 ha for Nomi Island, and Nomi Island was about half the interview value. [S5] In Okayama Prefecture's summary too, the eelgrass beds in the prefecture went from 549 ha in 1989 to 1,878 ha in 2020 (values from the prefecture's graph, with no statement of the survey method. The period overlaps both with the seed sowing by the fishers of Hinase [Chapter 3] and with the recovery of the sea environment, and the contribution of each is not shown. The Ministry of the Environment's case examples of initiatives [2020] state that in the waters off Kasaoka and Oku Town in the prefecture the eelgrass beds are gradually coming back with the recovery of the sea environment [in Kasaoka, not yet sufficiently], and that seed sowing was also started from fiscal 2013 in Oku Town and from fiscal 2016 in Kasaoka). [S25, S10]

In the latest comparison of satellite images, the Seto Inland Sea as a whole increased by about 9%, the total of Hiroshima Bay, Hiuchi-nada and Bingo-nada (including neighbouring prefectures) decreased, and the total for the sea areas of Hiroshima Prefecture was almost flat (Table 2). By bay and nada, there was a general increase on the eastern side, such as the Kii Channel, Osaka Bay, Harima-nada and Bisan-Seto, and a decrease on the western side, such as Hiroshima Bay, Hibiki-nada, Suo-nada and the Bungo Channel. The Ministry of the Environment states that the increase on the eastern side fits the interview results of a spread of eelgrass beds due to a rise in water transparency, and the decrease on the western side fits those of grazing damage by fish and a rise in water temperature, while stating that the detailed reasons are unknown. However, even within the same survey, the criteria for regarding something as a bed and the timing of the on-site checks differ between the eastern and western parts and the central part (Bisan-Seto, Bingo-nada, Hiuchi-nada, Aki-nada and Hiroshima Bay, and parts of Harima-nada and Iyo-nada) (note to Table 2), so there is also a possibility that part of the increase on the eastern side is due to the difference in method (this paper's interpretation). [S5]

Table 2 Area of seaweed and seagrass beds in the Seto Inland Sea (satellite images, ha. Bays and nada are totals including neighbouring prefectures)

Division	Fiscal 2015–17	Fiscal 2022–23	Of which, sea areas of Hiroshima Prefecture	Conditions and breakdown
Whole of the Seto Inland Sea	15,604	16,963 (+8.7%)	—	Seagrasses and seaweeds not separated
Hiroshima Bay	668	593	415→451	Yamaguchi Prefecture portion 238→134
Hiuchi-nada	3,251	2,745	1,535→1,724	What decreased is the portion outside the sea areas of Hiroshima Prefecture
Bingo-nada	470	397	415→234	—
Aki-nada	449	442	108→110	—
Bisan-Seto	—	—	46→44	Only the Hiroshima Prefecture portion is given

Division	Fiscal 2015–17	Fiscal 2022–23	Of which, sea areas of Hiroshima Prefecture	Conditions and breakdown
Total for the sea areas of Hiroshima Prefecture	—	—	2,519→about 2,563	The previous round was fiscal 2016. This paper's total

Note: Hiroshima Bay, Hiuchi-nada, Bingo-nada and Aki-nada (the central part) and the Hiroshima Prefecture portion of Bisan-Seto are a comparison of the surveys of fiscal 2016 and fiscal 2023. The fineness of the images (5 m → 3 m) and the criteria for a bed changed. In the central part, which includes the sea areas of Hiroshima Prefecture, unlike the previous round (in which large seaweeds and seagrasses counted regardless of cover), sites with a cover of 5% or more were treated as beds for large seaweeds too, the same as for small seaweeds (the criterion for seagrasses is not stated). This change can work in the direction of making the area look smaller. In the eastern and western parts, large seaweeds and seagrasses counted regardless of cover, and the on-site checks were in winter (6 December 2022 to 1 February 2023), before the season when the beds grow thickly. Whether the prefectural boundaries were cut in the same way is not stated, and the direction of increase or decrease can also change with the method. [S5]

Hiroshima Prefecture states, in a comparison of 1991 and 2021, that Sargassum beds declined mainly around the islands, but it does not give areas. The prefecture's vision for seaweed and seagrass beds gives as causes loss from the deeper side, the deposition of fluid mud (fine mud that accumulates on the seabed) and grazing damage by fish that eat seaweed, and it shows the comparison as points on a map (increase, no change, decrease, unknown). [S14]

There are two records in which the effect of high water temperature or climate change is suspected, but both are observations of one site, and neither has been confirmed as the cause. At an artificial beach (Eigashima Beach) in Akashi City, Hyogo Prefecture, facing Harima-nada, the area of eelgrass decreased by about 92%, from 0.800 ha in May 2024 to 0.065 ha in January 2025. During the 11 days of 11–21 September in between, the daily mean water temperature exceeded 28°C, which is regarded as a rough upper limit for the growth of eelgrass (the peak was 28.7°C on 14 September). The authors suspect high water temperature, considering that sunlight, turbidity, grazing damage, typhoons and competition with other seaweeds do not apply, but they state that, because the comparison is between May, when eelgrass grows thickly, and January, when it declines, it cannot be distinguished from the seasonal decrease, and that the degree of decline remains a qualitative judgement (one site of about 0.8 ha, one season). [S15]

The other record, Ikuno Island in Osakikamijima Town, has both a change that suggests decline and a change that shows expansion. Here the reporter regards the fact that eelgrass is shifting to a way of life in which it dies back within one year (annual) as an effect of climate change (10 years ago, large non-flowering shoots [vegetative shoots], characteristic of this place, formed a community with a cover of 90% or more). According to the same report, in 2025 (survey of 16 June) the cover near the centre of the distribution was close to 100%, and the range of depths at which it grows also widened slightly on both the shallow side and the deep side. Near the centre, flowering shoots remained numerous, but a few vegetative shoots were also seen for the first time in several years. [S15]

The figures linking seaweed and seagrass beds and fish in the Seto Inland Sea that we found are few. The guidelines introduce a report (2009) that puts the function of the Sargassum beds of the Seto Inland Sea in raising the juveniles of one species, the white rockfish (shiro-mebaru), as an economic value, at 540,000 to 725,000 yen per 1 ha (whether it is a value per year, and the method of calculation, are not stated. The guidelines also write that the calculation is difficult because the juveniles move to other places as they grow). [S1]

In the 8 water areas that Hiroshima Prefecture made the target in the preliminary draft of its plan to increase nitrogen, the function of seaweed and seagrass beds in removing nitrogen cannot be read as a benefit as it

stands (this paper's interpretation). This preliminary draft targets 8 water areas, being the prefecture's 9 water areas for which water quality standards for nitrogen and phosphorus have been set, less the sea area off Minoshima Town, which is high in nitrogen; it considers nitrogen to be low in 6 of those water areas, and would increase nitrogen through the winter (roughly October to March) operation of sewage treatment plants and the like (phosphorus is outside the scope for the time being. Chapter 4). [S20]

3. Existing measures, and how they are assessed

The national government sets out the strengths and weaknesses of measures to protect and bring back seaweed and seagrass beds by dividing them into "hard" measures and "soft" measures. The Vision for Seaweed and Seagrass Beds and Tidal Flats states that hard measures, such as putting in stones and the like to create places for seaweeds to attach and the creation of eelgrass beds, are local in extent but can be expected to have a lasting effect, and that soft measures, such as removing the animals that cause grazing damage and sowing seeds or planting, reach a wide area but take a great deal of labour. Together with this, it points out that upkeep such as managing the density of sea urchins is needed after a bed has been created, that watching over the site (monitoring) for a certain period is needed because seaweeds take from several months to several years to grow, and that there are also areas that returned to barren ground again after once recovering. [S6]

Seaweed beds of rocky shores: measures against grazing damage, parent seaweed and substrates

There are cases in which measures to reduce sea urchins have worked. The guidelines state that the density of sea urchins needs to be lowered to around 1/10 of the original, and that a net to keep sea urchins out costs about 1,500 yen per 1 m (whether labour costs are included is not stated), and that for 210 m it takes 4 people about 5 hours in total to make it and set it in place. At Shiraura in Kihoku Town, Mie Prefecture, volunteer divers removed about 200,000 sea urchins from about 9.3 ha in the 5 years of 2015–19 (a cumulative 335 people over 16 days), and the whole extent was judged to have recovered (about 5.3 ha) or to be on a recovering trend (about 4.0 ha) (the judgement was made by the NPO that carried out the activity, by looking at the distribution of the beds in aerial drone photographs; the criteria and any comparison site are not stated). [S1] On the other hand, in a table in a report of a survey commissioned by the national government (March 2026), the mean winter (December to February) cover of seaweeds and seagrasses of the "Shiraura activity group" in Mie Prefecture (an activity group is a group of fishers and others that protects seaweed and seagrass beds and the like with a grant under the national government's programme for bringing out the multiple functions of fisheries) fell from 48.1% in fiscal 2019 to 31.4% in fiscal 2023 (a comparison between the same seasons, based on the activity group's self-assessment. The places and area surveyed, and whether they are the same as the scope of the NPO's activity, are not stated). [S7]

In the restoration of kelps, the cost of the methods that reduce sea urchins is reported to be lower than that of planting, seeding and artificial reefs (stones, blocks and the like placed on the seabed). Of 259 kelp restoration projects around the world, about 80% were of less than 1 ha, and the mean cost of the work per 1 ha was in the range of about 530,000 to 710,000 US dollars for each of the three methods of planting, seeding and artificial reefs, about 68,000 US dollars for removing sea urchins by hand, and about 1,500 US dollars for the method of killing sea urchins with quicklime (2020 values. The costs of planning and monitoring are not included. Few projects reported costs, and Japanese projects are almost entirely not included). [S16]

The limit is the labour to keep it going. At Nagoya in Saiki City, Oita Prefecture, diving fishers (7 people at the time) began in 2007 to remove sea urchins in a 1.4 ha zone partitioned off with nets (the placing of parent seaweed began from the spring of the following year), and afterwards widened the extent. The barren places in

the district (seaweed cover of 5% or less) had become less than 1% by 2020, while large seaweeds increased to 20% of the district in the 10th year and then decreased through grazing damage by parrotfish (the proportions are values from the monitoring of the whole district from 2012, and the area of the district is not stated. As at the time of the 2021 guidelines). Since 2018, parrotfish have also been caught with gill nets and longlines (long lines carrying many fish hooks), and the guidelines state that this combination has made it possible to catch them efficiently (in the fiscal 2025 report too, this is treated as an issue on which work should continue). [S1, S7] At Hayataura in Owase City, Mie Prefecture, the beds were maintained even when the removal of sea urchins was reduced from 10,000 or more individuals a year to about 1,000 individuals a year (as at the time of the 2021 guidelines). The same guidelines state that methods of removing fish that eat seaweed are still in the middle of development, that much labour and time are needed to make them effective, and that there are few cases in which the method of partitioning off a bay with nets has succeeded on a continuing basis. In addition to the ageing of the fishers who can dive and the cost of hiring divers, for volunteer divers the worry that poaching will increase, legal restrictions (in Mie Prefecture, the fishery rules do not allow sea urchins to be taken using diving apparatus, and they are crushed with removal rods) and the trouble of the procedures are also regarded as barriers. [S1]

There are also cases in which the beds do not come back even when the work is continued for a long time. At Oshima in Saikai City, Nagasaki Prefecture, fishers began removing sea urchins and sea snails of their own accord in 1995, and have devised equipment to prevent grazing damage by sea urchins and fish. They succeeded in keeping the parent seaweed from being eaten, but it is said that this has not led to the recovery of the beds (as at the time of the 2021 guidelines). [S1]

The results of the activities that received national support are divided. Among the 122 activity groups (23 prefectures) for which cover could be compared in the same season of fiscal 2019 and fiscal 2023, it increased in 58 and decreased in 62. Many of the groups in which it decreased also combined sea urchin removal with parent seaweed, and there is no comparison with places where no activity took place, so the effect of the activities is not known (self-assessment. Groups in Hiroshima Prefecture are not included). [S7]

For substrates such as stones, it is not known how much the beds have grown. Hiroshima Prefecture plans, by fiscal 2026, to put in stones as a place where the juveniles of species important to fisheries, such as the red-spotted grouper (kijihata) and sea cucumbers, grow, and to create 14.0 ha of Sargassum-bed propagation grounds (places for increasing fish), and a total of 11.2 ha has been completed (this paper's total of the prefecture's materials). In the national government's ex-ante evaluation document, the cost of the substrates is 980 million yen (including tax) and the benefit-cost ratio (benefit ÷ cost) is 1.17 (about 60% of the benefit is a model value for water purification), which comes to about 70 million yen per 1 ha of propagation ground (this paper's calculation); but the stones are assumed to be placed on a total of 5 ha, and this is not the cost of producing 1 ha of bed. [S14]

Eelgrass beds: seed sowing, transplanting and improving water quality

For eelgrass, there is a case in which it came back on a large scale through seed sowing. In shallow bays in the US state of Virginia, 74.5 million seeds were sown on a total of 213 ha in 1999–2018, and 3,612 ha of eelgrass beds (including very sparse places) formed (conditions in which water quality was maintained and only seeds were lacking. Of these, volunteers gave a cumulative 3,500 hours or more to collecting 10 million or more seeds). The beds spread over a larger area than was sown mainly because seeds dispersed naturally from the sown plots. [S8]

In Japan too, there is a case in which eelgrass beds came back greatly after seed sowing. At Hinase in Bizen City, Okayama Prefecture, the eelgrass beds decreased from about 590 ha in the Showa 20s (1945–54) to 82 ha in 1971 and 12 ha in 1985. From 1985 the fishers took seeds from drifting eelgrass (eelgrass and the like that has

broken off and floats on the sea surface) and sowed them in autumn, and the eelgrass beds are reported to have returned to about 250 ha in 2015 (the method of measurement is not stated. The figures are from the materials of the fishery cooperative, the prefecture and the NPO that carried out the activity. This also overlaps with the recovery of the sea environment, and the contribution of the seed sowing is unknown). [S10, S8] A study that examined genes states that the sown seeds worked in a way that supplemented the spread by natural seed dispersal, and that the genetic diversity of the restored beds was of the same level as that of natural beds (abstract only checked. It does not show the portion of the recovery in area that is due to seed sowing). [S8]

There is also a case in which transplanting worked. In Etajima Bay in Hiroshima Prefecture, eelgrass beds moved using nursery sheets (sheets on which seedlings are raised) developed by the prefecture's Fisheries and Marine Technology Center spread from 513 m^2 to 6,722 m^2 (about 0.67 ha) (fiscal 2006 → fiscal 2015. Supplementary planting was done in fiscal 2008–09. Area from observation from the air. The prefecture's own report, one site, with no statement of cost). [S14]

The national government's guidelines (2025) show that several methods of seed sowing and transplanting already exist. According to the guidelines, most of the creation of eelgrass beds so far has been done by seed sowing or transplanting without waiting for eelgrass to grow naturally, and transplanting has been done by divers planting by hand one shoot at a time. At Hiai in Kumamoto Prefecture, 47,000 shoots were planted in order to move a natural eelgrass bed (1,700 m^2) that would be buried by beach nourishment (works that widen a beach by putting in sand); they increased to about twice the number (a mean of 55 shoots per 1 m^2) in the 4th year, and remain stable even after 10 years. The guidelines further introduce the development of a technique for creating a wide area at once by loading seeds into huge sheets, and of mechanical transplanting in which eelgrass is taken together with the sediment using a special bucket and moved. [S1]

The limits are the proportion of successes and the cost. Of 1,786 seagrass restoration trials around the world, about 37% were estimated to have lasted about 3 years (a conservative estimate looking trial by trial). The greater the number of shoots or seeds first planted, the higher both the proportion surviving and the speed of increase (55% of the trials were under 1,000). The authors recommend, after carefully choosing the site and the species, planting on a larger scale than those doing the planting expect. They also write that planting on a large scale involves costs for materials and work, but state that there is also a possibility that the value of the functions of the beds brought back will eventually make up for and exceed those costs (a citation of another study). In 235 coastal restoration projects, the median cost per 1 ha was about 80,000 US dollars (2010 values, the whole of five ecosystems, abstract only checked. The total cost is 2 to 4 times that), and seagrass, alongside coral reefs, was a high-cost ecosystem. The authors of this study also write that the proportion of successes reported in papers may be biased because successes are more readily published than failures (checked in the abstract). [S16]

Even if a created bed grows, the surrounding natural beds do not necessarily come back. Off Iwakuni City (Yamaguchi Prefecture), the habitable area (the area in which eelgrass is able to grow) of the creation zone has reached the target of about 3 ha, and shoot density and cover fluctuate in roughly the same way as in the natural bed used for comparison (the control plot) (the achievement of the target is due to be evaluated in fiscal 2026). On the other hand, the surrounding natural eelgrass beds have remained almost entirely gone since the typhoons of 2004, and the width of the distribution in July to December 2025, taking June 1997 as 1, is around 0.0–0.4 on the northern survey lines and around 0.0–0.2 on the southern ones. [S7]

There is also a case in which the beds came back widely without planting, by reducing water pollution. In Chesapeake Bay in the United States, the concentration of nitrogen fell by 23% from 1984 onwards, and about 17,000 ha of beds of underwater plants (including freshwater species) came back (the relationship with nitrogen is an estimate by a model. The eelgrass of the same bay decreased by a further 29%). [S16, S8]

In the world's records too, there is recovery after water quality was improved. Of the 215 sites with records, the area increased at 25% of the sites, and at 11 of those sites this is attributed to improvement of water quality and restoration of the habitat. In Tampa Bay and the Wadden Sea too, recovery after reducing nutrients (the nitrogen and phosphorus that are nourishment for seaweeds and the like) is recorded, while it is also said that such recovery may be an exception in the world. [S13]

Public support and regional plans

The national government's support for activities amounts to 1.35 billion yen in the government's draft budget decision for fiscal 2026 (the whole programme. It includes tidal flats, ensuring safety at sea and so on), and the target is to bring the conserved area of seaweed and seagrass beds to 6,200 ha by fiscal 2029 (in fiscal 2021 more than 400 activity groups were active over about 58,000 ha, but this is the area covered by activities for seaweed and seagrass beds and tidal flats under the programme for bringing out the multiple functions of fisheries and other schemes, not the area recovered). [S6]

The achievement rates of regional plans also need to be read with an eye to the conditions. The interim evaluation (March 2024) of the Hiroshima Bay Restoration Promotion Council stated that the shallow areas, such as tidal flats and seaweed and seagrass beds, conserved and restored in Hiroshima Bay had reached a cumulative 66.8 ha by the end of fiscal 2022, reaching 216% of the target (about 30 ha). However, the target of 30.9 ha is the 28.5 ha that already existed at the time the plan was made (fiscal 2016) with a new 2.4 ha added. What was newly conserved or developed from fiscal 2017 onwards is 38.3 ha, which also includes dredging (scooping up mud and sand from the seabed) and projects on the Yamaguchi Prefecture side, and is not the area of seaweed and seagrass beds alone (the area for each single year has tended to decrease after fiscal 2016, and it is stated that the target will not be raised). [S22]

J Blue Credits

J Blue Credits are voluntary credits, not a national government scheme. The Japan Blue Economy Association (JBE), which was established in July 2020 with the establishment approval of the Minister of Land, Infrastructure, Transport and Tourism, examines applications independently and certifies, year by year, the amount of CO2 regarded as remaining for 100 years or more in seaweed and seagrass beds and the like. However, the guidance (March 2026) treats security against the danger of the CO2 returning (a buffer) as "basically unnecessary", and does not regard it as an emission even if the beds decrease in the following year. Additionality (whether the effect arises only because the credit exists) is defined as "obtaining the credit leads to the maintenance or development of the activity", which is looser than the general definition, and the guidance too acknowledges that there is room for debate. It states that it conforms to the thinking of the international quality principles (the Core Carbon Principles of the ICVCM), but it does not appear in the ICVCM's list of assessments (October 2026) (acceptance of applications is due to resume in April 2027). [S17, S18]

The amounts are small and are concentrated in a small number of projects (Table 3). Issuance is a cumulative 12,406.5 t-CO2 (fiscal 2020 to 16 October 2026. This paper's total, including tidal flats and seaweed aquaculture); in fiscal 2022–25 it was about 2,200–3,700 t a year, and the top 3 projects account for about 64% (this paper's calculation). For the amount sold, only the portion in JBE's public offerings has been published (1,387.1 t and about 88.9 million yen excluding tax in the 10 result announcements from March 2022 to June 2026. This paper's total). The amount sold in the public offerings corresponds to about 11% of cumulative issuance (this paper's calculation), but this is a ratio of amounts from different periods, and the rest is not necessarily unsold. For bilateral transactions (transactions decided directly between seller and buyer) and use by the holder's own company, neither amounts nor prices have been published. The average unit price in the public offerings is 11,494–99,051 yen/t excluding tax per result announcement (82,465 yen in fiscal 2025), and there was also a round in which 1,444.0 t was offered and 127.3 t was sold. [S17, S19]

Table 3 Amounts and prices of J Blue Credits and international blue carbon credits

Item	Value	Conditions
Issuance of J Blue Credits [S17]	Cumulative 12,406.5 t-CO2	Fiscal 2020 to 16 October 2026. Includes tidal flats and seaweed aquaculture. This paper's total of the published values for each round
Amount sold in JBE's public offerings [S17]	1,387.1 t-CO2 (about 88.9 million yen excluding tax)	This paper's total of the 10 result announcements from March 2022 to June 2026. About 11% of cumulative issuance (a ratio of amounts from different periods)
Average unit price in JBE's public offerings [S17, S19]	11,494–99,051 yen/t excluding tax (82,465 yen in fiscal 2025)	Average per result announcement
Public offering of fiscal 2025 [S19]	328.5 t-CO2 (average 82,465 yen/t excluding tax)	A cumulative 123 purchasers. The public offering portion only; bilateral transactions are not included. The figures are from JBE (a material of the Ministry of Land, Infrastructure, Transport and Tourism)
Average unit price of public offering transactions [S9]	About 400 US dollars/t	Public offering transactions of the portion certified in 2021–2025 (471 transactions, 1,081 t). Converted at 1 US dollar = 145.96 yen. A paper by JBE researchers
Blue carbon credits in international registries [S9]	Issued about 6.96 million t-CO2; retired (the portion used and cancelled) about 3.65 million t-CO2	2014 to 15 March 2025. The domestic schemes of Japan and Australia are not included. Includes the portion for emissions avoided through conservation. Of the 81 projects assessed (March 2025), mangroves are 72 projects with 99% of the estimated reductions, and seagrass is 4 projects. 69% of the issuance is one project in Pakistan
Published prices of international blue carbon credits [S9]	5–35 US dollars/t	The small number of projects for which the price is known
Reference: forest J-Credits (credits of a scheme separate from J Blue Credits, which can be used in the mandatory emissions trading scheme [GX-ETS] from fiscal 2026) [S19]	About 5,000 yen/t	Tokyo Stock Exchange, end of fiscal 2025 (a footnote in the material of the Ministry of Land, Infrastructure, Transport and Tourism)

Compared with international credits, the amounts are small and the level of the unit price is very different. The cumulative issuance of J Blue Credits is about 0.2% of the amount of blue carbon credits issued in international registries (a ratio of amounts from different periods, this paper's calculation), and the average unit price of the public offering transactions (about 400 US dollars/t) is at a very different level from the international published prices (5–35 US dollars/t) (the projects for which international prices are known are few, and both the schemes and the ecosystems covered differ). [S9, S17]

The "about 69,000 to 83,000 yen per 1 t" found in some materials (including past materials of the publisher of this paper) is a range that joins the average of the most recent 2 years of JBE's public offerings (69,000 yen excluding tax, as of 29 June 2026) and the average of the 2 rounds announced on 23 March 2026 (83,035 yen excluding tax). Both are prices in JBE's public offerings, and are not the transaction price of the market as a whole. JBE carries out the public offering procedure as part of research and development and demonstration trials for building a funding mechanism that uses credits. The fee for certification and issuance is 110,000 yen

including tax (a fixed amount) without a public offering, and with a public offering too it is deducted from the proceeds; holding is limited to corporations in Japan, and resale is not possible. [S17]

The income is small, and a paper by JBE researchers (2026) states that one transaction is 2.3 t on average and that the income often cannot cover the costs (what was sold is about 30% of the amount put up for public offering. This paper's calculation). [S9] For the 0.871 ha of eelgrass beds at Ninoshima in Hiroshima City (the applicants are the Hiroshima City Fishery Cooperative and Hiroshima City), 2.6 t was certified for fiscal 2025 (October 2026. Previously it was 2.4–6.4 t a year, and in some years the scope covered was different). If the whole amount were sold at the average unit price of the fiscal 2025 public offering, it would be about 210,000 yen excluding tax (before fees, this paper's trial calculation). It cannot be used in Phase 2 of the GX-ETS (the mandatory emissions trading scheme), which began in fiscal 2026. [S17, S19]

The other project in Hiroshima Prefecture, that of Onomichi City and the Urashima Fishery Cooperative, is on a scale of 75.8–130.7 t per round for tidal flats and eelgrass beds combined. For the four tidal flats (completed in 1989–2020) that the national government (the Chugoku Regional Development Bureau) built with dredged soil, a total of 387.3 t (including the tidal flat portion. This paper's total) has been certified in four rounds so far. In the most recent application (the portion for September 2024 to August 2025), the 41.87 ha of eelgrass beds was multiplied by a coefficient (1.72 t per 1 ha per year) that the applicants calculated from research examples in the Seto Inland Sea and a national government report, giving 72.0 t. This was discounted, as an assessment of certainty, by multiplying the area by 95% and the coefficient by 85%, and after subtracting the emissions of the boat used for the survey (0.37 t) and the portion for the eelgrass beds that existed before the creation (16.7 t, a value after the same discount), the portion for the seaweed and seagrass beds was 41.1 t; in addition the tidal flat portion was 34.8 t, for a total of 75.8 t. [S17]

The application document for this project gives, as the reason for applying for credits, the need for funds to continue and widen the upkeep of the tidal flats and the seaweed and seagrass beds. A grant from the Fisheries Agency is used for the activities, and Onomichi City is also working on them as one part of its fisheries promotion, but the document states that there is a shortage of labour due to ageing. The credits of this project are shown to have been sold in five result announcements of JBE's public offerings (July 2023 to March 2026) (this paper counted the rounds in which this project appeared in the list of purchasers). The unit prices in the result announcements are only the averages for each announcement, including other projects, and for these five rounds they were 11,494–99,051 yen/t excluding tax (the highest is the round announced in July 2023 and the lowest is the round announced in November 2023, and in the latter a total of 87.0 t from three projects was 1 million yen). The result announcements do not show a unit price for this project alone. [S17]

4. What is changing

Seaweed and seagrass beds have come into both kinds of system, the plans for biodiversity and fisheries and the accounting and crediting of carbon, but much of this is at the stage of plans, projections and drafts (as of 1 November 2026). Of the items dealt with in this chapter, those that have come into force as laws relating to the conservation and restoration of seaweed and seagrass beds are two: the amendment of the Seto Inland Sea Act (2022) and the Act on Promoting Regional Biodiversity (2025). Phase 2 of the GX-ETS (the mandatory emissions trading scheme), which began in fiscal 2026, is also a scheme based on the GX Promotion Act (a law to advance the transition to decarbonisation) as amended in 2025, but J Blue Credits cannot be used in it (Chapter 3). [S19] The rest are plans and projections decided by the Cabinet, the national accounting (the inventory), IPCC guidelines and decisions, national subsidy programmes, voluntary mechanisms, drafts and the like.

Plans for biodiversity and fisheries

- 25 March 2022: The Cabinet decides the Long-term Plan for the Development of Fishing Ports and Fishing Grounds (fiscal 2022–26, with fiscal 2026 as the final year. Measures for about 7,000 ha of seaweed and seagrass beds, which is not an area of increase) and the current Basic Plan for Fisheries. The Basic Plan for Fisheries treats seaweed and seagrass beds as important also as a sink for CO2, and states that monitoring over wide areas and the development of methods for assessing CO2 fixation by beds, with seaweeds as the subject, will be advanced. [S6]
- April 2022: With the entry into force of the amended Seto Inland Sea Act, prefectures became able to make management plans for nutrients, and restored seaweed and seagrass beds too became able to be designated as natural seashore conservation areas (zones that prefectures designate by ordinance in order to protect natural sandy beaches and the like that have decreased through past development and other causes). In the Ministry of the Environment's table of the state of designations (as of December 2022), all the designations date from 1980–93, and we found no example of the designation of a restored or created bed (not checked after that). [S20]
- 31 March 2023: The Cabinet decides the National Biodiversity Strategy 2023-2030 (not a law). It sets out "nature positive", halting and reversing the loss of biodiversity by 2030, and states that the conservation, restoration and creation of seaweed and seagrass beds, tidal flats, coral reefs and the like will be pursued. [S23]
- April 2025: With the entry into force of the Act on Promoting Regional Biodiversity, the nature coexistence sites (shizen kyosei sites), which began in fiscal 2023 as a certification by the Minister of the Environment, become a statutory scheme (under the law, the three ministers for the environment, for agriculture, forestry and fisheries, and for land, infrastructure, transport and tourism certify the plans of companies, municipalities and others for activities that maintain, restore or create biodiversity). Including those under the previous scheme, there were 700 sites as of October 2026. Those including "seaweed and seagrass beds and rocky reefs" (not a category for seaweed and seagrass beds alone) were, in the most recent three rounds for which numbers by type were shown (March, June and October 2026), 4 of 108 sites, 2 of 56 sites and 3 of 122 sites; the materials for the rounds before that have no numbers by type, and the cumulative total could not be confirmed from published materials. [S20]
- February 2026: The interim evaluation of the national strategy is published (a liaison conference of the 12 ministries and agencies concerned evaluated the state of implementation up to June 2025. It is not an evaluation of seaweed and seagrass beds alone). It stated that, while almost all of the action targets (targets for actions to be taken by 2030) had advanced, progress had been made on slightly under half of the state targets (targets for the state to be achieved by 2030), and that Japan's biodiversity as a whole continues to be lost. As reasons, it gives the fact that actions take time to have an effect and that the scale and other aspects of the actions were not sufficient. [S23]
- 20 April 2026: The Minister of Agriculture, Forestry and Fisheries consults the council on the next Basic Plan for Fisheries (a Cabinet decision is planned for late March 2027). [S6]
- 3 August 2026: On 30by30 (the target of conserving 30% or more of land and sea by 2030), it is announced that the proportion of protected areas and OECMs (zones outside protected areas that serve the conservation of biodiversity. The zones of nature coexistence sites that do not overlap with protected areas are registered, a total of 64.6 thousand ha) combined is 21.0% for land and 13.3% for sea (apparently unchanged from the previous fiscal year. The proportion of OECMs within the sea figure is not shown). The protected areas at sea are counted as including, besides natural parks, protected waters (zones for protecting fishery resources), common fishery right zones (zones in which fishery cooperatives and others fish in common) and others, and they are not the area of seaweed and seagrass beds. [S23]

- 9 October to 9 November 2026: Public comments are being invited on the preliminary draft of Hiroshima Prefecture's nutrient management plan. It considers total nitrogen to be under 0.2 mg/L (a value at which productivity is regarded as low) in 6 of the 8 water areas, and is a proposal to increase nutrients through the operation of 33 facilities, such as sewage treatment plants, roughly from October to March. The target organisms are oysters, wakame and nori (laver), and seaweed and seagrass beds are included neither in the target organisms nor in the targets (they only appear in the explanation of the background). [S20]

Carbon accounting and credits, and corporate disclosure

- October 2013: The IPCC adopts the wetlands guidelines (published in 2014. The source of the default value in Table 1). The chapter on coastal wetlands covers seagrass beds, mangroves and wetlands subject to the ebb and flow of the tide, and does not deal with seaweeds (macroalgae). [S12]
- April 2024: The inventory records the amount absorbed by seaweed and seagrass beds for the first time (about 350,000 t for fiscal 2022; about 315,000 t in the 2026 recalculation). [S3]
- 18 February 2025: A related document of the Plan for Global Warming Countermeasures, decided by the Cabinet, projects the amount absorbed by blue carbon at 1 million t in fiscal 2035 and 2 million t-CO2 in fiscal 2040 (not an obligation. By this paper's calculation, about 3 times that of fiscal 2024. The accounting methods are described as "with some exceptions, including some that are not established"). The projection is to be made concrete in future follow-up, and the means also include an initiative to grow seaweed offshore and sink it in the deep sea (at the stage of "examining the possibility"). [S19]
- October 2025: The IPCC decides at its plenary session (Lima, Peru, 27–30 October) to produce a methodology report on national accounting for carbon dioxide removal (adoption is planned for the latter half of 2027). The instructions to the authors give tidal flats and seaweeds (macroalgae) as examples of coastal wetlands not dealt with in the guidelines so far. Whether seaweeds will enter the accounting methods has not been decided. [S12]
- Fiscal 2026: Phase 2 of the GX-ETS (the mandatory emissions trading scheme) begins. The material of the Ministry of Land, Infrastructure, Transport and Tourism notes that J Blue Credits are voluntary credits different from the J-Credits that can be used in this phase, and they cannot be used (Chapter 3). [S19]
- June 2026: The Ministry of the Environment selects 5 projects in its subsidy programme for large-scale demonstration of blue carbon (the first call ran from 27 March to 30 April and covered blue carbon only. There were 7 applications). All 5 are projects for seaweed aquaculture or for creating seaweed beds, and there is no project for seagrasses such as eelgrass. We have not checked the results of the second call (10 July to 17 August, also covering things other than blue carbon). [S19]
- September to October 2026: Verra, an international body that operates credits, invites comments on a draft revision of the methodology for the restoration of tidal wetlands (wetlands subject to the ebb and flow of the tide) and seagrass beds (VM0033) (3 September to 5 October). It is a draft that in principle excludes beds that were there originally (they need not be excluded if they are under 5% of the project area) and puts the portion by which they spread naturally into the baseline (the portion that would occur even without the project), and it has not yet been adopted. The draft revision also lists as covered activities that reduce the inflow of nitrogen and the like to make the water clearer and widen seagrass beds. The current version (v2.1, from September 2023) does not cover seaweed beds, and in the ICVCM's assessment table (updated August 2026) it is under assessment and does not yet have high-quality (CCP) approval. [S18]
- October 2026: The ISSB (International Sustainability Standards Board) issues an exposure draft on the disclosure of nature-related information (the deadline for comments is 19 February 2027). Its form is not a standard but a practice statement (guidance used voluntarily); an entity can state compliance with the standards without following it, and whether to use it depends on the company's own choice or on each country's regulation. The framework of the TNFD (Taskforce on Nature-related Financial Disclosures), on

which it is based, was published in September 2023, and the number of Japanese companies that have declared disclosure in line with it is 233 (as of 14 July 2026. The number of declarations, not the number that have disclosed). [S24]

5. What is not yet known

Things for which there are no figures

- We found none of the following: the current area of eelgrass beds in Hiroshima Prefecture (the Ministry of the Environment's satellite survey does not separate eelgrass beds from seaweed beds), the area of beds that have recovered nationwide, a Japanese public figure for the cost of bringing back 1 ha of bed, a comparison of cover for the activity groups of Hiroshima Prefecture (no group from Hiroshima Prefecture is among the 122 groups compared in the survey commissioned by the national government), and the area of Sargassum beds that have grown on the propagation grounds of Hiroshima Prefecture. [S5, S7, S14]
- The size of the past decrease nationwide is not known. The 4th survey does not count deep places or small beds, and the guidelines also contain a statement, with no source given, that about 8,000 ha disappeared in the 1990s in the waters off Omaezaki in Shizuoka Prefecture alone. [S4, S1]
- We found no public value that actually measured the amount of carbon buried in the eelgrass beds of the Seto Inland Sea (the national coefficients are model values), and we could not check the original source of the multiple in the statement that "seagrasses absorb carbon many times faster than forests". [S3]
- We also found no public statistics linking the area of seaweed and seagrass beds in Hiroshima Prefecture with the fish catch (the national government's ex-ante evaluation document contains benefit values in which the increase in fish was calculated by a model). [S14]
- We also found no public record that eelgrass decreased in Hiroshima Prefecture because of high water temperature (treating the shift to an annual form at Ikuno Island as an effect of climate change is the reporter's own assessment). [S15]
- We also found no statistics showing how far corporate nature-related disclosure (TNFD and the like) leads to funding for seaweed and seagrass beds. [S24]

Limits of the comparisons

- We found no Japanese public data comparing places where restoration or conservation was done with places where it was not, and it is not known which method works, and how well, in proportion to the labour (the 122 groups, Shiraura and so on). [S1, S7]
- Every series of area mixes methods (in the same areas the satellite value is 25–112% of the interview value. The satellite criteria have also changed), and neither the size of the past decrease nor the direction of recent increases and decreases is certain. [S5]
- The portion due to seed sowing in the recovery at Hinase is unknown. [S8]
- Because the national amount absorbed counts the whole of the natural beds by a model, individual plantings appear in the national amount absorbed only to the extent that they change the estimate of the area of beds nationwide (this paper's interpretation). [S3]

Figures that disagree

- The area of seaweed and seagrass beds nationwide in 1990 differs by about 1.6 times between the 4th survey and the inventory (this paper's calculation. The reason is not stated). [S3, S4]

- Even within the document on the inventory's accounting methods, the main text gives the current area of beds as "about 160,000–170,000 ha (the most recent assessed value)", which does not agree with the 146,179 ha for 2024 in a table of the same document (the reason is not stated). [S3]
- The guidelines show the causes of the beds that disappeared in the 4th survey by area as well, but their total (6,907 ha) does not agree with the area lost in the report (6,403 ha) (the proportions in the breakdown match the ratios to 6,907 ha, and the reason is not stated). [S1, S4]
- The amount of phosphorus taken up in the guidelines is, in the main text, 7.8–8.5 g per 1 m^2 per year for kombu kelp beds, arame kelp beds and Sargassum beds, but in the table of the same guidelines Sargassum beds are 6.98 g, which does not fall within the range in the main text (the about 10.34 million to 12.58 million yen per year per 1 ha in Chapter 2 is based on the values in the table. The reason is not stated). [S1]
- The carbon coefficient for eelgrass beds is 4.9 t and 1.72 t per 1 ha per year in the two credit projects in Hiroshima Prefecture, a difference of about 2.8 times (this paper's calculation). The 4.9 for Ninoshima is the mean of the nationwide estimate of Kuwae et al. (2019), and is the carbon that increases within the ecosystem. Its definition differs from that of the inventory's coefficient for 100-year storage in the Seto Inland Sea (2.32), and even after JBE's discount (70%) it is about 1.5 times (this paper's calculation. We do not judge which is appropriate). [S17, S11, S3]
- For the carbon of seaweeds, there is a rough estimate (2016) that about 170 million t a year in weight of carbon (range 60 million to 270 million t) could remain for a long time, and a model (2024, with a different pathway) in which what remains in the deep sea for 100 years or more is 4 million to 44 million t a year, and there is also an analysis (2022) that seaweed ecosystems may, on the mean of 18 cases, be on the releasing side. The authors of this analysis also acknowledge that the data are few and the scatter is large, and because the margin of error is larger than the mean, it cannot be decided statistically whether there is absorption or release (this paper's interpretation). [S11]

Data unfavourable to new means

- There are cases in which beds came back without planting, and large successful cases of seed sowing (Chapter 3). What decreased greatly is the seaweed beds of rocky shores (the inventory's estimate), and planting eelgrass does not stop this decrease (this paper's interpretation).
- At one restoration site in the US state of Virginia, which the authors treat as a large successful case, the present effect after subtracting methane and the like was 0.42 t per 1 ha per year (the main text writes weight of carbon and the abstract writes CO2 equivalent, so the units disagree). The authors treat this as almost the same as the IPCC default value (Table 1. 0.43 t in weight of carbon) and lower than temperate and tropical forests, and calculate on a trial basis that at 10 US dollars per 1 t it would be about 10% of the restoration cost (this depends on the price assumption. The level is very different from the unit price of the J Blue Credit public offerings. Table 3). [S8, S12]
- There is a review article (2022; it covers mangroves, seagrasses and salt marshes, and does not deal with seaweeds) that regards the removal of CO2 by restoration as uncertain and of low reliability. As reasons it gives 7 points, including the variability of burial rates and the errors in measuring them, the carrying of carbon to the outside, the generation of methane and the like, and vulnerability to climate change and human activity, and it states that it can take 10–20 years for the burial rate of a restored site to catch up with that of a mature site (a citation of another study). The same review article also states that restoration is of great help for adaptation to the climate, coastal protection, food and biodiversity. [S9]
- Most of the international credits are mangroves, and of the 81 projects in the registries (March 2025), seagrass accounts for 4 (Table 3). [S9]

Reliability and the standpoint of the sources

Reliability is medium for the function as a home and for the direction in which the seaweed beds of rocky shores are decreasing; low to medium for carbon per 1 ha, the size of the nationwide decrease, and the large decrease in the Seto Inland Sea before 1990 (which includes values whose original source cannot be checked); and low for the Seto Inland Sea from 1990 onwards.

There is also a bias in the standpoint of the sources. The analysis of credits relies on JBE's paper (S9. All the authors belong to JBE, and they declare no conflict of interest), the lead author of the carbon coefficient (Kuwae et al. in S11) is the current chair of the board of JBE, the area model of the inventory is also that of the same Port and Airport Research Institute, and the table in the Ministry of the Environment's explanatory page (S10) is also based on JBE's materials. Shiraura and Hinase are figures from the side that carried out the activities, and many of the authors of the Akashi City paper belong to a construction company.

The publisher of this paper (SeatecHIROSHIMA Ltd.) runs a business related to the restoration of seaweed and seagrass beds, and is in a position that may compete with the existing measures covered in this paper. This paper does not cover the company's own technology or results. Of the organisations taken up in this paper, with Hiroshima Prefecture there is the relationship of having been selected in fiscal 2022 and fiscal 2023 for the prefecture's startup support programme "HIROSHIMA UNICORN 10". The Japan Blue Economy Association (JBE) is an organisation that Imai, the co-representative CEO, named as a candidate collaborator (not yet arranged) in an application for research to a research hub of Tohoku University (nature positive) in October 2026. There are no business dealings or buying or selling of credits with JBE, the Hiroshima City Fishery Cooperative, or the credit projects of Ninoshima and Onomichi.

6. Sources

Materials up to 1 November 2026. Reliability: A = laws and regulations, government materials; B = papers, reports, records of schemes; C = explanatory materials, records of organisations, trial calculations quoted indirectly; D = trade magazines.

ID	Source (publisher, year)	Type	Reliability	Chapters used
S1	Fisheries Agency: Guidelines on measures against barren ground (isoyake), third edition (2021; chapter-by-chapter version: Chapter 7; Chapter 8); Guidelines for fishing port facilities of the seaweed and seagrass bed creation type (2025) (in Japanese). Includes Shiraura (an NPO's record, C) and Nagoya and Oshima (fishers' records, B)	Guidelines	A	Chapters 1–3, 5
S2	Lefcheck et al. (2019, abstract only); Konuma et al. (2020)	Paper	B	Chapters 1, 2
S3	Ministry of the Environment and others: inventory; accounting methods (2026); announcement (2024); Port and Airport Research Institute: material (2024) (in Japanese)	Estimate	A	Chapters 1, 2, 4, 5
S4	Environment Agency: analysis and general summary of the 4th basic survey (1994); Ministry of the Environment: results of the seaweed and seagrass bed survey (fiscal 2018–20) (2021); website of the seaweed and seagrass bed survey (on the use of the results) (accessed 2026) (in Japanese)	Survey	A	Chapters 1, 2, 5
S5	Ministry of the Environment: Setouchi Net; present state of land reclamation; survey of the distribution of seaweed and seagrass beds and tidal flats (central part 2017; 2018; 2024; table) (in Japanese)	Survey	A	Chapters 1, 2, 5

ID	Source (publisher, year)	Type	Reliability	Chapters used
S6	Fisheries Agency: Vision for Seaweed and Seagrass Beds and Tidal Flats (2023); Long-term Plan (2022); Basic Plan for Fisheries (2022); council materials (consultation; schedule) (2026); Ministry of Agriculture, Forestry and Fisheries: budget (2026) (in Japanese)	Plan	A	Chapters 1–4
S7	JF Zengyoren (National Federation of Fisheries Co-operative Associations) and others (commissioned by the Fisheries Agency): survey report; Ministry of Defense: Iwakuni committee (2026) (in Japanese)	Report	B	Chapters 1, 3, 5
S8	Orth et al.; Oreska et al. (2020); Hori and Sato (2021) (for Hori and Sato, abstract only)	Paper	B	Chapters 1, 3, 5
S9	Kuwae et al. (all belonging to JBE) (2026); Farahmand et al. (2025); Williamson and Gattuso (2022)	Paper	B	Chapters 1, 3, 5
S10	Ministry of the Environment: What is blue carbon (accessed 2026; the table is based on JBE's materials); case examples of initiatives for seaweed and seagrass beds and tidal flats (2020) (in Japanese)	Explanatory	C	Chapters 1–3, 5
S11	Duarte et al.; Fourqurean et al.; Kuwae et al. (the lead author is the current chair of the board of JBE) (in Japanese); Krause-Jensen et al.; Gallagher et al.; Filbee-Dexter et al. (2005–24, abstract only for some)	Paper	B	Chapters 2, 5
S12	IPCC: wetlands guidelines, Chapter 4 (2014); Special Report on the Ocean and Cryosphere, Summary for Policymakers (2019); plenary decision IPCC-LXIII-6 (2025)	Guidelines	A	Chapters 2, 4, 5
S13	Waycott et al. (2009); Krumhansl et al. (2016); Dunic et al. (2021)	Paper	B	Chapters 1–3
S14	Hiroshima Prefecture: vision for seaweed and seagrass beds; prefectural plan; outline of projects; white paper on the environment; Fisheries Agency: ex-ante evaluation document (2005–26) (in Japanese)	Plan	A	Chapters 1–3, 5
S15	Tanaka et al. (2025); Ministry of the Environment: Monitoring Sites 1000 preliminary report (2026) (in Japanese)	Paper	B	Chapters 2, 5
S16	van Katwijk et al.; Bayraktarov et al. (2016); Lefcheck et al. (2018); Eger et al. (2022) (abstract for some)	Paper	B	Chapters 1, 3
S17	JBE: certifications (fiscal 2020; fiscal 2021; fiscal 2026); register; public offering results (March 2022; February 2023; July; November; March 2024; May; March 2025; June; March 2026; June); fees; guidance; FAQ; application documents (Ninoshima; Onomichi) (in Japanese) (2021–26)	Record	B	Chapters 3, 5
S18	ICVCM: list of assessments (2026); Verra: VM0033 v2.1; draft revision v3.0 (2023–26)	Record	B	Chapters 3, 4
S19	Ministry of Land, Infrastructure, Transport and Tourism, Ports and Harbours Bureau: study group material (2026); Ministry of the Environment: Plan for Global Warming Countermeasures, related document 3 (2025); selection results of the large-scale demonstration; start of the second call (2026); Ministry of Economy, Trade and Industry: Emissions Trading Scheme Subcommittee, interim summary (draft) (2025) (in Japanese)	Policy	A	Chapters 3, 4
S20	Ministry of the Environment: Seto Inland Sea Act; Setouchi Net, state of designations of natural seashore conservation areas (as of December 2022); Act on Promoting Regional Biodiversity; nature coexistence sites (materials for each round of certification: March 2026; June; October); Hiroshima Prefecture: preliminary draft of the nutrient plan and invitation of comments (2021–26) (in Japanese)	Law	A	Chapters 2, 4
S21	Science Council of Japan: report; annex (trial calculation by the Mitsubishi Research Institute) (2004, posted on the Fisheries Agency website. The figures are an indirect quotation of the trial calculation) (in Japanese)	Report	C	Chapter 2

ID	Source (publisher, year)	Type	Reliability	Chapters used
S22	Hiroshima Bay Restoration Promotion Council (the secretariat is the Chugoku Regional Development Bureau of the Ministry of Land, Infrastructure, Transport and Tourism, and others): Hiroshima Bay Restoration Action Plan (second term) (2017); 2nd interim evaluation (2024) (in Japanese)	Plan	A	Chapters 2, 3
S23	Ministry of the Environment: National Biodiversity Strategy 2023-2030 (2023); White Paper on the Environment (2026 (Reiwa 8) edition) (2026); 30by30 an - nouncement (2026) (in Japanese)	Plan	A	Chapter 4
S24	Ministry of the Environment: Nature Finance Practical Guidelines (in Japanese) (2026); ISSB: exposure draft on nature-related disclosures (Basis for Conclusions) (2026)	Guidelines	A	Chapters 4, 5
S25	Okayama Prefecture: eelgrass bed restoration activities (trends in the prefecture's eelgrass bed area) (in Japanese) (accessed 2026. The graph runs to 2020)	Record	A	Chapter 2

Related materials: R3-1 Oyster mortality (die-off), R3-2 Fouling organisms on oysters, R3-3 The workforce and manual work of oyster aquaculture, R4-1 The disposal of rice husks, R4-2 Replant failure (continuous-cropping injury) and soil improvement, R4-3 Abandoned farmland, R6 What is changing (why now), R7-A03 The decrease in the eelgrass beds of Nanao Bay, R7-A04 The decline of the Sargassum beds of Nanao Bay, R7-A26 The suspension of activities to restore eelgrass beds (the earthquake), R7-B08 Shallow seaweed beds dried out by uplift, and the decrease in the area of seaweed beds in Sotoura, R7-B10 The decline of the offshore-side seaweed beds of the Sotoura coast of Suzu (tsunami or winter waves), R7-B11 Barren ground (isoyake) that has continued since before the earthquake, and the decline of the seaweed beds of the offshore islands, R7-B26 Rebuilding the local activities that protect the seaweed beds of Wajima, R7-C11 Uwa Sea: barren ground (isoyake) and the decrease of seaweed and seagrass beds, R7-C32 Seto Inland Sea side: the decline of the tidal flats of Hiuchi-nada and the decrease of Manila clams and swimming crabs, R7-C33 Seto Inland Sea side: the decrease of seaweed and seagrass beds (Hiuchi-nada and the islands), R7-D08 The shrinking of the eelgrass beds of Mikawa Bay, R7-D09 The decline of the rocky-reef seaweed beds of the southern Chita Peninsula and of Shinojima and Himakajima (barren ground of sagarame and arame kelps), I1 List of assessments