R7-A04 The decline of the Sargassum beds of Nanao Bay

Since when, and by how much, have the beds of Sargassum species (Sargassum beds) of Nanao Bay decreased? What happened after the earthquake, how reliable are those values, and what has been given as the reasons?

Readers

Fishers and fishery cooperatives, local governments (staff in charge of fisheries and the environment), research institutions and others without specialist knowledge, who want to check, with figures and sources, how much the Sargassum beds of Nanao Bay have decreased, how reliable the values after the earthquake are, and what is thought to be the reason.

Takeaways

1. Sargassum beds are seaweed beds where large seaweeds called Sargassum species grow thickly. In the prefecture's table, the Sargassum beds of the Nanao Bay district went from 1,473 ha to 508.4 ha, and those of the Anamizu Town district from 780 ha to 338.9 ha. What was compared is the national government's survey of around 1990 and the prefecture's survey of fiscal 2018. The prefecture states that, because the methods differ, they cannot simply be compared. On that basis, it judges that a tendency to decline is seen on the inner side of the bay.
2. At the head of the West Bay, the Sargassum beds went from 44 ha to 6 ha (a comparison of the surveys of 1990 and December 2011). On the Uchiura coast of the Noto Peninsula as a whole, the depth to which Sargassum beds extend went from about 20 m to about 10 m. The prefecture takes the view that the beds have declined in deep places. The Ishikawa Prefecture record of the national government's survey of around 1990 also wrote that the Sargassum species inside the bays already showed a tendency to decrease.
3. The area after the earthquake was measured by the Kanazawa Association of Corporate Executives, a business association, from a satellite image of 14 March 2025. The Sargassum beds of the Nanao Bay district were 733 ha, a value 44.6% larger than the previous 507 ha. The Anamizu Town district also increased, from 324 ha to 485 ha. The previous values are the prefecture's fiscal 2018 survey as recalculated by the report. Because the timing and resolution of the images and the timing of the field surveys differ, the increase cannot be said to be, as it stands, an actual change.
4. The reason for the decline is not clear. The prefecture lists rising water temperature, turbidity of the sea and the fine mud that settles on the seabed (fluid mud) as candidate reasons. On feeding damage by fish that eat seaweed, the national government described it in 2023 as a "concern" and published a photograph of a bed eaten by rabbitfish (aigo). The prefecture states that the feeding damage that has been confirmed is not of an amount that would lead to the decline of the beds. We found no public material that describes Nanao Bay as "barren ground (isoyake)".
5. In fiscal 2006–2022, the prefecture built enhancement grounds totalling 24.4 ha at 17 sites in Nanao City and Anamizu Town (this paper's calculation; this includes several sites that appear to be on the Nadaura side). We found no assessment showing how much Sargassum bed was formed. Since fiscal 2023, works to build 14 ha of beds of Sargassum species have been under way on the Uchiura coast of the Noto Peninsula. In fiscal 2026, 0.2 ha each will be built at Koda and Hidegashima on Notojima Island. A local fishers' group has also placed blocks fitted with bags that release the seeds of seaweed, and states that small seaweeds have attached to some of the blocks.

After reading

When using the area of the Sargassum beds of Nanao Bay in documents or plans, add the name of the district (the Nanao Bay district or Anamizu Town), the year of the surveys compared (around 1990, fiscal 2018, 2025) and the survey method (satellite images, or a survey of swimming to look),

and treat increases and decreases between values from surveys with different methods as a rough guide.

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

1. Key points

- Sargassum beds are seaweed beds where large seaweeds called Sargassum species grow thickly. In the prefecture's table, the Sargassum beds of the Nanao Bay district went from 1,473 ha to 508.4 ha, and those of the Anamizu Town district from 780 ha to 338.9 ha. What was compared is the national government's survey of around 1990 and the prefecture's survey of fiscal 2018. The prefecture states that, because the methods differ, they cannot simply be compared. On that basis, it judges that a tendency to decline is seen on the inner side of the bay. [S1, S6]
- At the head of the West Bay, the Sargassum beds went from 44 ha to 6 ha (a comparison of the surveys of 1990 and December 2011). On the Uchiura coast of the Noto Peninsula as a whole, the depth to which Sargassum beds extend went from about 20 m to about 10 m. The prefecture takes the view that the beds have declined in deep places. The Ishikawa Prefecture record of the national government's survey of around 1990 also wrote that the Sargassum species inside the bays already showed a tendency to decrease. [S3, S1, S6]
- The area after the earthquake was measured by the Kanazawa Association of Corporate Executives, a business association, from a satellite image of 14 March 2025. The Sargassum beds of the Nanao Bay district were 733 ha, a value 44.6% larger than the previous 507 ha. The Anamizu Town district also increased, from 324 ha to 485 ha. The previous values are the prefecture's fiscal 2018 survey as recalculated by the report. Because the timing and resolution of the images and the timing of the field surveys differ, the increase cannot be said to be, as it stands, an actual change. [S2, S8]
- The reason for the decline is not clear. The prefecture lists rising water temperature, turbidity of the sea and the fine mud that settles on the seabed (fluid mud) as candidate reasons. On feeding damage by fish that eat seaweed, the national government described it in 2023 as a "concern" and published a photograph of a bed eaten by rabbitfish (aigo). The prefecture states that the feeding damage that has been confirmed is not of an amount that would lead to the decline of the beds. We found no public material that describes Nanao Bay as "barren ground (isoyake)". [S1, S7, S11, S2, S14]
- In fiscal 2006–2022, the prefecture built enhancement grounds totalling 24.4 ha at 17 sites in Nanao City and Anamizu Town (this paper's calculation; this includes several sites that appear to be on the Nadaura side). We found no assessment showing how much Sargassum bed was formed. Since fiscal 2023, works to build 14 ha of beds of Sargassum species have been under way on the Uchiura coast of the Noto Peninsula. In fiscal 2026, 0.2 ha each will be built at Koda and Hidegashima on Notojima Island. A local fishers' group has also placed blocks fitted with bags that release the seeds of seaweed, and states that small seaweeds have attached to some of the blocks. [S1, S7, S12, S17]

2. What is happening

Japan and the world: Sargassum beds, and how Japan's seaweed and seagrass beds have decreased

Seaweed and seagrass beds are places in shallow seas where seaweeds and seagrasses grow thickly like a forest. They play an important role as places where fish and shellfish lay their eggs and where young fish grow. Among these beds, places where Sargassum species grow thickly are called Sargassum beds. Sargassum species belong to the large brown-coloured seaweeds (brown algae) and include many kinds, such as mametawara, yatsumatamoku and nokogirimoku. They are distinct from the beds of eelgrass (eelgrass beds), a seagrass that grows on seabeds of sand and mud; Sargassum beds form mainly on seabeds of rock and stone. [S16, S1, S21]

One survey in which the national government compiled the extent of Japan's seaweed and seagrass beds for the whole country is the 4th National Survey on the Natural Environment of the Environment Agency (now the Ministry of the Environment) (reported in 1994). This survey put the seaweed and seagrass beds of the whole country at 201,212 ha. By type, Sargassum beds were the largest, accounting for 27.1% (85,682 ha; the share is of a total of 315,876 ha, in which beds for which 2 or more types were shown were counted under each of those types). It states that 6,403 ha (3.2% of the beds) disappeared in the roughly 13 years since the previous survey. The reasons for the disappearance were direct alteration such as land reclamation at 28.1%, barren ground (isoyake) at 14.7%, other changes in the state of the sea and the like at 16.2%, and unknown at 40.6%. The report states that the causes of barren ground and of changes in the state of the sea are also unclear, and that together with the unknown share they come to 71.5%. [S6]

In this survey, Ishikawa Prefecture was one of the prefectures with extensive beds. The seaweed and seagrass beds of Ishikawa Prefecture were 14,761 ha, the 3rd largest by prefecture after the 43,167 ha of Hokkaido (21.5% of the national total) and the 19,969 ha of Aomori Prefecture. In this survey the sea of Ishikawa Prefecture was counted as a single sea area called "Noto Peninsula", and by sea area too it was the largest value, at 14,761 ha (7.3% of the national total). For Sargassum beds, Ishikawa Prefecture accounted for 13.8% of the national total, the largest by prefecture. These are values for the whole of Ishikawa Prefecture and the whole of the Noto Peninsula, not values for Nanao Bay alone. The survey in Ishikawa Prefecture was carried out in fiscal 1990–1991, and the prefecture states that the range surveyed was places shallower than a water depth of 20 m. [S6, S1]

In later surveys, the way the ranking is shown changes. The prefecture's Fisheries Promotion Vision (2017) gives the seaweed and seagrass beds of Ishikawa Prefecture, as the value of the next, 5th survey, as 9,424 ha (7% of the national 142,459 ha), and as the 2nd largest in the country. Because the national total differs from that of the 4th survey (201,212 ha), the values of the 2 surveys cannot be compared as they stand. A researcher at the prefecture's Fisheries Research Center, writing in 2017, presented, as values of the 4th survey, the seaweed and seagrass beds of Ishikawa Prefecture as about 148 km^2 and 3rd in the country, and the beds of Sargassum species as about 118 km^2 and 1st in the country. Both are values for the whole prefecture (chapter 5). [S14, S16]

Places where seaweed and seagrass beds are decreasing are still found widely across the country. The Fisheries Agency's Guidelines for Measures against Barren Ground (Isoyake) (2021) state that, in a 2020 questionnaire to the prefectures, 31 prefectures answered that a decline of beds was recognised (34 in 2013). The reasons why the decline continues (multiple answers) were feeding damage by sea urchins at 26%, feeding damage by fish that eat seaweed (herbivorous fish) at 21%, rising seawater temperature at 21%, and turbidity and the settling of fluid mud at 11%, among others. The guidelines state that, from around 1990, herbivorous fish came to be reported frequently, mainly on the coasts of southern Japan, as a reason for the decline of beds of arame and kajime kelps and of Sargassum beds. [S21]

Japan and the world: cases in which beds of Sargassum species and similar seaweeds decreased, and the reasons

Sargassum species have periods when they are vulnerable to temperature. A presentation (2022) by a researcher at the Marine Ecology Research Institute gives, from experiments on Sargassum species of Niigata Prefecture and other work, the temperature at which they grow well as 14–30°C and the upper limit of temperature at which they can live as 27–33°C. The same presentation states that on the coast of Tosa Bay, from the 1990s, the distribution of temperate Sargassum species narrowed and a subtropical kind (hiiragimoku) spread. It also reports that in the summer of 2013, on the Sea of Japan coast of western Japan, water temperatures 2°C or more above normal continued, and arame and kajime kelps died off and drifted away in large quantities. [S22]

There are other cases that have been linked to warming. A paper that studied the coast of Kochi Prefecture (2012) states that over the past 40 years the annual mean sea surface temperature rose by 0.3°C per 10 years, the distribution of temperate seaweeds narrowed, and the distribution of tropical kinds widened. It states that the temperate Sargassum species that grew thickly and widely in the 1970s decreased as the water temperature rose. Another paper (2014) states that tropical fish that eat seaweed spreading into temperate seas and eating up the large temperate seaweeds has already happened in Japan and the Mediterranean. [S23, S24]

There is also a case in which beds were driven into shallower places by turbidity. In the Baltic Sea in northern Europe, a paper (1986) that examined the same diving sites in 1943–1944 and in 1984 states that the lower limit of growth of bladderwrack (a brown alga close to Sargassum species) rose from a water depth of 11.5 m to 8.5 m. The depth at which it grows most thickly also rose, from 5–6 m to 3–4 m. The paper takes the view that this was because the nutrients in the sea increased too much (eutrophication) and the transparency of the water fell. [S26]

On the French coast of the Mediterranean, of the 14 species of the order Fucales (the group that includes Sargassum species) recorded at the end of the 19th century, only 5 species can still be seen today (a 2005 paper). The paper states that the kinds of shallow places decreased because of overgrazing by sea urchins, destruction of habitat and the like, and the kinds of deep places because of increased turbidity of the water and the like. It also takes the view that, because the fertilised eggs cannot spread far, it is difficult for the kinds that have disappeared to return naturally. There is also a paper (2008) stating that on the urban coast of Sydney, Australia, a large brown alga was not found on about 70 km of rocky reefs, and that there is evidence that it used to grow there. A paper from South Australia (2009) states that in places that had been replaced by small turf-like seaweeds, large seaweeds were slow to return, and that when those small seaweeds were removed, young plants of large seaweeds began to attach. [S25, S27, S28]

The range over which the seeds of Sargassum species spread from bags packed with seaweed is said to be narrow. The national government's guidelines, having stated that it differs with the state of the currents, give the range within which young plants attach when bags packed with seaweed (spore bags) are placed in the sea as a radius of several metres for Sargassum species and a radius of roughly 10–20 m for kombu kelps and kajime kelps. They state that with another method (a mid-water net, in which parent seaweeds are inserted into a net and floated up from the seabed), there is also a case in which many parent seaweeds of Sargassum species were placed in a place with fast currents and spread over about 2 ha. [S21]

Table 1 Main cases in Japan and abroad in which beds of Sargassum species and similar seaweeds decreased

Place (material)	What changed	What was given as the reason
Japan as a whole (the national government's 4th survey, 1994)	3.2% of the seaweed and sea - grass beds (6,403 ha) disap - peared in about 13 years	Land reclamation and the like 28.1%, barren ground (isoyake) 14.7%, unknown 40.6%, among others

Place (material)	What changed	What was given as the reason
Japan as a whole (the national government's guidelines, 2020 questionnaire)	A decline of beds was recog - nised in 31 prefectures	Feeding damage by sea urchins 26%, feeding damage by herbivorous fish 21%, rising seawater temperature 21%, turbidity and fluid mud 11%, among others (multiple answers)
Coast of Kochi Prefecture (2012 paper)	Temperate Sargassum species decreased and tropical kinds spread	Rising sea surface temperature (0.3°C per 10 years)
Baltic Sea (1986 paper)	The lower limit of growth of bladderwrack rose from a wa - ter depth of 11.5 m to 8.5 m	Fall in transparency due to eutrophication (the paper's view)
French coast of the Mediterranean (2005 paper)	Of the 14 species of the order Fucales, 5 species remain	In shallow places, overgrazing by sea urchins and the like; in deep places, increased turbidity and the like
Urban coast of Sydney (2008 paper)	A large brown alga is not found on about 70 km of rocky reefs	The abstract of the paper presents evidence that it used to grow there

Note: The values are as worded in each material. Because the seas, the periods and the survey methods all differ, they cannot be compared directly with Nanao Bay. For the Mediterranean and Sydney papers, we read only the abstracts. [S6, S21, S23, S26, S25, S27]

Region (Nanao Bay): the Sargassum beds of Nanao Bay

Nanao Bay in this paper means the North Bay, West Bay and South Bay that surround Notojima Island, on the coasts of Nanao City and Anamizu Town. The prefecture's materials on seaweed and seagrass beds divide the sea of Nanao City into the "Nanao Bay district" and the "Nadaura district" on the eastern side facing Toyama Bay. The figures in this paper are the values for the Nanao Bay district and the Anamizu Town district, and do not include the Nadaura district. [S1, S2]

Mametawara, yatsumatamoku, nokogirimoku and others are listed as the main kinds in the Sargassum beds of Nanao Bay. The Ishikawa Prefecture record of the national government's survey of around 1990 states, as a description of the whole prefecture, that at the heads of bays, where the influence of the water of the open sea is small, there are many places where yatsumatamoku and mametawara dominate even in shallow water. It states that in places deeper than a water depth of 1 m, yatsumatamoku, mametawara, fushisujimoku, yoremoku and togemoku dominate. Off Tanegashima in the West Bay, in a survey in 2012–2014, yoremoku, mametawara and yatsumatamoku grew thickly on stones and rocks shallower than a water depth of 2 m, with akamoku also mixed in. In the place that the Ministry of the Environment surveyed in June 2020 in the north-western part of Notojima Island (around Ubagaura-machi), yatsumatamoku, mametawara and others grew thickly on the rocks and stones of the west shore (the maximum cover was 80%; cover is the share of the seabed covered by seaweed). [S2, S6, S3, S9]

Nanao Bay is also listed as a place of rare seaweeds. The Ministry of the Environment has made Nanao Bay one of the "wetlands of high importance from the viewpoint of biodiversity", and among the reasons for its selection it gives, together with the large eelgrass beds, the fact that there are many rare kinds such as itoyoremoku, usuiromoku and sugimoku. [S10]

The prefecture expects the Sargassum beds of Nanao Bay to be of use to fish. The prefecture's Seaweed and Seagrass Bed Vision (2022) states that in the sea around Nanao Bay it is hoped that Sargassum beds will be built to serve as places where fish gather, places where they lay their eggs and places where young fish grow. According to the national government's assessment material (2023), young red sea bream in Nanao Bay grow on

sandy seabeds where eelgrass grows thickly at water depths of 5–15 m and, as they grow larger, move to seabeds of stones and rocky reefs. [S1, S7]

Region (Nanao Bay): the area from around 1990 to fiscal 2018

The area of the Sargassum beds of Nanao Bay can be compared in a table of the prefecture's Seaweed and Seagrass Bed Vision (2022) (Table 2). This table sets side by side the values of the national government's 4th survey (fiscal 1990–1991 for Ishikawa Prefecture) and the values of the prefecture's survey of fiscal 2018 (Heisei 30). The Sargassum beds of the Nanao Bay district went from 1,473.0 ha to 508.4 ha, and those of the Anamizu Town district from 780.0 ha to 338.9 ha. The share of decrease is about 65% in the Nanao Bay district and about 57% in Anamizu Town (this paper's calculation). [S1]

Table 2 Area of the seaweed and seagrass beds of Nanao Bay (values by survey)

District	Beds	Around 1990	Fiscal 2018	2025
Nanao Bay district (Nanao City)	Sargassum beds	1,473.0 ha	508.4 ha (507 ha in the Doyukai recalculation)	733 ha
Nanao Bay district (Nanao City)	Eelgrass beds	1,923.0 ha	768.8 ha (same, 769 ha)	4 ha
Nanao Bay district (Nanao City)	Total of beds	3,396.0 ha	1,277.3 ha (same, 1,276 ha)	742 ha
Anamizu Town	Sargassum beds	780.0 ha	338.9 ha (same, 324 ha)	485 ha
Anamizu Town	Total of beds	950.0 ha	340.0 ha (same, 326 ha)	486 ha

Note: Around 1990 and fiscal 2018 are the values in the table of the prefecture's Seaweed and Seagrass Bed Vision. Around 1990 is the values of the national government's 4th survey, edited by the prefecture to match the classification of fiscal 2018. 2025, and the values in parentheses, are the values in the tables of the report of the Kanazawa Association of Corporate Executives (Kanazawa Keizai Doyukai); the values for fiscal 2018 (which the report calls the survey of "Heisei 30 + Heisei 31") were recalculated by the report after revising the district boundaries. The survey methods differ for all 3 (this chapter and chapter 5). The total of beds also includes beds of small seaweeds. [S1, S2]

The prefecture has written a caution on this comparison. The Seaweed and Seagrass Bed Vision states that the 2 surveys differ in both method and classification, and so cannot simply be compared. The national government's survey of around 1990 used the method of swimming round the same points, on the basis of the report of the earlier survey, to look at the kinds and the cover. The prefecture's survey of fiscal 2018 was a survey by analysis of satellite images and by underwater camera and sonar from a boat. On that basis, the prefecture judges that the large brown algae of the Suzu district and the Nadaura district, which face the open sea, remain in good condition, but that a tendency to decline is seen on the inner side of the bay, from the Noto district to the Nanao Bay district. In the same table, the Sargassum beds of the Nadaura district, which is outside the scope of this paper, went from 695.0 ha to 778.7 ha. [S1, S6]

In the Nanao Bay district, the share of Sargassum beds within the seaweed and seagrass beds has not changed much. In the prefecture's figure, the share of Sargassum beds in the beds of the Nanao Bay district went from 43.4% (1990) to 39.8% (2018). The pattern is that eelgrass beds and Sargassum beds both decreased. In the Anamizu Town district, Sargassum beds went from 82.1% to 99.7%. In the fiscal 2018 table, the eelgrass beds of

Anamizu Town are 0 ha (the prefecture states that it calculated places with no data as 0). The decrease of the eelgrass beds is covered in R7-A03 "The decrease of the eelgrass beds of Nanao Bay". [S1]

The tendency to decrease had been written about since the time of the survey of around 1990. The Ishikawa Prefecture record of the national government's 4th survey, while stating that no beds had disappeared through natural phenomena such as barren ground (isoyake), states that the make-up of the seaweed communities had changed a little compared with the previous survey (about 13 years earlier). As one such change, it states that a tendency to decrease was also seen in the Sargassum species inside the bays, and that the cause was unknown (this is a record for the whole of Ishikawa Prefecture, and it does not say which bay). It states that in the interviews, too, there were many opinions pointing to a decrease of Sargassum species. [S6]

Region (Nanao Bay): the head of the West Bay, and the beds in deep places

At the head of the West Bay, the Sargassum beds became especially small. According to a research report (2014) of the prefecture's Noto Marine Center, in the sea west of a line joining Kotanibana and Cape Byobu in the West Bay, the national government's 4th survey (1990) had recorded 44 ha of Sargassum beds. In a survey by a prefectural researcher in December 2011, the Sargassum beds of the same sea were 6 ha. Over the same period, the eelgrass beds went from 1,258 ha to 1,042 ha. An explanatory article by prefectural researchers (2021) also states that the Sargassum beds of this sea decreased from 44 ha to 6 ha (14%). However, it writes the period as "from 1999 to 2011", which differs from the year in the research report (chapter 5). [S3, S4, S16]

In the field survey of May 2025, too, there were only a few Sargassum beds in the shallow places of the West Bay. In the underwater camera survey of the report of the Kanazawa Association of Corporate Executives, of the 9 points that this paper read from the positions in the table as points in the West Bay (N-55 to N-63, water depths of 0.9–6.0 m), only 1 point, at a water depth of 0.9 m, was classed as a Sargassum bed (cover of mametawara 50%, among others). The other points had a little small seaweed or no seaweed. 9 points is not a number that can be used for a comparison of areas. [S2]

On the Uchiura coast of the Noto Peninsula, the depth to which Sargassum beds extend also became shallower. The prefecture's Seaweed and Seagrass Bed Vision states that in the survey of around 1990 Sargassum beds extended to a water depth of about 20 m, but in the survey of fiscal 2018 they extended to a water depth of about 10 m, and that a decline of beds is seen in deep places. It also infers that the beds are decreasing even in places shallower than a water depth of 10 m. This is the prefecture's view of the whole Uchiura coast of the Noto Peninsula, which includes Nanao Bay; we found no material that compared the depth for Nanao Bay alone. A prefectural researcher states that on the coast of Noto Town, too, in a 2011 survey, Sargassum beds that had previously extended to a water depth of 20 m extended only to a water depth of 10 m (outside the scope of this paper). On the other hand, the Doyukai report states that in the field survey of May 2025, Sargassum beds had formed down to a water depth of around 15 m near the mouth of Nanao Bay. In the table, the points at water depths of 15.4 m and 15.8 m were Sargassum beds. Both are in a sequence of points that can also be read as points on the Nadaura side (chapter 5). This was a single survey of points, and it is not a comparison by the same method as the prefecture's view. [S1, S16, S2]

Region (Nanao Bay): the area after the earthquake

After the Noto Peninsula Earthquake of 1 January 2024, there is 1 material that surveyed the seaweed and seagrass beds of Nanao Bay over their whole area. It is the report (March 2026; hereafter, the Doyukai report) of a survey that the Kanazawa Association of Corporate Executives (Kanazawa Keizai Doyukai), a business association, carried out with a grant from The Nippon Foundation. Nanao Bay was analysed using an image (resolution 1.5 m) taken by the satellite SPOT6 on 14 March 2025. The report defined as beds those places shallower than a water depth of 20 m where seaweeds or seagrasses cover 25% or more of the seabed (beds found in places deeper than 20 m are also added). Stating that it is difficult to distinguish Sargassum beds,

eelgrass beds, beds of small seaweeds and so on from the images alone, it had engineers interpret them on the basis of the field surveys, earlier materials, the seasons in which the seaweeds grow thickly and so on. The results of the image analysis have been corrected using, among other things, the results of the previous survey. The movement of the coast caused by the earthquake is covered in R7-B01 "Earthquake uplift on the Sotoura coast" and R7-A19 "Land subsidence and flooding in Nanao Bay". [S2]

The area of the Sargassum beds of Nanao Bay after the earthquake was a larger value than in the previous survey (Table 2). The Sargassum beds of the Nanao Bay district were 733 ha, 44.6% more than the previous 507 ha, and those of the Anamizu Town district were 485 ha, a value 49.7% more than the previous 324 ha. The report states that in the Nanao Bay district the Sargassum beds increased near the eastern part of Notojima Island. In the Anamizu Town district, it states that the places where there are Sargassum beds were broadly the same as the previous time and that the beds increased in the district as a whole. The report does not give the reason for the increase. [S2]

The previous values are the data of the prefecture's fiscal 2018 survey as recalculated by the report. The report states that, in connection with the revision of the district boundaries and other matters, it recalculated the areas from the data of that time. For this reason, the previous values in Table 2 differ a little from the values in the prefecture's Seaweed and Seagrass Bed Vision (the Sargassum beds of the Nanao Bay district are 507 ha and 508.4 ha, and those of Anamizu Town 324 ha and 338.9 ha). [S2, S1]

Even in the same Nanao Bay district, the area of the beds as a whole decreased. The total of beds in the Nanao Bay district was 742 ha, 41.8% less than the previous 1,276 ha, and it is one of the districts that the report classed as having a large decrease of 40% or more. This is because the eelgrass beds, which had been extensive at the head of the bay, went from 769 ha to 4 ha. The decrease of the eelgrass beds is covered in R7-A03 "The decrease of the eelgrass beds of Nanao Bay". [S2]

The previous survey and this one are not surveys by the same method. According to the specification for the prefecture's fiscal 2018 survey, the previous survey was to use spring images taken within the past 3 years (resolution 5 m or finer), and the field survey was to be carried out at 120 points from late August to late October, mainly targeting the Sargassum species that live for many years. This time, an image of 14 March 2025 (resolution 1.5 m) was used, and the field survey of Nanao Bay was on 2 May 2025. Whether the report's way of defining a bed (cover of 25% or more) is the same as the previous time is not known from the materials (chapter 5). [S8, S2]

Region (Nanao Bay): the state of things under the sea after the earthquake

In the field survey of May 2025, too, Sargassum beds were found widely inside the bay. The Doyukai report surveyed the kinds and cover of seaweed by underwater camera at 63 points along the coast of Nanao Bay on 2 May 2025. It states that Sargassum beds were seen on rocky reefs and stony seabeds from the water's edge to a water depth of around 10 m, around Notojima Island and in the North Bay and South Bay. The text of the report gives the main kinds as mametawara, yatsumatamoku and others, and near the water's edge umitoranoo and others. Near the mouth of the bay, Sargassum beds had formed down to a water depth of around 15 m. It states that Sargassum beds tended to grow more densely the shallower the place, and that the main kinds in beds shallower than a water depth of 10 m were joromoku, nokogirimoku, mametawara, yatsumatamoku, yoremoku and others. [S2]

When this paper counts the table of the 63 points, 16 points were classed as Sargassum beds. At 11 of the 16 points, nokogirimoku had the highest cover, with mametawara at 3 points and yatsumatamoku and yoremoku at 1 point each (counted from the table by this paper). The highest cover was 95% (of which nokogirimoku was 85%) at a point at a water depth of 6.1 m. Even in the 15 m depth range, there were Sargassum bed points with cover of 60% and 75%. However, Figure 3-4 of the report shows N-18, N-24 and N-37, like N-36, as points "inside

Nanao Bay (Nadaura)". The point with 95% cover (N-16) and the points in the 15 m depth range (N-33 and N-37) are points in the same sequence as these, and can also be read as points on the Nadaura side (chapter 5). [S2]

On the other hand, there were also places where sand and stones had covered the beds. The report states that, in Sargassum beds in shallow places, a state in which sand and stones had been moved by the force of high waves, the tsunami and the like and covered the original beds was seen at some points. On the photograph of the 1 point it gives as an example (N-36), it writes "Declined under the influence of the tsunami?", with a question mark. This point is off the north-east of Notojima Island (its position in the table is latitude 37 degrees 9 minutes north, longitude 137 degrees 3 minutes east) at a water depth of 17.9 m; yatsumatamoku and mametawara grew sparsely there (cover 15%), and it was classed as not being a bed. In its figure, the report shows this point as a point "inside Nanao Bay (Nadaura)" (chapter 5). The report's summary states that on the Uchiura coast, places where the beds were in poor condition were seen on seabeds shallower than a water depth of 5 m that were affected by the tsunami and where the base to which seaweed attaches is unstable. The locations are not shown. [S2]

Observation of rocky shores about half a year after the earthquake also shows that Sargassum species remained. On 26 June 2024, the prefecture's Noto Marine Center surveyed the rocky shores of Niizaki in Anamizu Town and of Karashima in Nanao City, at the westernmost end of the West Bay. At Niizaki, in the zone that stays under the sea even when the tide is out (the subtidal zone), fushisujimoku and umitoranoo were abundant, and mametawara, yoremoku and yatsumatamoku were also often found. At Karashima, umitoranoo and yoremoku were abundant in the subtidal zone, and miru, isomoku and wakame, which had been seen the previous time (2020–2021), were not found. It states that at Karashima the tide was high and the water turbid at the time of the survey, and the subtidal zone was hard to observe. This report recorded the kinds, and has no figures for area or cover. [S5]

Region (Nanao Bay): what has been given as the reasons for the decline

The prefecture states that the reason cannot be narrowed down to one. The prefecture's Seaweed and Seagrass Bed Vision, having stated that at the present stage it is difficult to identify the cause of the decline of the beds on the Uchiura coast of the Noto Peninsula, lists the following 3 as possible reasons. They are: growth becoming poor and the seaweed disappearing because of rising seawater temperature and the like; fine particles in the sea increasing, transparency falling and photosynthesis being hindered; and settled fluid mud hindering the photosynthesis of seaweed and the attachment of young plants to the seabed. The national government's assessment document (2023) also states that the beds on the Uchiura coast of the Noto Peninsula are tending to decline because photosynthesis is hindered by rising seawater temperature and by an increase in fine particles entering from the land. The prefecture's plan for the Nanao Bay area (from fiscal 2022) also gives, for the seas in the prefecture where a decline of beds is seen, increased turbidity of the seawater and the resulting fall in transparency as one cause. None of these materials confirmed the share of each reason for the Sargassum beds of Nanao Bay. [S1, S7, S11]

Water temperature and turbidity each have their own paper. The rise in the water temperature of Nanao Bay is covered in R7-A02 "The rise in seawater temperature in Nanao Bay". Turbidity and fluid mud are covered in R7-A05 "Turbidity and fluid mud in Nanao Bay". [S1]

Damage by creatures that eat seaweed is at the stage of a "concern". The prefecture's Seaweed and Seagrass Bed Vision lists rabbitfish (aigo), small snails such as koshidaka-gangara, and the purple sea urchin as creatures whose feeding damage has been confirmed in the prefecture, and states that it is not of an amount that would lead to the decline of the beds (a view of the whole prefecture). On that basis, it expresses concern that, as the water temperature rises, the feeding power of these creatures will strengthen and that the seas inhabited by budai (parrotfish), nizadai (sawtail) and gangaze (long-spined sea urchin) will spread northwards. The Vision

states that these 3 have not at present been confirmed to live in the prefecture. The Fisheries Agency's assessment material (March 2023) states that in the district of the Uchiura coast of the Noto Peninsula, which includes Nanao Bay, feeding damage to beds by herbivorous fish "is a concern", and carries a photograph of "a bed being eaten by rabbitfish" (the place and date it was taken are not given). At the same meeting, the Fisheries Agency official who explained the project named Nanao Bay as a place where the decrease of beds is marked, and stated that enhancement grounds would be built there together with nearby Iida Bay. [S1, S7]

The overall summary of the Doyukai report states that, on the coast of the Noto Peninsula, there are reports that gangaze sea urchins have appeared on the Uchiura coast and that rabbitfish have eaten eelgrasses, but that no decline of beds through conspicuous feeding damage or through large-scale dying-off and loss of seaweed is known. As for rabbitfish eating seaweed in schools, the prefecture's Noto Marine Center observed schools of several hundred fish around Tsukumo Bay in Noto Town in 2000 and 2022 (outside the scope of this paper). The same article states that for parrotfishes, too, against the 1 to several fish seen until then, a school of 30 or more was seen in 2022. This does not agree with the wording of the prefecture's Seaweed and Seagrass Bed Vision (chapter 5). We found no material that showed feeding damage to Sargassum beds in Nanao Bay in numbers. [S2, S19]

We found no public material that describes Nanao Bay as "barren ground (isoyake)". Barren ground (isoyake) is a phenomenon in which, in shallow seas of rock and stone, seaweed beds decline greatly or disappear beyond the range of their seasonal and year-to-year variation (the explanation in the national government's guidelines). The national government's survey of around 1990 stated that in Ishikawa Prefecture no beds had disappeared through natural phenomena such as barren ground. The prefecture's Fisheries Promotion Vision (2017) also states that no large-scale barren ground has so far been confirmed on the coast of the prefecture, but that beds are disappearing in some seas. Barren ground on the Sotoura coast (the outer, Sea of Japan coast of the Noto Peninsula) is covered in R7-B11 "Barren ground (isoyake) that has continued since before the earthquake, and the decline of the beds of the offshore islands". [S21, S6, S14]

There is also a view that links the decrease of the beds with the increase of other seaweeds. An explanatory article by prefectural researchers (2021), after writing that the beds in the West Bay decreased, writes that seaweeds such as tsurushiramo and nagamiru are growing in large quantities and getting in the way of fishing. This matter is covered in R7-A17 "The mass occurrence of seaweed in Nanao Bay". [S4]

3. Existing measures, and how they are assessed

The efforts directed at the Sargassum beds of Nanao Bay centre on works in which the prefecture places stones and blocks on the seabed to build a base for beds, and on the activities of a local fishers' group. In the materials this paper looked at, there was no assessment showing how much the Sargassum beds of Nanao Bay had increased through these efforts.

Works to build enhancement grounds (fiscal 2006–2022)

The prefecture has been building enhancement grounds around Nanao Bay. An enhancement ground is a works project that places stones, or blocks to which seaweed attaches easily, on the seabed to build a place where young fish and the like grow. According to the table of the prefecture's Seaweed and Seagrass Bed Vision, in fiscal 2006–2022 (Heisei 18 to Reiwa 4), enhancement grounds of 1.4–1.6 ha per site were built at 3 sites in Anamizu Town (Furukimi, Iwaguruma and Kabuto) and at 14 sites in Nanao City (Suso, Tori, Odomari, Enome, Nanao West Bay, Kuki, Sazanami, Nozaki, Unoura, Iori, Tajiri, Magari, Kurosaki and Nagasaki). In total this is 17 sites and 24.4 ha (this paper's calculation). The target fish were black sea bream and red sea bream. In the

prefecture's figure, several of these sites appear to be on the Nadaura side (this paper's reading of the figure). [S1]

How much Sargassum bed was formed by these works is not known. The "effect" column of the table says "seaweed, fish", but these are not measured values. The prefecture's Seaweed and Seagrass Bed Vision adds the 9 ha of the 6 enhancement grounds completed by fiscal 2021 to the present area of the beds on the Uchiura coast of the Noto Peninsula, but this is an expected figure for the purpose of calculation. We found no material that examined how beds had become established in each works section. [S1]

Works to build beds of Sargassum species (fiscal 2023–2031)

Since fiscal 2023, the prefecture has been carrying out works to build beds of Sargassum species on the Uchiura coast of the Noto Peninsula. The prefecture's Seaweed and Seagrass Bed Vision states that, so that the young plants of Sargassum species scatter widely, enhancement grounds will be built with priority around Nanao Bay, which lies up-current in the tidal flow. The places where they are built are places where the depth is suitable for seaweed to grow but no beds have formed because there are no stones or rocks; stones, and blocks to which seaweed and small creatures attach (feed-culture reefs), are placed there. In the enhancement grounds completed in fiscal 2025 or later, it is planned to place Sargassum species from the surrounding sea as parent seaweeds and to watch over how they grow (monitoring). [S1]

The scale of the works is given in the national government's assessment material. According to the Fisheries Agency's assessment document (2023), this project (the Noto–Uchiura district fisheries environment improvement project) is to build, in fiscal 2023–2031 (Reiwa 5–13), 14.0 ha of enhancement grounds, fish reefs, and observation buoys to watch for sudden strong tidal currents; the project cost is 1.288 billion yen and the ratio of benefit to cost is 1.18 (an expected value of the benefit). The enhancement grounds are at 10 sites on the Uchiura coast of the Noto Peninsula (Tanizaki, Horyu, Nakai, Niizaki, Neya, Museki, Koda, Hidegashima, Onogi and Higashihama), each of 1.4 ha. Tanizaki and Horyu are in Suzu City and outside the scope of this paper. The observation buoys are covered in R7-A25 "Damage to set nets and aquaculture facilities from sudden strong currents (kyucho) in Nanao Bay". [S7, S1, S12]

In fiscal 2026 there are works on Notojima Island. According to the prefecture's drawing (June 2026), in fiscal 2026 (Reiwa 8), enhancement grounds of 0.2 ha each will be built off Notojima Koda-machi and off Notojima Hidegashima-machi in Nanao City, and 10 blocks (each 3.4 m × 3.4 m × 2.2 m) and stones will be placed. The prefecture's fiscal 2026 budget includes 28.896 million yen as the cost of the wide-area enhancement ground construction project for the Hidegashima district (the national government's share of the burden is 1/2). [S12, S13]

The prefecture states that it will build up-current and have the young plants scatter widely. The national government's guidelines, having stated that it differs with the state of the currents, give the range within which young plants attach from a bag as a radius of several metres for Sargassum species. The same guidelines also give a case in which, with another method (a mid-water net), many parent seaweeds were placed in a place with fast currents and spread over about 2 ha (chapter 2). The prefecture's Seaweed and Seagrass Bed Vision carries the monthly tidal currents of 2018 measured by observation buoys at 4 points on the Uchiura coast of the Noto Peninsula (Kodomari, Koura, Ukawa and Kishibata). It states that at Kodomari, Koura and Ukawa a current heading north along the peninsula was common throughout the year, and that at Kishibata there was a current heading north in winter and, in summer, heading south towards Himi in Toyama Prefecture. By their positions in the table, all 4 points are outside Nanao Bay (this paper's reading). Data on the tidal currents inside Nanao Bay are not carried in the Seaweed and Seagrass Bed Vision. We found no material that showed how the young plants of Sargassum species scatter in Nanao Bay. [S1, S21]

Activities of local fishers

In Nanao Bay, a fishers' group carries out activities to protect the beds. According to the information website of the national government's measures to bring out the multiple functions of fisheries (a scheme in which the national government supports activities by fishers and others to protect seaweed and seagrass beds and tidal flats), the Ishizaki Satoumi Conservation Group of Nanao City (27 people: fishers and the Nanao branch of the Ishikawa Prefecture Fisheries Cooperative) hauls up rubbish from the seabed with bottom-trawl boats and cleans the coast and the fishing port. In the beds, it places on the seabed blocks fitted with bags that make seaweed release its seeds (spore bags), and puts in parent seaweeds. It also works together with a primary school. The group regards the decrease of eelgrass beds and Sargassum beds as a major issue for the area. [S17]

The group's report states that small seaweeds have attached to some of the blocks. The group states that from now on, with the attachment of large seaweeds as its goal, it will revise the seaweed put in the bags and the timing of placing them. On 16 May 2025, an expert dispatched from a project commissioned by the national government gave individual guidance on this group's activities for the beds. [S17, S18]

Surveying and watching over the beds

The prefecture's Seaweed and Seagrass Bed Vision also planned a system for watching over the beds. It consists of holding once every year a council (provisional name) made up of the prefecture, the cities and towns, the prefecture's Fisheries Research Center, and fishers and fishery cooperatives; surveying the distribution of beds over the whole of the prefecture in fiscal 2024; and dividing responsibility for monitoring the enhancement grounds between the prefecture and the prefectural fishery cooperative. We found no record that the council has been held. The material (September 2026) of the review committee for the prefecture's new Fisheries Promotion Vision compares distribution maps of the beds on the coast of the prefecture before the earthquake (fiscal 2018–2019) and after it (fiscal 2025–2026), and gives as its source the report of the prefecture's fiscal 2025 (Reiwa 7) survey of beds in the Kaga and Noto Sotoura districts, but the figures shown are values for the whole coast of the prefecture (they are not used in this paper). [S1, S15]

The Doyukai report states that continuing to watch over the beds is essential. In Nanao Bay, as a model project of the Ministry of the Environment, a Wakura Onsen organisation and others began in fiscal 2025 to create a system in which citizens take part in looking at the beds, but its subject is eelgrass (R7-A03). [S2, S20]

Assessment of the efforts

We found no record showing that the Sargassum beds of Nanao Bay have been restored. Nor is there any material that linked the values showing that the area of Sargassum beds increased from fiscal 2018 to 2025 (chapter 2) with the effect of the enhancement ground works or the local activities. This paper does not link them either. For the enhancement ground works, the amount for each year is set in the prefecture's plan, but records of how beds became established after the works have not been published. [S1, S2, S12]

4. What is changing

For the Sargassum beds of Nanao Bay, what has moved in the past few years is the single survey of area after the earthquake and the plans for works to build beds (as of 12 November 2026). Most of what this chapter covers is the prefecture's plans and schedules.

How the beds have changed over time

The prefecture expects the beds on the Uchiura coast of the Noto Peninsula to go on decreasing. The prefecture's Seaweed and Seagrass Bed Vision takes it that the beds decreased by 3,735 ha on the Uchiura coast

of the Noto Peninsula as a whole in the 28 years from 1990 to 2018, and assumes that a decrease of 133 ha per year will continue. From this assumption, it puts the trend value of the area of beds on the Uchiura coast as a whole (a value that adds the 9 ha of enhancement grounds completed by fiscal 2021 and does not add the later works) at 4,026 ha in fiscal 2026, and sets the target for fiscal 2031 at 3,380 ha. This is not a value for Nanao Bay alone, and it is a value that combines Sargassum beds and eelgrass beds. [S1]

The values after the earthquake show a movement different from this expectation. In the 2025 values of the Doyukai report, the Sargassum beds of the Nanao Bay district and Anamizu Town were larger values than in fiscal 2018 (chapter 2). However, it is a single comparison and the methods also differ, so whether this is a continuing change is not known. The 2025 values, too, when compared with the values of around 1990, are about 50% in the Nanao Bay district and about 60% in Anamizu Town (this paper's calculation; a comparison between surveys with different methods). [S2, S1]

Sargassum species have a temperature at which they grow well and an upper limit of temperature at which they can live (chapter 2). How the water temperature of Nanao Bay is changing is covered in R7-A02 "The rise in seawater temperature in Nanao Bay". [S22]

Plans and schedules

- March 2022: The prefecture draws up the Seaweed and Seagrass Bed Vision. It stated that enhancement grounds for Sargassum species would be built with priority around Nanao Bay. The interim target is fiscal 2026 and the target year is fiscal 2031. [S1]
- Fiscal 2022–2026: The prefecture's plan for the Nanao Bay area (comprehensive fisheries infrastructure improvement project plan). It lists the placing and monitoring of parent seaweeds of Sargassum species, blocks using oyster shells, and increasing blue carbon (the carbon taken up by the living things of the sea) by building beds. [S11]
- 8 March 2023: Prior assessment of the project for the Noto–Uchiura district at a meeting of the Fisheries Agency. Fiscal 2023–2031, 14.0 ha of enhancement grounds, project cost 1.288 billion yen. [S7]
- 14 March and 2 May 2025: The satellite image of the Doyukai report, and the field survey of 63 points in Nanao Bay. [S2]
- 16 May 2025: An expert from a project commissioned by the national government gives guidance to the Ishizaki Satoumi Conservation Group on its activities for the beds. [S18]
- March 2026: Publication of the Doyukai report. [S2]
- Fiscal 2026: Enhancement grounds of 0.2 ha each are built at Koda and Hidegashima on Notojima Island (the prefecture's drawing of June 2026). The budget for the Hidegashima district is 28.896 million yen. [S12, S13]
- Fiscal 2026: The prefecture draws up a new Fisheries Promotion Vision (the review committee held its 1st meeting on 4 September 2026, with the 2nd and 3rd meetings scheduled for around December and around March 2027). The present Vision states that it will support activities to protect the beds carried out by fishers, such as the placing of parent seaweeds, and the directions of the new Vision also include creating healthy fishing grounds through protecting the beds and the like. [S15]
- Fiscal 2027–2031: Works on the remaining enhancement grounds (in the 2023 assessment material, Nakai, Niizaki and Koda are in fiscal 2029–2031). The target year of the Seaweed and Seagrass Bed Vision is fiscal 2031. [S7, S1]

The schedule of the works has changed between materials. In the 2023 assessment material, the Koda section was scheduled for fiscal 2029–2031 and the Hidegashima section for fiscal 2027–2029, but in the prefecture's drawing of June 2026, both have works in fiscal 2026. The number of observation buoys has also gone from 4 to 3 (chapter 5). [S7, S12]

5. What is not yet known

Things for which there are no figures

- The area of the Sargassum beds of Nanao Bay after the earthquake exists only for a single occasion, from the image of March 2025. The material of the prefecture's review committee (September 2026) mentions the prefecture's survey of beds in fiscal 2025–2026, but the figures shown are values for the whole coast of the prefecture, and we found no values for Nanao Bay. [S2, S15]
- We found no material that compared, for Nanao Bay alone, the depth to which Sargassum beds extend in the past and now. The change from a water depth of about 20 m to about 10 m is the prefecture's view of the whole Uchiura coast of the Noto Peninsula. [S1]
- We found no material showing the amount of Sargassum beds eaten by rabbitfish and other creatures in Nanao Bay. [S1, S7, S2]
- We found no material that confirmed, for the Sargassum beds of Nanao Bay, the share of each reason for the decline (water temperature, turbidity, fluid mud, feeding damage). [S1]
- We found no survey of how much Sargassum bed was formed in the enhancement grounds built in fiscal 2006–2022, and no record of the placing of parent seaweeds and monitoring from fiscal 2025 onwards. We also found no record that the council of the Seaweed and Seagrass Bed Vision has been held. [S1]
- The original report of the survey that gave 6 ha (December 2011) for the Sargassum beds of the West Bay was a lecture at an academic society, and this paper has not read it. The value is as quoted by the prefecture's research report and the explanatory article. [S3, S4]
- We found no material that measured, for fiscal 2018 onwards, the amount of each kind of Sargassum species or how they change with the seasons. [S2, S5]

Limits of the comparisons

- The 3 values, for around 1990, fiscal 2018 and 2025, come from different survey methods. Around 1990 was a survey of swimming round to look, based on the earlier survey, and its range was places shallower than a water depth of 20 m. For fiscal 2018, according to the prefecture's specification, satellite images (spring images from within the past 3 years, resolution 5 m or finer) were to be used and a field survey of 120 points was to be carried out from late August to late October. 2025 was an image of 14 March (resolution 1.5 m) and a field survey in May. The prefecture, too, states that around 1990 and fiscal 2018 cannot simply be compared. [S6, S1, S8, S2]
- Whether the way of defining a bed is the same in the 3 surveys is not known. The 2025 report defined as beds places with cover of 25% or more, but the prefecture's Seaweed and Seagrass Bed Vision does not say from what cover a place was treated as a bed in the surveys of around 1990 and fiscal 2018. The values for around 1990 are values edited by the prefecture to match the classification of fiscal 2018. The Sargassum beds of Ishikawa Prefecture around 1990 in the prefecture's table (11,888.0 ha) differ by 50 ha from the value in Appended Table 2 of the national government's survey (11,838 ha) (see "Figures that disagree"). [S2, S1, S6]
- Differences of method can also enter into the comparison from a water depth of about 20 m to about 10 m. The survey of around 1990 took places shallower than a water depth of 20 m as its range, and fiscal 2018 used satellite images. The Doyukai report states that the depth that could be analysed from the satellite images was at most about 20 m when the water quality was good. [S1, S8, S2]
- The timing of the images bears on how Sargassum species are growing. The specification for the prefecture's fiscal 2018 survey states that spring images, when the beds grow thickly, are to be used, and the field survey mainly targets the Sargassum species that live for many years. The 2025 image is from 14 March. When the

previous images were taken is written neither in the report nor in the prefecture's Seaweed and Seagrass Bed Vision. [S8, S2, S1]

- Identification of beds from satellite images has misses. The Doyukai report states that, for the whole of the sea surveyed, when checked against 355 field points, it correctly distinguished places with beds from places without at 82.3%. These points were also used as the training examples for the identification. The report states that misses tended to be more frequent for beds on the offshore side. There is no value for the accuracy for Nanao Bay alone, and no value for the accuracy of the distinction between Sargassum beds and eelgrass beds. The satellite survey of the 3 districts of the Sotoura coast is covered in R7-B08 "Shallow beds left dry by uplift, and the decrease in the area of beds on the Sotoura coast". [S2]
- The previous values compared with the 2025 values are values recalculated after revising the district boundaries, and differ from the values in the prefecture's Seaweed and Seagrass Bed Vision (Table 2). The shares of increase (44.6% and 49.7%) were obtained between the report's own values. [S2, S1]
- The 63 field points of 2025 are a survey of points inside the bay, done only once at each point. They have not been compared with records of the same points from before the earthquake. [S2]
- The cases in Japan and abroad (Table 1) differ in sea, period and survey method, and cannot be compared directly with Nanao Bay. For the papers on Kochi Prefecture, Sydney, the Mediterranean and the Baltic Sea, we wrote within the range of what we read in the abstracts and the like. [S23, S27, S25, S26]

Figures that disagree

- There are places where, on the same matter, the value or the wording differs from one material to another (Table 3).

Table 3 Values and wordings that differ from one material to another

Item	Value or wording	Material
Period of the 44 ha → 6 ha of Sargassum beds in the West Bay	From 1990 (the national government's 4th survey) to December 2011	Research report of the prefecture's Noto Marine Center (2014)
Period of the 44 ha → 6 ha of Sargassum beds in the West Bay	From 1999 to 2011	Explanatory article by prefectural re - searchers (2021)
Sargassum beds of the Nanao Bay district in fiscal 2018	508.4 ha, 507 ha	The prefecture's Seaweed and Seagrass Bed Vision, the Doyukai report (recalculated value)
Sargassum beds of Anamizu Town in fiscal 2018	338.9 ha, 324 ha	Same
Total of beds of Anamizu Town in fiscal 2018	340.0 ha, 326 ha	Same. In the report's table, 324 ha of Sargassum beds and 1 ha of small seaweeds give a total of 326 ha (a difference due to rounding)
National ranking of the sea - weed and seagrass beds of Ishikawa Prefecture	14,761 ha, 3rd by prefecture	The national government's 4th survey (1994 report)
National ranking of the sea - weed and seagrass beds of Ishikawa Prefecture	9,424 ha, 2nd	The prefecture's Fisheries Promotion Vision (2017; value of the 5th survey)

Item	Value or wording	Material
Sargassum beds of Ishikawa Prefecture (around 1990)	11,838 ha, 13.8% of the national 85,682 ha of Sargassum beds (the largest by prefecture)	Appended Table 2 of the national govern - ment's 4th survey (values in which beds for which 2 or more types were shown were counted under each of those types)
Sargassum beds of Ishikawa Prefecture (around 1990)	About 118 km^2 and 1st in the country, 11,888.0 ha	The article of the prefecture's Fisheries Research Center (2017), the table of the prefecture's Seaweed and Seagrass Bed Vision (values edited by the prefecture)
Depth to which Sargassum beds extend	To about 10 m (fiscal 2018; the whole Uchiura coast of the Noto Peninsula)	The prefecture's Seaweed and Seagrass Bed Vision
Depth to which Sargassum beds extend	To around 15 m near the mouth of the bay. The points at 15.4 m and 15.8 m were Sargassum beds (survey of points in May 2025)	Text and table of the Doyukai report
Whether budai (parrotfish) and gangaze (long-spined sea urchin) are present in the prefecture	Not at present confirmed to live there	The prefecture's Seaweed and Seagrass Bed Vision (2022)
Whether budai (parrotfish) and gangaze (long-spined sea urchin) are present in the prefecture	Around Tsukumo Bay, 1 to several parrot - fishes, and in 2022 a school of 30 or more. There are reports that gangaze sea urchins have appeared on the Uchiura coast	Article of the Noto Marine Center (2023), the overall summary of the Doyukai report
Points N-18, 24, 36 and 37	N-36 is an example of a Sargassum bed in a shallow place	Text of the Doyukai report
Points N-18, 24, 36 and 37	N-36 is at a water depth of 17.9 m and is not a bed. All 4 points are in the figure of "in - side Nanao Bay (Nadaura)"	Table and figure of the Doyukai report
Quantities of the project for the Noto–Uchiura district	Fish reefs 15,021 bulk m^3, enhancement grounds 14.0 ha, 4 observation buoys	The Fisheries Agency's assessment docu - ment (2023)
Quantities of the project for the Noto–Uchiura district	Fish reefs 15,078 bulk m^3, enhancement grounds 14.0 ha, 3 observation buoys	The prefecture's drawing (June 2026)
Timing of the Koda section	Scheduled for fiscal 2029–2031	The Fisheries Agency's assessment material (2023)
Timing of the Koda section	Works in fiscal 2026	The prefecture's drawing (June 2026)
Timing of the Hidegashima section	Scheduled for fiscal 2027–2029	The Fisheries Agency's assessment material (2023)
Timing of the Hidegashima section	Works in fiscal 2026	The prefecture's drawing (June 2026); the prefecture's fiscal 2026 budget

Note: The values are as worded in each material. [S3, S4, S1, S2, S6, S14, S16, S19, S7, S12, S13]

- For the period in the West Bay, we adopted the "1990" of the research report. The research report states explicitly that 44 ha is the value of the national government's 4th survey (1990), and the article of the prefecture's Fisheries Research Center (2017) also treats the eelgrass beds of the same sea as a comparison

from 1990 to 2011. As for the "1999" of the explanatory article, this paper has not checked the original value in the paper it quotes (2016), so it cannot be said outright to be an error, but it does not agree with the other 2 materials. [S3, S16, S4]

- The Sargassum beds of Ishikawa Prefecture around 1990 are 11,838 ha in Appended Table 2 of the national government's survey and 11,888.0 ha in the table of the prefecture's Seaweed and Seagrass Bed Vision, a difference of 50 ha. Appended Table 2 of the national government's survey counts beds for which 2 or more types were shown under each of those types. The prefecture states that, because the classification of bed types in the national government's survey differs from that of the fiscal 2018 survey, it edited the values so that they would be the same. The 1,473.0 ha of the Nanao Bay district is also a value from the table edited by the prefecture. [S6, S1]
- The points N-18, N-24, N-36 and N-37 can be read, within the report, either as points in Nanao Bay or as points in Nadaura. The point with 95% cover and the points in the 15 m depth range are also in the same sequence, and this paper has not used these as evidence that the Sargassum beds of Nanao Bay have declined, or as values for Nanao Bay alone. [S2]
- From fiscal 2018 to 2025, the values show Sargassum beds increasing (the Doyukai report), and from around 1990 to fiscal 2018 the values show them decreasing (the prefecture's Seaweed and Seagrass Bed Vision). The 2 comparisons differ in both method and period, and the relationship is not one in which either is wrong. Differences of method can enter into either comparison. [S2, S1]
- The view of feeding damage is worded differently according to the year and the standpoint of the material. The prefecture's Seaweed and Seagrass Bed Vision (2022) says "not of an amount that would lead to the decline of the beds", the Fisheries Agency's material (2023) says "is a concern", and the Doyukai report (2026) says that no decline through conspicuous feeding damage on the coast of Noto "is known". None of them is a material that showed amounts. Whether parrotfishes and gangaze sea urchins are present in the prefecture is also written differently from one material to another (Table 3). [S1, S7, S2, S19]

Reliability and the standpoint of the materials

Reliability differs from item to item. That the Sargassum beds of the Nanao Bay district and Anamizu Town decreased greatly from around 1990 to fiscal 2018 rests on the values in the prefecture's official table, and the prefecture also judges that there is a tendency to decline, but the prefecture itself states that the methods differ and the values cannot simply be compared, so the reliability is medium. The shares of decrease (about 65% and about 57%) include the effect of the differences of method, and so are a rough guide. That the Sargassum beds at the head of the West Bay went from 44 ha to 6 ha is a comparison of 2 surveys written in the prefecture's research report, and the original report of the 2011 survey was a lecture, so the reliability is medium. That the depth to which Sargassum beds extend on the Uchiura coast went from about 20 m to about 10 m is the prefecture's view and is not a comparison for Nanao Bay alone, so the reliability is medium. That the area of Sargassum beds increased from fiscal 2018 to 2025 is a comparison of 2 surveys with different methods in 1 report that is not peer-reviewed, and the reliability can be said to be low. On the other hand, that in May 2025 there were Sargassum beds on rocky reefs and stony seabeds down to a water depth of around 10 m inside the bay is something on which the field survey of 63 points and the observation of rocky shores in June 2024 agree, and the reliability is medium. For the reasons for the decline (water temperature, turbidity, fluid mud), the prefecture states that identifying them is difficult, and the reliability can be said to be low. Whether feeding damage is a reason for the decline also has no material on amounts, and the reliability can be said to be low. That no public material describing Nanao Bay as barren ground (isoyake) can be found agrees with the descriptions by the national government and the prefecture (both of which concern the whole prefecture), but the most recent of them is a description from 2017, so the reliability is medium. The effect of the enhancement ground works is not known, because there is no assessment material.

Care is also needed over the standpoint of the materials. The Doyukai report is the report of a survey that the Kanazawa Association of Corporate Executives, a business association, carried out with a grant from The Nippon Foundation and the special cooperation of the Hokkoku Shimbun newspaper company, and it is not peer-reviewed. The head of the survey team is the president of the Japan Seaweed Association, the satellite analysis was handled by a surveying company (Kokusai Kogyo), and people from the prefecture's Fisheries Division and Fisheries Research Center took part as observers. None of the 7 points of the diving survey is a point in Nanao Bay, and the Sargassum beds of Nanao Bay do not come up in the interviews with fishers either (32 people; 2 from Anamizu Town and none from Nanao City). The materials on the Sargassum beds of Nanao Bay are only the satellite analysis and the underwater camera survey. Because the report's previous values use the data of the prefecture's fiscal 2018 survey, the fiscal 2018 values and the 2025 values rely in part on the same prefectural survey. The values for around 1990 in the prefecture's Seaweed and Seagrass Bed Vision are the values of the national government's survey as edited by the prefecture. The Noto Marine Center is a prefectural facility, and its research report, the explanatory article by prefectural researchers and the article of the prefecture's Fisheries Research Center were all written by prefectural researchers, and the values for the West Bay are based on the same prefectural survey (2011). The explanatory article (2021) is an explanatory article in the journal of an academic society, and its authors include prefectural researchers. The Fisheries Agency's assessment material is a material that explains the need for the prefecture's project (at the meeting, a Fisheries Agency official gave the explanation), and the value of the benefit is an expected value. Of the overseas papers, for the Mediterranean, Sydney and South Australia papers we read only the abstracts.

The publisher of this paper (SeatecHIROSHIMA Ltd.) runs a business that controls the attachment of living things by surface treatment of materials. This covers both preventing fouling (antifouling) and making it easier for eelgrass (a kind of seagrass) to take root for the restoration of seaweed and seagrass beds. It is also developing a system that identifies the positions of oyster rafts and informs boats of them. This paper does not cover the company's own technology or results. This paper covers the decline of the Sargassum beds of Nanao Bay, the prefecture's works to build beds and the local activities, and the restoration of beds overlaps with the publisher's field of business. This paper also touches on the reliability of the method of identifying beds from satellite images. The publisher is developing, in joint research with Hiroshima University and others, a system that identifies the positions of oyster rafts using satellite data, and the analysis of satellite images overlaps with the publisher's field of development. The publisher's relationships with the organisations taken up in this paper and with organisations active in Nanao Bay are as follows (as of 12 November 2026; based on information the publisher has made public, the publisher's contracts and records, and the research for this paper). With Ishikawa Prefecture, there is the relationship of having been selected (in September 2025) for the prefecture's (Commerce, Industry and Labour Department, Industrial Policy Division) "survey project for attracting start-ups to Noto" (fiscal 2025 [Reiwa 7]). In this project, specialists accompany and support the selected companies in drawing up business plans and building connections in Noto (according to the prefecture's announcement). In October 2026, in the "Startup Business Plan Contest Ishikawa 2026" held by Ishikawa Prefecture and the Ishikawa Sunrise Industries Creation Organization, a public interest incorporated foundation, the publisher received the top entrepreneur award for a plan on the theme of Nanao Bay (according to the announcement on the Organization's website). The Organization's website states that this award comes with a subsidy and, among other things, the free loan for 3 years of a facility that rents rooms to newly founded companies. In Noto, the publisher collaborates, under non-disclosure agreements, with Nanaibe LLC and Yamaguchi Suisan of Nanao City, with Atsumasa Nakamura of Kanazawa University, and with the Noto fisheries profitability improvement council. With the Ishikawa Prefecture Fisheries Cooperative (which also has branches in Nanao Bay, and whose representative director and senior managing director is a member of the review committee for the prefecture's new Fisheries Promotion Vision), there is the relationship of having secured the site for the publisher's demonstration through its collaboration partner Nanaibe LLC. The Nanao branch of the same cooperative has joined the Ishizaki Satoumi Conservation Group quoted in this paper. A section manager and the chair of the

steering committee of the Nanao branch of the same cooperative, and a staff member of its purchasing business department, also attended the meetings of the Ministry of the Environment's model project run by the Wakura Onsen organisation and others, and in the interviews of the Doyukai report, the branches of the same cooperative were asked to cooperate. The publisher is not a member of the Noto fisheries profitability improvement council. The area in which the publisher has been involved in Ishikawa Prefecture is mainly Nanao Bay, which overlaps with the area of this paper. On the Sotoura coast (Shika Town, Wajima City and the north coast of Suzu City as far as Jike), the publisher is not active. Among the materials quoted in this paper, a researcher who was at the time at the marine laboratory of Kanazawa University took part in the 2014 research report of the Noto Marine Center. One of the members of the review committee for the prefecture's new Fisheries Promotion Vision is also a person from the same university. The name of Atsumasa Nakamura does not appear among the authors of the materials quoted in this paper, or in the lists of members of that review committee or of the committee and survey team of the Doyukai report. Apart from the above, between the publisher and the organisations taken up in this paper (national government bodies, the prefecture and the cities and towns, the prefecture's research institutions, universities and research institutions, the business association and its survey team, the companies and organisations named in this paper, overseas universities and research institutions, and so on) or the organisations active in Nanao Bay (fishery cooperatives, local organisations and so on), there is no relationship of a kind that would affect the content of this paper. Relationship here means transactions, funding, joint research, and officers or employees of the publisher concurrently serving as employees or officers of that organisation. This is the publisher's judgement, made after checking the information the publisher has made public, the publisher's contracts and records, and the research for this paper.

6. Sources

We examined materials that had been published by 12 November 2026. Working mainly from materials of the national government and the prefecture, reports of the prefecture's research institutions and peer-reviewed papers, we used figures that a separate researcher had checked against the very materials listed as sources (for some of the overseas papers, the abstract only; this is written after the "Type" column of the table). Among the figures that materials quote from other surveys, there are some that we have not checked back to the original survey, and we have indicated this in the text. Values that this paper calculated from the values in the sources are marked "this paper's calculation", and things read from figures are marked "this paper's reading of the figure". Reliability: A = laws and regulations, statistics, materials of the national government and prefectures; B = papers, reports of research institutions that state their method; C = explanatory materials for the general public, explanations and reports by organisations, materials with little description of method; D = news reports.

ID	Source (publisher, year)	Type	Reliability	Chapters used
S1	Ishikawa Prefecture: Ishikawa Prefecture Seaweed and Seagrass Bed Vision (Ishikawa Prefecture plan for building seaweed and seagrass beds) (in Japanese) (March 2022. The area by district is in Table 2, the caution on the comparison and the prefecture's view on p. 5 of the PDF, the tidal currents in Table 4 and Figure 14 [pp. 24–25], feeding damage and environmental factors on p. 26, the enhancement grounds built so far in Table 6, the depth and the targets on pp. 28–29, and the plan in Table 8)	Plan	A	Chapters 1–5

ID	Source (publisher, year)	Type	Reliability	Chapters used
S2	Kanazawa Association of Corporate Executives (Kanazawa Keizai Doyukai), special committee for the survey of earthquake impacts on the coast of the Noto Peninsula: Fiscal 2025 (Reiwa 7) report of the survey of earthquake impacts on the coast of the Noto Peninsula (in Japanese) (issued 24 March 2026. The head of the team is Daisuke Fujita [president of the Japan Seaweed Association]. Grant from The Nippon Foundation, special cooperation of the Hokkoku Shimbun newspaper company. The prefecture's Fisheries Division and Fisheries Research Center were observers. Not peer-reviewed. This paper's "Doyukai report". The areas for Nanao Bay are in Tables 3-10 and 3-11, the field survey in Tables 3-4 and 3-5 and Figures 3-3 and 3-4, and the view on feeding damage in the overall summary)	Report	C	Chapters 1–5
S3	Yukimasa Higashide (Noto Marine Center), Shouzo Ogiso (Noto Marine Laboratory, Institute of Nature and Environmental Technology, Kanazawa University) and Takahiko Ikemori (Ishikawa Prefecture Fisheries Research Center): On the growth of eelgrasses in the West Bay of Nanao Bay, Noto Peninsula (in Japanese) (Report of the Noto Marine Center 20: 17-23, 2014. The survey of December 2011 is quoted from a lecture by Ikemori [2013])	Report	B	Chapters 1, 2, 5
S4	Kotaro Harada, Noriyuki Okei, Kei Senbokuya and Junichi Okuno: The present state of and issues for the environment and fisheries of enclosed bays: the case of Nanao Bay (in Japanese) (Systems, Control and Information 65(1): 3-6, 2021. An explanatory article in the journal of an academic society. The values for the West Bay are quoted from Ikemori, Higashide and Sakai [2016])	Explanatory	C	Chapters 2, 5
S5	Yukimasa Higashide, Hiroaki Arakawa and Yusuke Nakade: Monitoring survey of benthic invertebrates and of seaweeds and seagrasses on rocky shores after the 2024 (Reiwa 6) Noto Peninsula Earthquake (in Japanese) (Report of the Noto Marine Center 30: 83-102, 2025)	Report	B	Chapters 2, 5
S6	Environment Agency: 4th National Survey on the Natural Environment, report of the survey of the biological environment of sea areas, Volume 2, seaweed and seagrass beds (1994. national results; Ishikawa Prefecture; summary; appended tables (in Japanese). The survey in Ishikawa Prefecture was in fiscal 1990–1991)	Survey	A	Chapters 1, 2, 5
S7	Fisheries Agency: project assessment of fisheries-related public works (prior as - sessment, Material 4-2, Ishikawa Prefecture, Noto–Uchiura district fisheries envi - ronment improvement project; stenographic record of the proceedings, 8 March 2023. Prior assessment document (reference number 8), fiscal 2022 [Reiwa 4]) (in Japanese)	Material	A	Chapters 1–5
S8	Fisheries Agency: Reference materials: survey of the distribution of seaweed and seagrass beds using satellite image analysis technology (in Japanese) (the speci - fication for Ishikawa Prefecture's fiscal 2018 [Heisei 30] survey of beds in the Noto–Uchiura district. The PDF was created in June 2020)	Material	A	Chapters 1, 2, 5
S9	Biodiversity Center of Japan, Ministry of the Environment: Survey of seaweed and seagrass beds, Sea of Japan coast of southern Honshu sea area, Nanao Bay (in Japanese) (survey of 18–19 June 2020)	Survey	A	Chapter 2
S10	Ministry of the Environment: List of wetlands of high importance from the view - point of biodiversity (important wetlands) (in Japanese) (No. 251 Nanao Bay. Version of April 2016)	Material	A	Chapter 2
S11	Ishikawa Prefecture: Nanao Bay area (Ishikawa Prefecture) comprehensive fish - eries infrastructure improvement project plan (R4-R8) (in Japanese) (from fiscal 2022. The placing and monitoring of parent seaweeds are on p. 5, turbidity and the policy on beds on p. 7, and oyster shells and blue carbon on p. 10)	Plan	A	Chapters 1, 2, 4
S12	Ishikawa Prefecture: Fisheries environment improvement project, Noto–Uchiura district (general), plan of the fishing grounds and detailed location map (in Japanese) (the PDF was created on 12 June 2026)	Plan	A	Chapters 1, 3–5

ID	Source (publisher, year)	Type	Reliability	Chapters used
S13	Ishikawa Prefecture: Budget explanatory material for fiscal 2026 (Reiwa 8) (in Japanese) (January 2026. The Fisheries Division's cost of the wide-area enhance - ment ground construction project)	Budget	A	Chapters 3–5
S14	Ishikawa Prefecture: Ishikawa Fisheries Promotion Vision (in Japanese) (2017. The description of barren ground [isoyake], and the table of the ranking of the area of seaweed and seagrass beds)	Plan	A	Chapters 1, 2, 5
S15	Ishikawa Prefecture: Review committee for drawing up the new "Ishikawa Fisheries Promotion Vision", 1st meeting, meeting materials (in Japanese) (4 September 2026. The values of the distribution maps of beds are for the whole coast of the prefecture); list of committee members	Meeting	A	Chapters 3–5
S16	Takahiko Ikemori (Ishikawa Prefecture Fisheries Research Center): The present state of the seaweed and seagrass beds of Ishikawa (in Japanese) (Fisheries Research Center newsletter No. 52: 12, May 2017)	Explanatory	C	Chapters 2, 5
S17	Hitoumi.jp (information website of the measures to bring out the multiple func - tions of fisheries; a project commissioned by the Fisheries Agency): Ishizaki Satoumi Conservation Group (Nanao City, Ishikawa Prefecture); list of the state of activities in Ishikawa Prefecture (in Japanese) (viewed November 2026. The ac - tivities and effects are as described by the group)	Explanatory	C	Chapters 1, 3
S18	JF Zengyoren (National Federation of Fisheries Co-operative Associations) and others: Fiscal 2025 (Reiwa 7) survey report of the commissioned project to support measures for strengthening the productivity of fishing grounds and the multiple functions of fisheries (in Japanese) (a project commissioned by the Fisheries Agency, March 2026. The table of the dispatch of experts)	Report	C	Chapters 3, 4
S19	Noto Marine Center: Noto no Kaichurin (The undersea forests of Noto) No. 58 (in Japanese) (March 2023. The article on rabbitfish and parrotfishes)	Explanatory	C	Chapters 2, 5
S20	Wakura Onsen council for promoting creative reconstruction and town develop - ment: Fiscal 2025 (Reiwa 7) report on the implementation of the model project in the work of supporting the building of a foundation for the conservation and use of seaweed and seagrass beds and tidal flats through satoumi creation (in Japanese) ("Nanao Bay satoumi project around Wakura Onsen", February 2026. A project of the Ministry of the Environment)	Report	C	Chapters 3, 5
S21	Fisheries Agency: Guidelines for Measures against Barren Ground (Isoyake), 3rd edition (in Japanese) (March 2021. The 2020 questionnaire is on p. 60, herbivorous fish on p. 31, and the spread from spore bags on p. 143)	Guidelines	A	Chapters 2, 3
S22	Masasuke Baba (Marine Ecology Research Institute): Growth responses and dis - tribution shifts of large brown algae due to warming (in Japanese) (presentation at the fiscal 2021 [Reiwa 3] national council on measures against barren ground [isoyake], March 2022)	Presentation	C	Chapters 2, 4
S23	Tanaka et al.: Warming off southwestern Japan linked to distributional shifts of subtidal canopy-forming seaweeds (Ecology and Evolution 2(11): 2854-2865, 2012. CC BY. Abstract checked)	Paper	B	Chapters 2, 5
S24	Vergés et al.: The tropicalization of temperate marine ecosystems (Proceedings of the Royal Society B 281: 20140846, 2014. Abstract checked)	Paper	B	Chapter 2
S25	Thibaut et al.: Long-term decline of the populations of Fucales (Cystoseira spp. and Sargassum spp.) in the Albères coast (Marine Pollution Bulletin 50(12): 1472-1489, 2005. Abstract only checked)	Paper	B	Chapters 2, 5
S26	Kautsky et al.: Decreased depth penetration of Fucus vesiculosus since the 1940's indicates eutrophication of the Baltic Sea (Marine Ecology Progress Series 28: 1-8, 1986. Abstract checked)	Paper	B	Chapters 2, 5

ID	Source (publisher, year)	Type	Reliability	Chapters used
S27	Coleman et al.: Absence of a large brown macroalga on urbanized rocky reefs around Sydney, Australia, and evidence for historical decline (Journal of Phycology 44(4): 897-901, 2008. Abstract only checked)	Paper	B	Chapters 2, 5
S28	Gorman and Connell: Recovering subtidal forests in human-dominated landscapes (Journal of Applied Ecology 46(6): 1258-1265, 2009. Abstract only checked)	Paper	B	Chapter 2

Related materials: R2 Seaweed and seagrass beds and the living things of the sea, R7-A02 The rise in seawater temperature in Nanao Bay, R7-A03 The decrease in the eelgrass beds of Nanao Bay, R7-A05 Turbidity and fluid mud in Nanao Bay, R7-A17 The mass occurrence of seaweed in Nanao Bay, R7-A19 Land subsidence and flooding in Nanao Bay, R7-A25 Damage to set nets and aquaculture facilities from sudden strong currents (kyucho) in Nanao Bay, R7-B01 Earthquake uplift on the Sotoura coast, R7-B08 Shallow seaweed beds dried out by uplift, and the decrease in the area of seaweed beds in Sotoura, R7-B11 Barren ground (isoyake) that has continued since before the earthquake, and the decline of the seaweed beds of the offshore islands, I1 List of assessments