R7-B11 Barren ground (isoyake) that has continued since before the earthquake, and the decline of the seaweed beds of the offshore islands

How have the seaweed beds of the offshore islands of Sotoura (Hegurajima Island, the Nanatsujima Islands and Yomeguri reef) and of the Wajima coast declined since before the earthquake? What did the surveys after the earthquake find, and how reliable are those values and the reasons given?

Readers

Fishers and ama (women divers), fishery cooperatives, local governments (staff in charge of fisheries), research institutions and others without specialist knowledge, who want to check, with figures and sources, how the seaweed beds of the offshore islands of Sotoura and of the Wajima coast declined since before the earthquake and changed after the earthquake, and how reliable those values and the reasons given are.

Takeaways

1. Barren ground (isoyake) is a state in which seaweed beds on rocky shores (places where seaweeds grow thickly) have declined beyond their ordinary rises and falls and remain lost. In Wajima, fishers were saying before the earthquake that kajime kelps had decreased compared with several decades earlier. Kajime kelps are large seaweeds such as tsuruarame. The ama (women divers) had also reported barren ground at the offshore Nanatsujima Islands. The prefecture, too, stated in its 2022 plan that a declining trend was seen in the seaweed beds of parts of Hegurajima Island and the Nanatsujima Islands. However, in 2017 the prefecture stated that no large-scale barren ground had been confirmed on the prefecture's coast.
2. There is a report of a survey made after the earthquake, in November 2025, of 32 points at Hegurajima Island and 13 points at the Nanatsujima Islands, using an underwater camera lowered from a boat and other means. Compared with the records for the same points in July 2019, at both islands the runs of points where tsuruarame grew densely in deep water had decreased. The pattern in which seaweeds are arranged from shallow water to deep water had been kept. Because the season differs, how thickly the Sargassum species grew has not been compared. This report is a report of a survey by a business association, and it is not peer-reviewed.
3. The area of the islands' seaweed beds measured from satellite images had also decreased greatly from the survey of fiscal 2019, before the earthquake. Hegurajima Island went from 1,941 ha to 862 ha, the Nanatsujima Islands from 662 ha to 162 ha, and Yomeguri reef from 253 ha to 55 ha. The ha is a unit of area, and 1 ha is a square of 100 m on each side. What decreased was mainly the beds in deep water that include kajime kelps, and the beds of Sargassum species had increased. The values for Hegurajima Island and Yomeguri reef are from images of 2024, after the earthquake. Even for the same island, the area changes greatly with the survey method.
4. The reason for the decrease has not been confirmed. The report presumes that it is the result of recent changes in climate combined with the tsunami and uplift of the earthquake. The movement of the ground at Hegurajima fishing port was 0.1 m or less, and it can be said that the decrease in the deep water of Hegurajima Island is hard to explain by uplift alone (this paper's view). On the other hand, traces of a tsunami 2.9 m high have been found at Hegurajima fishing port. According to the Japan Meteorological Agency, in the central Sea of Japan and the south-western Sea of Japan, which are close to the sea off the Noto Peninsula, the sea surface

temperature has risen by 2.05°C and 1.57°C per 100 years. We found no source that measured feeding damage by sea urchins or fish in the deep water of the islands.

5. Shellfish had also been decreasing since before the earthquake. According to a prefectural body, the abalone catch of Wajima City fell from 41 t in 1983 to 6 t in 2014. A decrease in tsuruarame is considered to be one of the reasons. A local group has removed sea urchins, and the prefecture has placed parent seaweeds (the parent seaweeds that give out seed) and built foundations for seaweed beds. However, we found no source showing an effect on the decline in the deep water of the islands.

After reading When using the values for the seaweed beds of the offshore islands, or the term "barren ground (isoyake)", in documents or plans, state which material the value comes from, the year and season of the survey, the survey method (satellite images, underwater camera, diving, interviews) and the water depth. The difference between fiscal 2019, before the earthquake, and 2024–2025, after the earthquake, may also include change that has continued since before the earthquake and differences in survey methods, so do not treat it as the effect of the earthquake alone.

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

- Barren ground (isoyake) is a state in which seaweed beds on rocky shores (places where seaweeds grow thickly) have declined beyond their ordinary rises and falls and remain lost. In Wajima, fishers were saying before the earthquake that kajime kelps had decreased compared with several decades earlier. Kajime kelps are large seaweeds such as tsuruarame. The ama (women divers) had also reported barren ground at the offshore Nanatsujima Islands. The prefecture, too, stated in its 2022 plan that a declining trend was seen in the seaweed beds of parts of Hegurajima Island and the Nanatsujima Islands. However, in 2017 the prefecture stated that no large-scale barren ground had been confirmed on the prefecture's coast. [S15, S6, S7, S2, S3]
- There is a report of a survey made after the earthquake, in November 2025, of 32 points at Hegurajima Island and 13 points at the Nanatsujima Islands, using an underwater camera lowered from a boat and other means. Compared with the records for the same points in July 2019, at both islands the runs of points where tsuruarame grew densely in deep water had decreased. The pattern in which seaweeds are arranged from shallow water to deep water had been kept. Because the season differs, how thickly the Sargassum species grew has not been compared. This report is a report of a survey by a business association, and it is not peer-reviewed. [S1]
- The area of the islands' seaweed beds measured from satellite images had also decreased greatly from the survey of fiscal 2019, before the earthquake. Hegurajima Island went from 1,941 ha to 862 ha, the Nanatsujima Islands from 662 ha to 162 ha, and Yomeguri reef from 253 ha to 55 ha. The ha is a unit of area, and 1 ha is a square of 100 m on each side. What decreased was mainly the beds in deep water that include kajime kelps, and the beds of Sargassum species had increased. The values for Hegurajima Island and Yomeguri reef are from images of 2024, after the earthquake. Even for the same island, the area changes greatly with the survey method. [S1, S2]
- The reason for the decrease has not been confirmed. The report presumes that it is the result of recent changes in climate combined with the tsunami and uplift of the earthquake. The movement of the ground at Hegurajima fishing port was 0.1 m or less, and it can be said that the decrease in the deep water of Hegurajima Island is hard to explain by uplift alone (this paper's view). On the other hand, traces of a tsunami

2.9 m high have been found at Hegurajima fishing port. According to the Japan Meteorological Agency, in the central Sea of Japan and the south-western Sea of Japan, which are close to the sea off the Noto Peninsula, the sea surface temperature has risen by 2.05°C and 1.57°C per 100 years. We found no source that measured feeding damage by sea urchins or fish in the deep water of the islands. [S1, S9, S10, S11]

- Shellfish had also been decreasing since before the earthquake. According to a prefectural body, the abalone catch of Wajima City fell from 41 t in 1983 to 6 t in 2014. A decrease in tsuruarame is considered to be one of the reasons. A local group has removed sea urchins, and the prefecture has placed parent seaweeds (the parent seaweeds that give out seed) and built foundations for seaweed beds. However, we found no source showing an effect on the decline in the deep water of the islands. [S4, S6, S2, S30]

2. What is happening

Japan and the world: barren ground, and decline that advances from deep water offshore

Barren ground (isoyake) is a state in which seaweed beds on rocky shores have declined beyond their ordinary rises and falls and remain lost. The Fisheries Agency's Guidelines for Measures against Barren Ground (Isoyake) (2021; hereafter, the national guidelines) give, as the wording of a 2002 report by Daisuke Fujita, that it is when, on rocky shores of the shallow sea or on stony seabeds, communities of seaweed (seaweed beds) decline markedly or disappear beyond the range of the seasonal rises and falls and of some change from year to year, and a state poor in seaweed results. The guidelines state that, once barren ground occurs, it takes many years for the seaweed beds to return, and the resources of the rocky shore such as abalone and turban shells (rocky-shore resources) decrease or grow poorly. [S15, S16]

There are said to be 4 routes by which the seaweeds of a seaweed bed decrease. The national guidelines state that seaweeds decrease because they are eaten by animals that eat seaweed, die back, stop sprouting, or are washed away, or because of a combination of these. They state that the warming of recent years works in the direction of reducing seaweeds on every one of these 4 fronts. They state that, when the seawater temperature rises suddenly, seaweeds die back, but that in many cases, before the temperature at which they die back (for example 30°C) is reached, they are eaten up by animals that eat seaweed at a lower temperature (for example 27°C). [S15]

Barren ground is said often to advance from deep water offshore. The national guidelines divide the ways in which places poor in seaweed appear from the shore to the offing into 5 types, and state that "offshore barren ground" (oki-yake), in which seaweeds decline from the offshore (deep-water) side, is the most usual. Seaweed beds remain on the shore side because, in shallow water, the movement of the seawater is large, so that the harm from animals that eat seaweed and from fluid mud (light mud that settles on the seabed) is held down and the growth of seaweeds is also helped. Fujita (2002) also states that what is most commonly seen is offshore barren ground. [S15, S16]

However, offshore barren ground is also a type that is easy to misjudge. The national guidelines state that, when judging barren ground, the case most liable to error is that of offshore barren ground. This is because the offshore side of a seaweed bed is often a place that was poor in seaweed to begin with, for reasons such as lack of light, stagnant seawater, the presence of fluid mud, and sea urchins constantly eating the seaweed. The amount and area of seaweed beds and the lower depth limit at which seaweeds grow ordinarily change more or less from year to year, and the guidelines state that such places that are always poor in seaweed, and such small rises and falls, are not called barren ground. Fujita (2002) also states that the place on the offshore side that is always poor in seaweed should be called barren ground only when the balance has broken down and the place poor in seaweed has spread towards the shore side. [S15, S16]

On the seabed of barren ground, calcareous seaweeds that cover the rock like a crust stand out. According to the national guidelines, what often covers the rock on the seabed of barren ground is non-geniculate coralline algae (red algae like a calcareous crust), which are not readily eaten by sea urchins and the like, and which go on growing thickly even in the place on the offshore side of a seaweed bed that is always poor in seaweed. The guidelines state that the period for which barren ground continues is about several years where it is due to temporary changes in the weather or the sea, but that, where the reason that makes it hard for seaweed beds to form continues, it may extend to half a century or more. When barren ground continues, abalones and turban shells decrease and shellfish with thin meat increase, and sea urchins such as the purple sea urchin (murasaki-uni) and the long-spined sea urchin (gangaze) may increase. [S15]

Japan and the world: rising water temperature, and the decline of beds of kajime kelps

The decline of Japan's seaweed beds has not been grasped clearly in national figures. The national guidelines state that the area of seaweed beds and of barren ground nationwide has not been surveyed continuously over the same range and by the same standard, and that how much barren ground has increased is not known. As a rough guide, it was estimated in 2008, from materials for part (about 42%) of the sea areas, that seaweed beds had decreased by 22% from around 1990 (quoted from a 2009 report of the Marine Ecology Research Institute). How seaweed beds nationwide have decreased, and the causes, are dealt with in R2 "Seaweed and seagrass beds and the living things of the sea". [S15]

The way they decline differs from sea area to sea area. In the summary by sea area in the national guidelines, the main seaweed beds of the northern Sea of Japan, in which Ishikawa Prefecture falls, are Sargassum beds (beds of the large seaweeds called Sargassum species) and kajime (tsuruarame) beds. In this sea area, the guidelines state, seaweed beds are tending to decline, but conspicuous barren ground and places where the kinds of seaweed forming the beds have changed are local. The animals that eat seaweed and cause problems are the purple sea urchin, the northern purple sea urchin (kita-murasaki-uni), small sea snails (okoshidaka-gangara) and others, and south of Sado, feeding damage by aigo (rabbitfish), a fish that eats seaweed, is also often seen. In the western Sea of Japan, too, barren ground is said to be local. On the other hand, in the East China Sea, which includes Iki and Tsushima, barren ground is occurring throughout, and there are places where kajime (tsuruarame) beds have changed into Sargassum beds or beds of small seaweeds. That Ishikawa Prefecture falls in the northern Sea of Japan is based on a reading of the figure in the guidelines and on the division of sea areas in the statistics on agriculture, forestry and fisheries. [S15]

At Iki Island, north-west of Kyushu, the beds of kajime kelps disappeared after summers of high water temperature. According to a study (a 2021 paper) that surveyed, once every year from 2004 to 2018, the water temperature and the distribution by depth of seaweeds of the kajime kelps off Waka on Iki Island, the distribution widened in 2004–2007, when the summer water temperature was low. In 2010, 2013 and 2016, when the summer water temperature was high, many seaweeds lost their blades, and in the following year the number of large seaweeds fell greatly. In 2011 and 2014, many young seaweeds were newly added and the beds were kept, but in 2017 the young seaweeds were very few, and in 2018 neither large seaweeds nor young seaweeds were seen any longer. The authors consider that the decline of the large seaweeds at high water temperature and the failure of young seaweeds to be added afterwards were the causes of the disappearance. The discussion in the main text presumes that the decline in the years of high summer water temperature was due, in addition to the loss of blades at high water temperature and other things, to the feeding damage by fish that eat seaweed that occurs in autumn, and states that the influence of sea urchins was small. This paper states that, in Shizuoka, Kochi and Wakayama, it has been reported that the catch of abalones fell greatly along with the decline of kajime kelps (quoted). A report of a survey commissioned by the Fisheries Agency (March 2026; a study of building seaweed beds in step with the rise in seawater temperature) also states that, in the sea of Iki

City, kurome, a relative of tsuruarame, is now almost not seen in the wild, and that the rise in seawater temperature appears to be the main factor. [S18, S19]

There are also cases in which kajime kelps died back all at once in a summer of high water temperature. A presentation (2022) by a researcher at the Marine Ecology Research Institute cites a report (2014) stating that, in the summer of 2013, water temperatures 2°C or more above normal continued on the Sea of Japan coast of western Japan, and arame and kajime kelps died back and were washed away in large quantities. The national guidelines also state that, in the same summer of 2013, in the East China Sea, arame and kajime kelps were washed away in large quantities by typhoon waves during the period of high water temperature (quoted from a 2014 report). [S17, S15]

Kajime kelps are said to be more vulnerable to high water temperature than Sargassum species. The same presentation, from a summary of experiments in which they were grown indoors, gives the upper-limit water temperature at which warm-water kelps such as kajime, kurome, tsuruarame and arame grow as 26–30°C and the water temperature at which they grow well as 10–27°C, and states that these are lower than for Sargassum species (upper limit 27–33°C, growing well at 14–30°C). In the northern seas, the opposite movement is also seen. At Cape Oma on the Shimokita Peninsula, in 1976–2001, cold-water kelps decreased and warm-water kelps such as aowakame and tsuruarame increased (quoted from a 2006 study). In the questionnaire to the prefectures summarised by the national guidelines, too, it is said that in eastern Japan there are places where kombu beds have shifted to beds of tsuruarame or of Sargassum species. [S17, S15]

Southern creatures that eat seaweed are also spreading northwards. According to the national guidelines, the long-spined sea urchin (gangaze) and arasaki-gangaze, sea urchins common in southern seas, are distributed, on the Sea of Japan side, south of the Noto Peninsula. Noto-isuzumi, a fish that eats seaweed, is distributed on the coasts of the Sea of Japan and the East China Sea from the Noto Peninsula to the southern shore of Kyushu, among other places, and feeding damage has been reported in Fukuoka, Nagasaki and Shizuoka. On the Oga Peninsula in Akita Prefecture, a replacement is said to be taking place in which the purple sea urchin is increasing and the northern purple sea urchin is decreasing (quoted from a 2019 study). The rate of the amount that the purple sea urchin eats in 1 day is said to be highest at a water temperature of 20–25°C. [S15]

There is also a study stating that, over the whole of Japan's coast, warming has been changing the make-up of seaweed beds. A study (a 2018 paper) that examined the movements in distribution of 45 species of seaweeds, corals and fish that eat seaweed, from records of 60 years or more centred on 1950–2015, states that warming and ocean currents such as the Kuroshio are shrinking the communities of temperate seaweeds and spreading corals and tropical fish that eat seaweed northwards. [S28]

In the world, too, the change in which sea urchins eat up forests of seaweed is occurring widely on temperate rocky shores. A study (a 2015 paper; 10,901 quadrat surveys and 57 experiments changing conditions in the field) that examined 13 communities of rocky-shore creatures in 11 regions of both hemispheres states that, through sea urchins eating seaweed, a "catastrophic" switch occurs in which seaweed beds collapse suddenly. It states that there is a difference of about one order of magnitude (10 times) between the amount of sea urchins when the beds collapse and the amount of sea urchins when the urchins decrease and the beds return, and that, to bring the beds back, the sea urchins need to be reduced to far fewer than when the collapse began. There is also a review article (2014) stating that the "urchin barren", in which sea urchins and calcareous seaweeds cover the seabed, can continue as a different stable state after the beds have collapsed. This review article states that climate change and human influence are making this switch more likely to occur. [S22, S23]

When warming and other human influences are combined, sudden change is said to occur more easily. In the east of the island of Tasmania, Australia, the seawater temperature rose at about 4 times the speed of the world average, and the distribution of a sea urchin related to the long-spined sea urchin spread southwards and it began to eat the seaweed beds. From surveys and experiments inside and outside marine protected areas, it is

said that overfishing of large relatives of the spiny lobster that eat sea urchins lowered the power of the seaweed beds to withstand without collapsing (a 2009 paper). [S24]

In Western Australia, after decades of warming, in the extreme marine heatwave of 2011 (a marine heatwave is a state in which the water temperature of the sea remains abnormally high), the beds of seaweeds of the kajime genus contracted the edge of their distribution by 100 km. The beds changed into a state covered by turf-like seaweeds, and were replaced by tropical seaweeds, animals and fish. This change is said to be hindering the return of the beds (a 2016 paper). A presentation by a researcher in Japan reports that, in the following years 2016–2019, the beds did not return even though the water temperature was low, and the amount eaten by fish that eat seaweed increased (quoted from a 2021 study). [S25, S17]

There is also a case in which the collapse of seaweed beds went as far as stopping a shellfish fishery. In the north of the US state of California, in 2014, the forests of bull kelp, a kelp, were lost by more than 90% along more than 350 km of coast, and changed into urchin barrens of the American purple sea urchin (a different species from Japan's purple sea urchin). A mass die-off of starfish (from 2013), strong high sea water temperatures (2014–2017) and urchin barrens (from 2015) came together. In 2017, 80% of a species of abalone (red abalone) died, and in 2018 the recreational abalone fishery, estimated at 44 million US dollars, was closed, and the commercial fishery (3 million US dollars) for another species of sea urchin (its English name is red sea urchin) also collapsed (a 2019 paper). [S26]

However, it is not the case that all the seaweed beds of the world are decreasing. In a study (a 2016 paper) that gathered the records of seaweeds of the kelp order over the past half-century, of the sea regions (ecoregions) examined, they decreased in 38%, increased in 27% and were unchanged in 35%. The study states that the differences between regions greatly exceed the small decrease in the world average (−0.018 per year as a rate of change), and that, because regional factors are strong, it is important to keep watch region by region. [S27]

There is a report that the effect of a tsunami on seaweed beds differed greatly from place to place. Of 2 seaweed beds in Sanriku that had been surveyed since before the Great East Japan Earthquake of 2011, at Tomarihama on the Oshika Peninsula only a little of the arame, a large seaweed that lives for many years, was lost to the tsunami. Afterwards, because sea urchins decreased greatly, young arame grew over a wide range of depths and the bed spread into deep water. In the kelp bed at Nagane in Otsuchi Bay (written "Nagane" in the abstract), the amount did not change greatly, and no clear decrease of sea urchins was seen either (a 2017 paper). [S29]

Table 1 Main cases in Japan and abroad in which beds of large seaweeds declined through rising water temperature, sea urchins and the like

Place and period	What happened	Reasons given	Material
Sea of Japan coast of western Japan (summer of 2013)	Arame and kajime kelps died back and were washed away in large quantities	Water temperature 2°C or more above normal	Presentation by a research institute (quoted from a 2014 report)
Waka, Iki Island (2004–2018)	The beds of kajime kelps disappeared. In 2018, neither large seaweeds nor young seaweeds	Decline through high water temperature and feeding damage by fish in autumn, and the failure of young seaweeds to be added	Paper (2021)
East of the island of Tasmania (Australia)	The distribution of sea urchins spread southwards, and they began to eat the seaweed beds	Fast rise in water temperature, overfishing of relatives of the spiny lobster	Paper (2009)

Place and period	What happened	Reasons given	Material
Western Australia (2011)	Beds of the kajime genus con - tracted the edge of their distrib - ution by 100 km and changed into turf-like seaweeds	Extreme marine heatwave	Paper (2016)
North of the state of California (USA, from 2014)	Forests of bull kelp were lost by more than 90% along more than 350 km of coast, and the abalone fishery was closed	Mass die-off of starfish, high water temperature, increase of sea urchins	Paper (2019)
World (past half-century)	Decrease in 38% of the ecore - gions examined, increase in 27%, no change in 35%	Regional factors are strong	Paper (2016)
Offshore islands of the Sotoura coast of the Noto Peninsula (2019–2025)	The "Region (Sotoura)" sections of this chapter	The same sections	Report (2026) and others

Note: The values are as worded in each material. Because both the survey methods and the seas differ, they cannot be compared as they stand (chapter 5). For the English-language papers, we read only the abstracts (for the California case, we also checked the names of the species alone in the main text). [S17, S18, S24, S25, S26, S27, S1]

Region (Sotoura): the offshore islands, and the islands' seaweed beds before the earthquake

Sotoura is the coast of the Noto Peninsula on the Sea of Japan side. In this paper, it refers to the coast of Shika Town, Wajima City (including Monzen, Hegurajima Island and the Nanatsujima Islands), and the north coast of Suzu City as far as Jike. The offshore islands that this paper covers are Hegurajima Island, the Nanatsujima Islands and Yomeguri reef, off Wajima. According to the Ministry of the Environment, Hegurajima Island is an island about 50 km north of the Noto Peninsula, and the Nanatsujima Islands are a group of 7 islands about 20 km north of Wajima City. The Nanatsujima Islands are divided into a northern group (Oshima, Karimatajima and Tatsushima) and a southern group (Aramikojima, Eboshijima, Akashima and Mikuriyajima). According to the Plan for Revitalising Fishing Communities (Hama Plan) of the ama subcommittee of the Wajima district regional fisheries revitalisation committee (fiscal 2015–2019; hereafter, the ama subcommittee's plan), Yomeguri reef is a rocky reef 18 km offshore from the boundary between Wajima City and Suzu City that sinks beneath the sea on rough days, and it is used for ama fishing. The decline of the Sargassum beds of Nanao Bay is a matter of a different sea, and is dealt with in R7-A04 "The decline of the Sargassum beds of Nanao Bay". [S12, S31]

The offshore islands are important fishing grounds for the ama fishing of Wajima and for the islands' fisheries. The Ministry of the Environment has selected the seas around Hegurajima Island and the Nanatsujima Islands as "marine areas of high importance from the viewpoint of biodiversity", and states that at both, Sargassum beds extend and there are many rare warm-water species (for Hegurajima Island, that there are considered to be many). At Hegurajima Island, fishing by ama for abalone, turban shells, wakame, tengusa and other species is thriving. According to the prefecture's comprehensive fisheries infrastructure improvement project plan for the Kaga–Noto Sotoura area (2022; hereafter, the Sotoura fisheries infrastructure plan), Hegurajima fishing port is a landing base centred on ama fishing and gill nets, with 57 registered fishing boats, landings of 182 t (tonnes) and 113 million yen, and landings of turban shells and abalone from ama fishing of 28 t, among the highest in the prefecture. The year is not written, but 182 t is the same as the amount of landings at Hegurajima port in fiscal 2019 shown in another plan of the prefecture (this paper's cross-check). [S12, S5, S34]

On the islands' fishing grounds, seaweeds, shellfish and sea urchins are all targets of the local fisheries. According to the prefecture's fishing ground plan (as changed in June 2026), there are common fishery rights (rights under which the local fishers fish as a body) for the waters off Hegurajima Island (Common No. 9), the waters off Mikuriyajima, Eboshijima and Aramikojima in the southern group of the Nanatsujima Islands (Common No. 10), the waters off Oshima and Tatsushima in the northern group (Common No. 11) and Yomeguri reef (Common No. 12). The fisheries under the 3 fishery rights of Hegurajima Island and the Nanatsujima Islands include, besides abalone, turban shells and wakame, a kajime fishery and a sea urchin fishery. The fisheries under the fishery right of Yomeguri reef are abalone, turban shells, wakame, tengusa and others, and do not include the kajime and sea urchin fisheries. The seaweeds called "kajime" in Noto are tsuruarame and kurome. The duration of all 4 common fishery rights is from 1 September 2023 to 31 August 2033. [S39, S4]

In a national survey about 20 years ago, too, communities of tsuruarame were growing in the deep water of Hegurajima Island. The seaweed bed survey of the Ministry of the Environment's 7th National Survey on the Natural Environment (a 2008 report) surveyed the inside of the harbour of Hegurajima Island and the waters off the detached rocks in the north-east in July 2003 (the survey date on the Hegurajima Island page of the report is 8 July 2004; chapter 5). It states that there were Sargassum beds in shallow water, and that in the deep water that remains under the sea even when the tide goes out (the sublittoral zone) there was a typical bed of the open-sea, offshore type, in which tsuruarame and non-geniculate coralline algae grew together. It had not become a crowd of northern purple sea urchins (when they are many, barren ground results), and no traces of fish having eaten the seaweed were seen either. When the seaweed inside a quadrat of 50 cm on each side was cut and collected at a water depth of 12 m in the north-east of the island, the dry weight was 452 g, and 99.1% of it (448 g) was tsuruarame. The report, citing 1971 material of the prefecture's fisheries experimental station, states that Hegurajima Island is a good fishing ground for abalone and turban shells where communities of tsuruarame are developed. It states that the transparency is high and nature is well kept, but that the effects of warming and of feeding damage by fish are a concern for the future, and that the island is important as a point for continuing to watch natural seaweed beds. The same report also writes that, in the sublittoral zone of the Sotoura coast of the Noto Peninsula, feeding damage by aigo has been recognised. [S37]

In the prefecture's survey of fiscal 2019, too, beds of large seaweeds extended at the offshore islands. In fiscal 2019 (Heisei 31), the prefecture surveyed the seaweed beds of Sotoura by analysis of satellite images and by field surveys using an underwater camera from a boat and an instrument that probes the seabed with sound (a scanning sonar). Beds that were found are counted even in water deeper than 20 m. The prefecture's Ishikawa Prefecture Seaweed and Seagrass Bed Vision (March 2022; hereafter, the Bed Vision) states that good beds of large brown algae (brown seaweeds), of Sargassum species and arame kelps (kajime kelps), were confirmed, centred on the remote islands district (the Nanatsujima Islands, Hegurajima Island and Yomeguri reef) and the Wajima district. The area of seaweed beds in fiscal 2019 was 1,941.0 ha at Hegurajima Island, 661.8 ha at the Nanatsujima Islands and 253.2 ha at Yomeguri reef (Table 2). The ha is a unit of area, and 1 ha is a square of 100 m on each side. Most of the islands' seaweed beds were beds that include kajime kelps. The share taken up by arame beds and mixed beds of arame and Sargassum is 87% at Hegurajima Island, 95% at the Nanatsujima Islands and 93% at Yomeguri reef (the shares are this paper's calculation). [S2]

The area changes greatly with the survey method. In the Environment Agency's survey of fiscal 1990–91 (the 4th National Survey on the Natural Environment; covering water shallower than 20 m), the seaweed beds of the same 3 islands were 420 ha at Hegurajima Island, 225 ha at the Nanatsujima Islands and 0 ha at Yomeguri reef, and all were taken to be Sargassum beds. The prefecture states that the increase in the seaweed beds of Sotoura from 5,945 ha to 10,543 ha is due mainly to the difference in survey methods in the Wajima district and in the remote islands district of Hegurajima Island, Yomeguri reef and others, because the 4th survey covered only water shallower than 20 m while the survey of fiscal 2019 also included beds in water deeper than 20 m. [S2]

Table 2 Area of the seaweed beds of the offshore islands (3 surveys)

Island	Fiscal 1990–91	Fiscal 2019	After the earthquake	Change from fiscal 2019
Hegurajima Island	420 ha	1,941.0 ha	862 ha	−55.6%
Nanatsujima Islands	225 ha	661.8 ha	162 ha	−75.5%
Yomeguri reef	0 ha	253.2 ha	55 ha	−78.3%
Total	645 ha	2,856.0 ha	1,079 ha	−62.2%

Note: Fiscal 1990–91 is the Environment Agency's 4th National Survey on the Natural Environment (water shallower than 20 m; from the table in the Bed Vision), fiscal 2019 is the prefecture's survey (also including beds found in water deeper than 20 m; the values of the Bed Vision), and "after the earthquake" is the analysis of satellite images in the Doyukai report (values taking a cover of 25% or more as seaweed bed; the image of 1 September 2024 for Hegurajima Island, of 5 June 2025 for the Nanatsujima Islands, and of 22 March and 16 July 2024 for Yomeguri reef). Cover is the proportion of the seabed that seaweeds cover. The percentage changes are the report's values, and the report gives the fiscal 2019 values as whole numbers (Hegurajima Island 1,941 ha, Nanatsujima Islands 662 ha, Yomeguri reef 253 ha; the report writes the name of the Nanatsujima Islands with a different character). The heading of the report's table gives the earlier survey as "survey of past fiscal years (Heisei 30 + Heisei 31)". The survey of Sotoura, including the islands, is that of fiscal Heisei 31 (fiscal 2019) (the Bed Vision). The Total row is this paper's calculation, and the percentage change of the total was found from the report's whole-number values (from 2,856 ha to 1,079 ha). Because the survey methods differ, the values of the 3 surveys cannot be compared as they stand (chapter 5). [S2, S1]

Region (Sotoura): the decline of seaweed beds and shellfish that was spoken of before the earthquake

Before the earthquake, there were materials reporting the decline of the seaweed beds and shellfish of the sea of Wajima. However, the wording and the basis differ from material to material.

In 2017, the prefecture stated that no large-scale barren ground had been confirmed on the prefecture's coast. The prefecture's "Ishikawa Fisheries Promotion Vision" (2017) stated that no large-scale barren ground had been confirmed so far, but that seaweed beds were disappearing in some sea areas, and that it was necessary to grasp the actual state of seaweed beds throughout the prefecture and to consider how to protect them. The prefecture states that it has supported activities to protect seaweed beds carried out by the ama, such as placing parent seaweeds (the parent seaweeds that give out seed) and removing sea urchins. [S3]

Around the same time, a prefectural body considered that the decrease in tsuruarame was involved in the decrease in abalone in Wajima City. The public relations magazine of the prefecture's Fisheries Research Center (January 2017) stated that the abalone catch of Wajima City had decreased from a peak of 41 t in 1983 and was 6 t in 2014, and that, as one of the reasons for the decrease, it was considered that tsuruarame had decreased compared with before. From 41 t to 6 t is a decrease of 85% (this paper's calculation). The name of the statistics on which the figures are based is not written. According to this magazine, tsuruarame is an especially important food for abalone. The ama have protected the resource by closed areas, a shortened fishing season and size limits, but the magazine states that the resource "has not reached recovery". [S4]

The material of a local group writes of the decrease in shellfish and the decrease in kajime kelps. A material explaining the activities of the "Wajima Satoumi Conservation Group" of fishers and residents (launched in 2012; hereafter, the Conservation Group) (from around 2016; the writer is Ryoko Ishikawa, a specialist who supports the group) states that the catch of shellfish such as abalone and turban shells has halved in the last 10 years (the underlying statistics and the range are not written). In the group's observations down to a water depth of 20 m,

Sargassum species and kajime kelps were growing at a cover of 5–10% even in deep water. On the other hand, there were voices from local fishers that seaweeds, especially kajime kelps, had decreased compared with several decades earlier. The material states that barren ground advancing from deep water (offshore barren ground) needs to continue to be watched with care. It states that tsuruarame, too, according to local fishers, has tended to decrease in recent years, and that, because the decline of kajime kelps is a concern, monitoring that measures the amount will be continued. [S6]

The plan of the ama of Wajima and the site of a national programme also write of the decline of seaweed beds. The ama subcommittee's plan (drawn up in 2016) states that, in addition to it not being known whether the number of ama can be kept, the decrease in the abalone and turban shell resources and the decline of seaweed beds are a concern. The information site of a Fisheries Agency programme (posted in September 2020) introduces the activities of the Conservation Group, stating that in Wajima abalone, turban shells and others have decreased recently, that the decline of seaweed beds has been pointed out as the cause, and that barren ground at the Nanatsujima Islands has also been reported by the ama. The place, time and extent of this report are not written. [S31, S7]

The prefecture, too, in its Bed Vision of 2022, acknowledges the decline of part of the seaweed beds of the offshore islands. The Bed Vision states that in Sotoura the area of seaweed beds increased (a difference in survey methods), but that a declining trend is seen in parts of Hegurajima Island and the Nanatsujima Islands, and that part of the arame beds is declining. The figures of the islands' seaweed beds carry marks for places that have declined and places with no decline, and underwater photographs. The marks are at several places per island, and are not an assessment of the whole island as an area (this paper's reading). The prefecture stated that it would give priority in treatment to the districts of Hegurajima Island and the Nanatsujima Islands, where ama fishing depends on seaweed beds to a high degree and where the importance of bringing back the beds is also high as a spawning ground for red sea bream (chapter 3). [S2]

On the other hand, the prefecture states that the feeding damage confirmed in the prefecture is not of an amount that would lead to the decline of seaweed beds. According to the Bed Vision, what has been confirmed is feeding damage by aigo, by small sea snails such as koshidaka-gangara, and by the purple sea urchin. It states that the rise in water temperature is continuing, and that there is concern that the amount these creatures eat will increase and that budai (parrotfish), nizadai (sawtail) and gangaze (long-spined sea urchin) will spread northwards. The Sotoura fisheries infrastructure plan (2022) also forecasts that, with the rise in sea surface temperature accompanying the climate change of recent years, effects such as a decrease in the catch as a whole will continue for a long time. [S2, S5]

The islands' landings had also been decreasing since before the earthquake. According to a table in the prefecture's plan on the maintenance of local communities in Ishikawa Prefecture's specified inhabited remote border island areas (drawn up in 2017, revised in 2022; hereafter, the border islands plan), the amount of landings at Hegurajima port fell from 361 t in fiscal 2015 to 176 t in fiscal 2017, and was 180 t in fiscal 2018, 182 t in fiscal 2019 and 155 t in fiscal 2020. The value fell from 201.87 million yen in fiscal 2015 to 113.75 million yen in fiscal 2019 and 79.81 million yen in fiscal 2020 (material of the Wajima branch of the prefectural fisheries cooperative; the heading of the table is "year", but the same plan elsewhere gives 361 t as the value for fiscal Heisei 27 [2015]). In the table of main fishery products that follows (it appears to be a table for Hegurajima Island; this paper's view), turban shells decrease from 65.7 t in fiscal 2015 to 27.9 t in fiscal 2019 and 10.3 t in fiscal 2020 (a decrease of 58% up to fiscal 2019 and of 84% up to fiscal 2020; this paper's calculation). Fiscal 2020 was the year in which the novel coronavirus disease spread, and other reasons may also enter into the fishing and the prices (this paper's view). The plan does not write the reason for the decrease. [S34]

The ama, too, were saying since before the earthquake that shellfish and kajime kelps had decreased. In a news report of April 2024, the chair of Wajima's association for the preservation and promotion of ama fishing said

that, in the summer of 2023, only very few abalone could be taken, and that even when 5 people dived, 3 of them could not take a single one. The chair also said that about 7 years earlier there were abalone in the deep water offshore but now there are none, that the kajime that abalone eat has gone, and that the cause is not clear but the rise in water temperature may also be having an effect. At a survey of the fishing grounds carried out at the Nanatsujima Islands in August 2024, one of the ama said that turban shells and abalone have been decreasing year by year since about 10 years ago, because of barren ground and other things (news report). Both are the account of one person. [S42, S40]

News reports after the earthquake also tell of the decrease since before the earthquake. A news report of June 2026 states, citing Wajima City and others, that the amount of abalone landed off Wajima went on decreasing from a peak in 1984 and in recent years had fallen to less than 1 t. A news report of July 2026 also states that the amount of the turban shell and abalone resources around Hegurajima Island had been tending to decrease since before the earthquake. The mass die-off of shellfish after the earthquake and the catch are dealt with in R7-B13 "The mass die-off of abalone and turban shells, and the fall in catches that continues for some years". [S45, S46]

There are also records of the very shallow water of the island. A report of the prefecture's Noto Marine Center sets out in tables the records of 2008, 2017 and 2022 (8–9 June) for the intertidal zone (the part that is under the sea at high tide and exposed as land at low tide) and just below it at 4 places on Hegurajima Island. The 2008 records are from the survey of Sakai and others (a 2010 report), and in 2017 and 2022 the Center looked from the sea surface down to about 0.5 m with a glass-bottomed viewing box and recorded the amount of living things on 4 levels. At a place called Kitazura, tsuruarame was rated "often found" on all 3 occasions just below the intertidal zone. The purple sea urchin has no record in the tables for 2008 and 2017, and was recorded at 3 of the 4 places in 2022. The main text of the report does not touch on this change. Because the legend of the tables marks with "×" the case where a careful search found none, what a blank cell indicates cannot be known from the tables. The changes in the living things of the intertidal zone after the earthquake are dealt with in R7-B07 "The wiping out of the living things of the intertidal zone and shallow rocky reefs, and the recovery afterwards". [S8]

Region (Sotoura): comparison of the same points at the islands after the earthquake

The islands' seaweed beds after the earthquake were surveyed in November 2025, in a survey by a business association. The Kanazawa Association of Corporate Executives (Kanazawa Keizai Doyukai), a business association, with a grant from The Nippon Foundation and with the prefecture's Fisheries Division and Fisheries Research Center as observers, surveyed the seaweed beds of the coast of the Noto Peninsula in 2025 and issued a report in March 2026 (hereafter, the Doyukai report). The survey of the islands was carried out in November, because days of rough seas continued. Positions were fixed from the survey boat by satellite positioning, and the water depth, the cover by type of seaweed bed and the state of the seabed were recorded with a small underwater camera lowered from the boat on a cable (ROV), a glass-bottomed viewing box and a fish finder. The points were 32 points at Hegurajima Island (water depth 5.0–43.5 m) and 13 points at the Nanatsujima Islands (water depth 11.5–41.3 m), and there are no points at Yomeguri reef (the numbers of points and the water depths are this paper's count). The date on which the photographs in the report were taken is 16 November 2025. [S1]

What they were compared with is the records of the same points in July 2019, before the earthquake. The report does not write who took these records. The timing matches the prefecture's survey of fiscal 2019 (this paper's view). The cover values for each point in 2019 are not given in the report. [S1]

At Hegurajima Island, the tsuruarame in deep water had become broken up. In November 2025, Sargassum species grew mixed together at water depths of 5–15 m, and at 15–25 m Sargassum species, mainly nokogirimoku (a Sargassum species), and tsuruarame grew mixed together. In water deeper than 25 m, the

cover of Sargassum species falls sharply and tsuruarame becomes the main seaweed, but its continuity was weak, and there were stretches where crust-like seaweeds covered the rock. In July 2019, too, the arrangement by water depth was broadly the same, but in deep water points with a comparatively high cover of tsuruarame formed a run. The report states that the decrease in points with a high cover of tsuruarame in deep water and the weakening of the continuity are considered to have occurred because the disturbance of the seabed at the time of the earthquake and environmental change such as warming came together. [S1]

At the Nanatsujima Islands, too, the same change was seen. In November 2025, Sargassum species grew mixed together in shallow water, and there were points of high cover here and there. At 15–25 m, Sargassum species and tsuruarame grew mixed together, and there were points where nokogirimoku was the main seaweed. In water deeper than 25 m, tsuruarame was the main seaweed as at Hegurajima Island, but the continuity as a community was weak, and there were stretches covered by crust-like seaweeds. In July 2019, it is said, points with a high cover of tsuruarame formed a run in deep water, and the cover of tsuruarame was comparatively high also from shallow water to the middle depths. The report states that the change at the Nanatsujima Islands, too, like that at Hegurajima Island, is considered to be due to environmental change caused by warming and the like. [S1]

The difference in season makes the comparison difficult. Sargassum species increase and decrease greatly with the season, July 2019 is close to the period when they grow thickly, and November 2025 falls in the period when they regrow, so the report states that a direct comparison is difficult. For tsuruarame, plants bearing sori (the parts that produce spores) were confirmed in November 2025, so the report judges that the cover at this time does not differ greatly from that in the period when it grows most thickly. [S1]

The report's conclusion states that the basic form of the islands' seaweed beds has not broken down greatly, but that the deep water has declined. It states that at the islands the pattern in which large brown algae are arranged from shallow water to deep water has been kept, and that it is not the case that the basic form of the seaweed beds has broken down greatly. On the other hand, it states that the decrease in points of high cover in the communities of tsuruarame in deep water and the weakening of the continuity are common to both islands and may have been affected by the environmental change of recent years. On that basis, it presumes that the present state of the islands' seaweed beds is the result of the climate change of recent years and the force of the water from the tsunami at the time of the earthquake and the uplift of the terrain acting together. The change in shallow water could not be compared. [S1]

The thinness of the seaweed beds in deep water can also be seen from the report's table of points. At the 10 points at Hegurajima Island with a water depth of 30 m or more, the cover of tsuruarame was 5–30%. At 4 of these points, the cover of seaweeds as a whole did not reach 25%, and they were "scattered" (cover 5–25%), which the report does not count as seaweed bed. At the 13 points with a water depth of 25 m or more, crust-like seaweeds covered 20–60% of the rock. At the 11 points at the Nanatsujima Islands with a water depth of 25 m or more, 6 points were scattered or the still sparser "very scattered" (cover less than 5%). In shallow water, 18 of the 21 points at Hegurajima Island at water depths of 5–26.5 m were seaweed bed, and the total cover of seaweeds was 25–70%. The categories in the report's table are Sargassum beds, mixed beds and kajime beds. At the 3 points classed as kajime beds, too, what grew thickly was mainly Sargassum species such as nokogirimoku (the figures in this paragraph are all this paper's count). The report does not touch on these points one by one. [S1]

Region (Sotoura): the area of the islands' seaweed beds seen in satellite images

The Doyukai report also measured the area of the islands' seaweed beds from satellite images. Places with a cover of 25% or more were taken as seaweed bed, and the water depth that can be distinguished in the images is about 20 m at most when the water is clear. Even in deeper water, if a bed was found in the field survey, it was

added to the seaweed beds. For Hegurajima Island it uses the image of 1 September 2024 from the satellite WorldView-2 (resolution 0.46 m), for Yomeguri reef the images of 22 March and 16 July 2024 from the satellite SPOT6, and for the Nanatsujima Islands the image of 5 June 2025 from SPOT6 (resolution 1.5 m). The heading of the report's table is "this survey (Reiwa 7 [2025])", but for Hegurajima Island and Yomeguri reef the images are from 2024, after the earthquake, and both are images from before the heavy rain of September 2024 (this paper's cross-check). The report's way of choosing images was to put first an image from the spring of 2025 (March–June), when seaweed beds grow thickly, and, failing that, to go in order to a nearby month, the period of thick growth in the previous year, and so on. [S1]

The seaweed beds of all 3 islands had decreased greatly from the fiscal 2019 values (Table 2). Hegurajima Island went from 1,941 ha to 862 ha (−55.6%), the Nanatsujima Islands from 662 ha to 162 ha (−75.5%), and Yomeguri reef from 253 ha to 55 ha (−78.3%). The report lists these 3 districts as the districts that decreased by 40% or more. Taking the 3 islands together, the area is smaller by 1,777 ha (62.2%), from 2,856 ha to 1,079 ha (this paper's calculation). The report states that it recalculated the fiscal 2019 values from the data of that time, and the values for the islands are the same as the values in the Bed Vision after rounding (this paper's cross-check). [S1, S2]

What decreased was mainly the beds in deep water that include kajime kelps (Table 3). The report states that at Hegurajima Island there were seaweed beds in the immediate surroundings of the island as in the earlier survey, but that, as the water deepens towards the offing, the decrease in kajime beds and in mixed Sargassum–kajime beds (beds in which Sargassum species and kajime kelps grow thickly mixed together) was conspicuous. At the Nanatsujima Islands, it states that kajime beds and mixed beds decreased greatly not only around the islands but also between the northern group and the southern group. At Yomeguri reef, the mixed beds in deep water decreased greatly, and the seaweed beds as a whole decreased by 78%. On the other hand, Sargassum beds had increased at all 3 islands. Taking the kajime beds and mixed beds of the 3 islands together, they decreased from 2,554 ha to 656 ha (−74.3%). The 656 ha includes the 48 ha of "kajime beds and small seaweeds", a category newly separated after the earthquake. Without this, the figure is 608 ha (−76.2%). Sargassum beds increased from 300 ha to 422 ha (+40.7%). These values for the 3 islands taken together are this paper's calculation. [S1]

Table 3 Area by type of seaweed bed at the offshore islands (analysis of satellite images)

Island	Type of seaweed bed	Fiscal 2019	After the earthquake	Percentage change
Hegurajima Island	Kajime beds	781 ha	204 ha	−73.9%
Hegurajima Island	Kajime beds and small seaweeds	No category	39 ha	—
Hegurajima Island	Mixed Sargassum–kajime	909 ha	294 ha	−67.7%
Hegurajima Island	Sargassum beds	251 ha	325 ha	+29.5%
Nanatsujima Islands	Kajime beds	366 ha	47 ha	−87.2%
Nanatsujima Islands	Kajime beds and small seaweeds	No category	9 ha	—
Nanatsujima Islands	Mixed Sargassum–kajime	261 ha	42 ha	−83.9%
Nanatsujima Islands	Sargassum beds	32 ha	64 ha	+100.0%
Nanatsujima Islands	Small seaweeds	2 ha	No category	—
Yomeguri reef	Kajime beds	66 ha	No category	—
Yomeguri reef	Mixed Sargassum–kajime	171 ha	21 ha	−87.7%
Yomeguri reef	Sargassum beds	17 ha	33 ha	+94.1%

Note: From the tables of the Doyukai report. The totals for each island are as in Table 2. The fiscal 2019 values are values that the report recalculated from the data of the prefecture's survey of fiscal 2019, and they are the same after rounding as the values of the Bed Vision (for Hegurajima Island, arame beds 780.7 ha, mixed Sargassum–arame 909.3 ha and Sargassum beds 251.0 ha; for the Nanatsujima Islands, 366.4 ha, 261.4 ha, 32.5 ha and small seaweeds 1.5 ha; for Yomeguri reef, 65.9 ha, 170.7 ha and 16.6 ha) (this paper's cross-check). "No category" indicates that the analysis for that year did not separate out that type. Because each value is rounded to the nearest whole number, there are places where the sum of the breakdown does not match the total. The increases and decreases by type are easily affected by differences in how the types are separated, and their reliability is considered to be lower than that of the increases and decreases in the totals (this paper's view). [S1, S2]

The identification by satellite has limits to its reliability. The report states that it used 355 points surveyed with an underwater camera from a boat and other means both to build the training examples for the calculation that distinguishes seaweed beds from the images and to check its correctness, and that the presence or absence of seaweed bed matched at 82.3% of the points. On the other hand, it states that there was a tendency for errors of identification to be many in the beds on the offshore side. Because what decreased at the islands was mainly the beds in deep water, this tendency to error bears on the reliability of the values for the islands (this paper's view; chapter 5). [S1]

In the 3 districts of Sotoura on the mainland side, too, the area of seaweed beds had decreased by 40–60%. In the districts of Wajima, Monzen and Saikai, much of what decreased was mixed beds in deep water. This is dealt with in R7-B08 "Shallow seaweed beds left dry by uplift, and the decrease in the area of seaweed beds on the Sotoura coast". The prefecture, too, states that the decline of the coastal seaweed beds was confirmed in its survey of the distribution of seaweed beds after the earthquake (the "R7–R8 survey" [Reiwa 7–8]) (material for a meeting in September 2026), but the figures shown are values for the whole coast of the prefecture. [S1, S14]

Region (Sotoura): what the earthquake and tsunami brought to the islands

The uplift of the offshore islands appears to have been small. In the prefecture's material of August 2024, the movement of the ground at the mooring facilities (quays and the like where boats are tied up) of Hegurajima fishing port was 0.1 m or less (a provisional value based on survey measurements, materials of the cities and towns, and other sources). The Nanatsujima Islands and Yomeguri reef have no fishing port, and we found no value measuring the uplift. At the survey of the fishing grounds of the Nanatsujima Islands in August 2024, the chair of Wajima's association for the preservation and promotion of ama fishing explained that the area around Akashima has not uplifted much (news report). The size and places of the uplift are dealt with in R7-B01 "Earthquake uplift on the Sotoura coast". [S9, S40]

On the other hand, a tsunami had reached the islands. In the results of the survey by the Japan Meteorological Agency's Mobile Observation Team on 11–20 January 2024, the height of the tsunami at Hegurajima fishing port in Wajima City was 2.9 m (a preliminary value of the height of the traces). The head of the island's district says that the places where the tsunami damage was great were the south-west side and the north-east side of the island (a news report of October 2024). In the interviews with fishers in the Doyukai report, there were cases in the districts where the tsunami damage was great (Suzu City and Hegurajima Island) in which fishing boats, sheds and fishing gear were all washed away. Preparing for tsunamis is dealt with in R7-B02 "The active faults just off the coast, and preparing for the next earthquake and tsunami". [S10, S41, S1]

We found no source that measured how the seabed of the islands changed in the earthquake. A news report of July 2026 states that Hegurajima Island suffered tsunami damage, but that no large change has been confirmed in the seabed of the fishing grounds. One of the ama who surveyed water a few metres deep around Hegurajima Island on 21 August 2024 said that, because there had been no ama diving, no human hand had been at work

and it felt as if the sea was "overgrown with weeds" (news report). The latter account is about shallow water a few metres deep. [S46, S41]

It can be said that the decrease in the seaweed beds in the deep water of Hegurajima Island is hard to explain by uplift alone. This is because the movement of the ground at Hegurajima fishing port (the prefecture's provisional value) was 0.1 m or less, and what decreased was beds centred on water deeper than 25 m (this paper's view). For the Nanatsujima Islands and Yomeguri reef, the same cannot be said, because no value measuring the uplift has been found. However, the report gives, as candidate reasons, the disturbance of the seabed at the time of the earthquake for Hegurajima Island and, in its conclusion, the force of the water from the tsunami and the uplift of the terrain. Because there were traces of a 2.9 m tsunami at Hegurajima fishing port, it cannot be said that the earthquake had no effect (this paper's view). We found no source that measured the effect of the tsunami on the islands' seaweed beds. [S9, S1, S10]

Region (Sotoura): the tsuruarame of the Wajima coast, and how fishers see it

On the Wajima coast on the mainland side, too, tsuruarame had decreased. In the diving survey of the Doyukai report (6 June 2025), on a line at Wajimazaki (by the report's values, the uplift is 1.5 m and the width by which the shoreline moved offshore is about 50 m) from the shoreline before the earthquake (the line of the water's edge) to a water depth of 8 m, the cover and kinds of Sargassum species had hardly changed, while tsuruarame had decreased markedly. What it was compared with is the Conservation Group's survey of June 2023, in which, at a place 25 m from the starting point and at a water depth of 2.2 m, the cover was yanagimoku 35%, tsuruarame 30%, wakame 20% and so on. [S1]

The report considers it highly likely that the decrease in tsuruarame at Wajimazaki had begun before the earthquake. According to the report, a tendency for tsuruarame to decrease has been reported in recent years from various places on the coast of the Sea of Japan, including the Noto Peninsula, and several reasons have been pointed out, such as the rise in seawater temperature, feeding damage by seabed animals that eat seaweed, and the decrease in the nutrients of the sea (nutrient salts). The case cited as the example for the Noto Peninsula is that of Noto Town on the Uchiura coast (chapter 4). At Hikariura, 1.5 km west of Wajimazaki, tsuruarame was already tending to decrease in 2023, before the earthquake. From this, the report states that it is highly likely that the earthquake had almost no effect on the decrease in tsuruarame at Wajimazaki, while also stating that the possibility of a decrease due to uplift cannot be ruled out. The basis for Hikariura is the report of the Conservation Group's survey of 2023, which has not been made public, and this paper has not checked the original report (as quoted by the report). [S1, S20]

In the places surveyed on the Wajima coast, no place where sea urchins have eaten up the seaweed bed has been found. The purple sea urchins at Wajimazaki were fewer than 5 individuals per 1 m^2 even where they were most numerous, and there was no place of barren ground on the lines surveyed. At Kaiso, there was no point where purple sea urchins exceeded 1 individual per 1 m^2, and places covered with mud 1–2 mm thick had become small patches of barren ground. The mud is dealt with in R7-B09 "The mud and turbidity that keep coming in from river mouths (the seaweed beds and rocky-shore fishing grounds of the Wajima coast)", and the abundance of sea urchins in the sea of the Sotoura coast of Suzu City in R7-B10 "The decline of the seaweed beds on the offshore side on the Sotoura coast of Suzu (tsunami or winter waves?)". [S1]

The overall summary of the report states that, on the coast of the Noto Peninsula, no decline of seaweed beds through conspicuous feeding damage is known. The overall summary by Daisuke Fujita, the head of the survey team, states that on the Sea of Japan side of Honshu the rise in water temperature in recent years is conspicuous, that in the south feeding damage by sea urchins (long-spined sea urchins [gangaze and its relatives] and the purple sea urchin) and by fish that eat seaweed (aigo and others) has become serious and seaweed beds are washed away in large quantities at times of high summer water temperature, and that in the

north the purple sea urchin is spreading northwards. On that basis, it states that the coast of the Noto Peninsula keeps its nature comparatively well and that, although there are reports from the Uchiura coast of the appearance of long-spined sea urchins and of feeding damage by aigo to relatives of eelgrass, no decline of seaweed beds through conspicuous feeding damage or through the mass dying back or washing away of seaweeds is known. However, it states that in Noto, too, there are points where purple sea urchins are many, and that breeding inside fishing ports has also been found in another survey, so that future movements deserve attention and management of the number of sea urchins is also necessary. We found no source that measured the numbers of sea urchins or of fish that eat seaweed in the deep water of the islands. [S1]

Fishers give warming, next after mud, as a reason why the resources have decreased. In the interviews of the Doyukai report (32 fishers who gather seaweeds and shellfish in the 4 cities and towns of Oku-Noto; 20 October 2025 to 16 January 2026), among the 31 people who answered on the reason why the resources had decreased, the inflow and accumulation of mud was the most frequent at 58%, and next, warming and the loss of places to grow through the uplift of the seabed were often given (multiple answers). The report states that it is also conceivable that, where the resources had been decreasing through the warming that has continued since before the earthquake, the effect of the earthquake was added and they decreased further. There were also people who gave, as a reason why the catch had increased, that the seaweed beds had declined through warming and the like and the turban shells and abalone on the seabed had become easier to see from on board the boat. At the same time, there were also voices worried about the temporary increase, because, if the decline of the places to grow becomes serious, the shellfish too will no longer grow. The 32 people include fishers of the Uchiura coast. [S1]

Region (Sotoura): matters dealt with in other papers

Other matters also overlap in the seaweed beds of the offshore islands and Wajima. All of them are dealt with in other materials of this series.

- Shallow seaweed beds left dry by uplift: On the Sotoura coast on the mainland side, shallow seaweed beds were left dry by the uplift and disappeared. Together with how the area decreased in the 3 districts on the mainland side, this is dealt with in R7-B08 "Shallow seaweed beds left dry by uplift, and the decrease in the area of seaweed beds on the Sotoura coast". [S1]
- High summer water temperature: The summer water temperature at the observation points of Sotoura is dealt with in R7-B12 "High summer water temperature (the shallow sea of the Sotoura coast)".
- Shellfish after the earthquake: At the round of inspection of the fishing grounds of the Nanatsujima Islands in late June 2025, it is said that there were almost no turban shells (news report). The mass die-off of shellfish and the decrease in catches are dealt with in R7-B13 "The mass die-off of abalone and turban shells, and the fall in catches that continues for some years". [S43]
- Ama fishing: The number of people in ama fishing at the islands and its resumption are dealt with in R7-B25 "The ama fishing of Wajima (numbers, resumption and the handing on of skills)".
- Rebuilding of the local group: The reorganisation of the Conservation Group's activities is dealt with in R7-B26 "Rebuilding the local activities that protect the seaweed beds of Wajima".
- Life on the islands: Life on the islands, the scheduled boat service and the restoration of the fishing port are dealt with in R7-B27 "Hegurajima Island and the Nanatsujima Islands (the fishing grounds of the offshore islands and life on the islands)".

3. Existing measures, and how they are assessed

Efforts to protect the seaweed beds and shellfish of the offshore islands and the Wajima coast have continued since before the earthquake. The efforts given in the materials that this paper examined are 4: protecting the resources by fishing rules, removing sea urchins and placing parent seaweeds, building foundations for seaweed beds and shellfish, and the efforts of the island's fishing community (Table 4). There are figures for the reduction of sea urchins in shallow water, but we found no source that assessed the effect of the efforts on the decline in the deep water of the islands.

Protecting the resources by fishing rules

The ama fishing of the islands has protected the resources by rules. According to the ama subcommittee's plan, at Hegurajima Island and the Nanatsujima Islands the taking of kajime (tsuruarame) is prohibited, and only the "drift kajime" (yori-kajime) washed ashore after a storm (rough seas) is picked up. The fishing season for abalone and turban shells used to be June–October, but was shortened to 1 July to 30 September in order to protect the resources. Under the local rules of Hegurajima Island, taking is from 9 to 13 o'clock and is limited to breath-hold diving. According to the public relations magazine of the prefecture's Fisheries Research Center, the ama have also set closed areas and size limits, but the resources have not recovered (2017). [S31, S4]

Removing sea urchins, and placing parent seaweeds

The Conservation Group has removed sea urchins from shallow water since 2012, and later also came to place parent seaweeds of tsuruarame. The placing of parent seaweeds is said to have been begun, with the group taking the lead, in the fiscal year in which the material was written (the PDF was created in February 2016). The group began in Najimi in 2012 and spread to Hikariura in 2013, and a little over 250 people joined in the 2 districts (material from around 2016). In the introduction of 2020, it is a group of 314 people: fishers, residents and the Wajima branch of JF Ishikawa (the Ishikawa Prefecture Fisheries Cooperative). The group has removed purple sea urchins a total of 6 times every year in the 2 districts, with a cumulative total of about 700 people, and has taken out about 2.5–3.6 t in 1 year. The sea urchins, which were 0.7–1.0 individuals per 1 m^2 before the activity, became 0.0–0.3 individuals after the activity, and the cover of seaweeds was stable at 60–100% throughout, before and after the activity. However, it is also written that the water depth of the activity was down to 5 m and that, because seaweeds grew densely from before the activity, it is difficult to discuss the effect by cover. [S6, S7]

At the Nanatsujima Islands before the earthquake, too, there was an activity to remove creatures harmful to seaweed beds. According to the report on conservation activities (for fiscal 2023; the waters off Wajima City) submitted to the prefecture by the Ishikawa Prefecture Fisheries Cooperative as a body that protects the coastal fishing grounds (a coastal fishing ground management body), on 30 September 2023 the "removal of harmful animals and plants" was carried out on 29.1 ha of seaweed beds at the Nanatsujima Islands with 95 people and 14 boats, and the amount was 150 kg (including 50 kg at Wajimazaki). The report does not write the kinds of creatures removed. In the introduction of the Conservation Group, what the group removes around September is the purple sea urchin. On 14 September of the same year, 630 kg was taken out on 17.6 ha of seaweed beds at Hikariura, and on 13 June and 14 October the seaweed beds of the Nanatsujima Islands were surveyed as a regular check. The income for the conservation activities in this fiscal year was 2.98 million yen in national government subsidies, 1 million yen each in prefectural and city subsidies, and 397,000 yen in other income (levies and contributions), 5,377,000 yen in total. The expenditure was the same amount. The title of the report of the Conservation Group's survey of 2023 that the Doyukai report cites also contains the names of Mikuriyajima and Aramikojima of the Nanatsujima Islands (the title writes the latter name with a different character). [S33, S7, S1, S12]

The prefecture, too, has tried methods of placing parent seaweeds of tsuruarame. At the request of the ama, the prefecture's Fisheries Research Center collected tsuruarame washed ashore at Hegurajima Island in December 2015, fixed it to stones, and placed it inside the breakwater of Hegurajima Island in May 2016. The method of placing young seaweeds grown on seed string did not go well, because feeding damage by small sea snails after they were placed was severe. The method of fixing the holdfast to natural stones with cable ties is simple and does little harm to the parent seaweeds, but, because they are weaker against waves than natural ones, the Center states that they need to be placed where the waves are weak. As of January 2017, the on-site check after placing had not yet been made, and we found no publication of the results afterwards. The ama subcommittee's plan also stated that, in fiscal 2015–2019, a trial of placing parent seaweeds of tsuruarame would be made in the sea of the Nanatsujima Islands. [S4, S31]

Building foundations for seaweed beds and shellfish

The prefecture has built, at the islands, foundations that serve as seaweed beds and as homes for shellfish. According to the Bed Vision, the prefecture, in its fisheries environment improvement project, prepared enhancement grounds (places where stones are put in, for example, to make places for seaweeds and shellfish to grow) of 1.0 ha at the Nanatsujima Islands of Wajima (fiscal 2008) and 1.0 ha at Hegurajima Island (fiscal 2016–2017). The targets are sea breams and turban shells. The Bed Vision further stated that, in order to build beds of tsuruarame, in which decline is seen, enhancement facilities totalling 2.0 ha would be built at Hegurajima Island and the Nanatsujima Islands in fiscal 2022–2023, and that, after completion, parent seaweeds of tsuruarame would be placed and watched over. It states that the construction method would be chosen, to suit the reason for the decline, by a study group including specialists, but we found no record of the study group. In the figure of the prefecture's plan of June 2026, the enhancement facilities of the Hegurajima Island and Nanatsujima Islands work sections (1.0 ha each; nursery reefs and stone placement) are shown in the colour for "portion built up to fiscal Reiwa 7 [2025]". In which fiscal year they were built, whether parent seaweeds were placed, and what became of them in the earthquake are not written. [S2, S30]

Efforts of the island's fishing community

The fishing community of Hegurajima Island has also protected the seaweed beds and resources with national grants. According to the prefecture's materials, the community of Hegurajima Island, with the grant for supporting the revitalisation of remote island fisheries, spent 2,126,000 yen on releasing seed and 1,583,000 yen on the management and improvement of seaweed beds and tidal flats in fiscal 2009 (58 households had joined the agreement), and 499,000 yen on the management and improvement of fishing grounds in fiscal 2014 (51 households). The efforts in fiscal 2014 are given as the release of abalone spat, the removal of harmful enemies such as the common octopus and starfish, the management of fishing grounds (seaweed bed measures) and others. Whether the content of the treatment of seaweed beds was the removal of sea urchins or parent seaweeds, and what the effect was, are not written. The plan for fiscal 2023–2027 (Reiwa 5–9) under the national grant for the revitalisation of remote islands states that it supports the efforts to increase resources, the removal of harmful enemies, the conservation of seaweed beds and other work carried out by the fishing community of Hegurajima Island, and the content for fiscal 2025 was the release of abalone and turban shell spat, the removal of the common octopus, starfish and others, and the making of "ishiru" (fish sauce) products using salt from the island's seawater. The border islands plan also states that, in order to secure seaweed beds suited to the increase of abalone and turban shells, seaweed beds will be protected by removing sea urchins and other means. [S36, S35, S34]

The release of seed to increase shellfish and the removal of creatures that eat shellfish have also been continued. The ama subcommittee's plan set the target of releasing a combined 100,000 abalone and turban shell seed (reared spat) in 1 year on the islands (Hegurajima Island, the Nanatsujima Islands and Yomeguri reef)

and on the rocky shores of the mainland. In fiscal 2015, 75,000 abalone (of which 65,000 at Hegurajima Island) and 30,000 turban shells were released in Wajima City as a whole. It also stated that the common octopus and starfish, which eat shellfish, and the sea urchins and okoshidaka-gangara, which eat seaweed and compete with shellfish, would be taken out. The column for numerical targets in the plan is empty, and we found no source that assessed the results. [S31]

The national government's thinking

The removal of sea urchins is regarded as one of the effective methods of measures against barren ground. The national guidelines state that it has been confirmed in various places that seaweeds grow thickly when sea urchins are removed, while the purple sea urchins removed have a low meat content of 1–2%, and the method of fattening them on land has not been able to handle numbers large enough to reverse barren ground. A report of a programme commissioned by the Fisheries Agency (March 2026; JF Zengyoren [National Federation of Fisheries Co-operative Associations] and others) also states that the removal of sea urchins is one of the effective methods as a measure against barren ground. [S15, S13]

The national government has also begun to show methods of building seaweed beds in step with the rise in seawater temperature. According to a report of a survey commissioned by the Fisheries Agency (March 2026), the Fisheries Agency compiled in April 2024 a provisional version of how to protect and build seaweed beds in step with the rise in seawater temperature, and showed 2 methods: using seaweeds that grow even at high water temperature, and using places where the water temperature does not rise easily. In the sea of Iki City, the building of kurome beds is being tried in a place where the water temperature does not rise easily. [S19]

Efforts after the earthquake

The efforts after the earthquake are dealt with in another paper. A report of a programme commissioned by the Fisheries Agency (March 2026) gives the present state of the seaweed beds for which the Conservation Group concluded an agreement (81 ha of tsuruarame and Sargassum beds) as "earthquake, flood damage", separating it from the "barren ground (isoyake)" of the other 3 districts in the same table (Tsushima City in Nagasaki Prefecture, Minami Town in Tokushima Prefecture and Furubira Town in Hokkaido). According to a news report of November 2025, purple sea urchins have not decreased that much even after the earthquake, and the ama, in order to protect the seaweeds that have become fewer, began full-scale removal in the summer of 2025 and made fertiliser from the sea urchins removed. The rebuilding of the Conservation Group and the content of the prefecture's support are dealt with in R7-B26 "Rebuilding the local activities that protect the seaweed beds of Wajima". The 3rd phase of Wajima's Plan for Revitalising Fishing Communities (fiscal 2025–2029) states that the fishing grounds changed by the earthquake will be surveyed, that things that have drifted in or accumulated will be removed, and that the landings of abalone and turban shells from ama fishing will be increased, but it does not write of treatment for the decline of seaweed beds or for barren ground. [S13, S44, S32]

Assessment of the efforts

We found no source that assessed the effect of the efforts on the decline of the seaweed beds in the deep water of the islands. The only figures showing an effect are the Conservation Group's numbers of sea urchins in shallow water down to a depth of 5 m, and no control plot for comparison was set. The effect of the prefecture's enhancement grounds and parent seaweeds aimed at the decline of tsuruarame in the deep water of the islands has not been published. The efforts have continued since before the earthquake, but the shellfish had not come back. We found no source that checked, effort by effort, the reason why the shellfish did not come back. In 2017, a prefectural body stated that the resources had not recovered. The news report of April 2024 also writes that, however much the resources are protected, no results are achieved (the article's own narrative text). In the cases from around the world, it is said that, to bring back seaweed beds that have collapsed through being eaten by

sea urchins, the sea urchins need to be reduced to far fewer than when the collapse began (chapter 2).
[S6, S4, S42, S22]

Table 4 Main efforts that have protected seaweed beds and shellfish at the offshore islands and on the Wajima coast

Period	Who	What	How the effect is known
From earlier times	Ama	Not taking kajime at the islands. Fishing season for abalone and turban shells shortened to July–September. Closed areas, size limits	In 2017, a prefectural body stated that the resources had not recovered
Fiscal 2005–2014 and others	Fishing community of Hegurajima Island	With national grants, release of seed, removal of harmful enemies, upkeep of seaweed beds and fishing grounds	No assessment found
Fiscal 2008	Prefecture	Enhancement ground of 1.0 ha at the Nanatsujima Islands	No assessment found
From 2012	Conservation Group	Removal of sea urchins in shallow water (about 2.5–3.6 t in 1 year). Later also the placing of parent seaweeds	Down to a water depth of 5 m, sea urchins went from 0.7–1.0 individuals per 1 m^2 to 0.0–0.3 individuals. Cover stable at 60–100%
2015–2016	The prefecture's Fisheries Research Center and the ama	Placed parent seaweeds at Hegurajima Island	No publication of the results found
Fiscal 2016–2017	Prefecture	Enhancement ground of 1.0 ha at Hegurajima Island	No assessment found
From fiscal 2022	Prefecture	Enhancement facilities for beds of tsuruarame at Hegurajima Island and the Nanatsujima Islands (1.0 ha each)	"Portion built up to fiscal Reiwa 7 [2025]" in the figure of June 2026. No publication of the effect
Fiscal 2023	Ishikawa Prefecture Fisheries Cooperative	Removal of harmful animals and plants on 29.1 ha of seaweed beds at the Nanatsujima Islands (150 kg including 50 kg at Wajimazaki; the kinds are not stated)	Only a record of the amount

Note: Compiled by this paper from the ama subcommittee's plan, the public relations magazine of the prefecture's Fisheries Research Center, the prefecture's materials, the Bed Vision, the material and the introduction of the Conservation Group, the figure of the prefecture's plan, and the report on conservation activities of the Ishikawa Prefecture Fisheries Cooperative. For the grant of the fishing community of Hegurajima Island, we looked at the materials for the periods fiscal 2005–2009 and fiscal 2010–2014.
[S31, S4, S36, S2, S6, S7, S30, S33]

4. What is changing

The islands' seaweed beds and the sea that surrounds them are still changing now (as of 6 November 2026; the latest survey of the islands' seaweed beds is that of November 2025). Much of what this chapter deals with is observed values, and plans and schedules.

The water temperature of the sea, and southern creatures

The water temperature of the Sea of Japan is rising fast even among the seas near Japan. According to the Japan Meteorological Agency (announcement of 5 March 2026; data up to 2025), the average sea surface temperature of the seas around Japan has risen by 1.36°C per 100 years, a larger rise than the world average (0.63°C). The rise in the annual average by sea area is 1.57±0.30°C per 100 years for the south-western Sea of Japan (1901–2025) and 2.05±0.34°C for the central Sea of Japan (1907–2025). By season, the central Sea of Japan was 2.64°C in winter, 1.97°C in spring, 1.29°C in summer and 2.30°C in autumn, and the south-western Sea of Japan was 1.75°C in winter, 1.58°C in spring, 1.17°C in summer and 1.82°C in autumn (all per 100 years). The Japan Meteorological Agency states that the rise in the central Sea of Japan is larger than the rise in Japan's air temperature (1.44°C per 100 years). [S11]

The last few years have been a run of years that were especially warm in the record. The difference from normal (the average of 1991–2020) was, in the central Sea of Japan, +2.03°C in 2023 (1st in the record), +1.99°C in 2024 (2nd) and +1.36°C in 2025 (4th), and in the south-western Sea of Japan, +1.43°C in 2024 (1st), +1.30°C in 2023 (2nd) and +0.64°C in 2025. In the summer of 2025 (July–September), the central Sea of Japan was +2.85°C and the south-western +2.40°C. Between the comparison of the islands in July 2019 and November 2025 fall these 2 years that were the warmest in the record (this paper's view). [S11]

However, which sea area's value applies to Sotoura differs between materials. The Doyukai report treats the south-western Sea of Japan as the sea area that includes the Sotoura coast of the Noto Peninsula and gives the value of the previous year's announcement (1.56±0.30°C per 100 years). On the other hand, a researcher of the prefecture's Noto Marine Center cites the value for the central Sea of Japan (1.87°C in the 2023 announcement) in an account of Tsukumo Bay on the Uchiura coast. In the Japan Meteorological Agency's figure of the sea areas, the coast of the Noto Peninsula is near the boundary between the central Sea of Japan and the south-western Sea of Japan, and the coastal water appears not to fall inside either box (reading of the figure). This paper treats these as the values of "2 sea areas of the Sea of Japan that include the sea off the Noto Peninsula", and does not treat them as values for Sotoura. The water temperature at the observation points of Sotoura is dealt with in R7-B12 "High summer water temperature (the shallow sea of the Sotoura coast)". [S1, S20, S11]

On the Uchiura side of the Noto Peninsula, there are places where tsuruarame has disappeared. According to a report (2023) by researchers of the prefecture's Noto Marine Center and others, the tsuruarame that was seen together with akamoku at Ossaka in Noto Town in 2010 was not seen in the diving quadrat survey of 20 May 2023. They state that, at the mouth of Tsukumo Bay, too, they confirmed that the communities of tsuruarame shallower than a water depth of 3 m had disappeared (unpublished). The authors state that it is highly likely that akamoku and tsuruarame have become unsuited to growing in the shallow sea of the east coast of the Noto Peninsula through the rise in water temperature of recent years. The monthly average water temperature in Tsukumo Bay in July–August 2022 was in the range of 27–28°C, and on hot days it was 30°C. The same report gives the upper-limit water temperature at which tsuruarame grows as 28°C for the gametophyte (the small generation that grows from a spore) and 27°C for the sporophyte (the body of the seaweed that is ordinarily seen) (quoted from a 2016 master's thesis). These are examples from the Uchiura coast, and the water temperature in the deep water of the islands of Sotoura is not known. [S20]

On the Uchiura coast, the overwintering of southern sea urchins has also been confirmed. From October 2022 to October 2023, arasaki-gangaze and gangaze that had passed the winter were recorded for the first time around Tsukumo Bay in Noto Town and at Uozu City in Toyama Prefecture. In Tsukumo Bay in August 2024, 21 individuals of arasaki-gangaze (mainly 2 years old) were collected. The national guidelines give the relatives of gangaze as one of the reasons for the decline of seaweed beds. We found no record of southern sea urchins passing the winter in Sotoura. [S21, S15]

Plans and schedules

- March 2022: The prefecture's Bed Vision. It acknowledged the decline of parts of Hegurajima Island and the Nanatsujima Islands, and planned enhancement facilities (2.0 ha) for beds of tsuruarame. It scheduled a survey of the distribution of seaweed beds throughout the prefecture for fiscal 2024 (no publication of the results found). The target for the area of the seaweed beds of Sotoura (10,545 ha in fiscal 2031) was decided before the earthquake, and cannot be compared with the values after the earthquake. [S2]
- Fiscal 2022–2031 (Reiwa 4–13): The prefecture's fisheries environment improvement project (Kaga and Noto Sotoura district). The enhancement facilities at the islands are given as "portion built up to fiscal Reiwa 7 [2025]" in the figure of June 2026. [S30]
- 1 September 2023 to 31 August 2033: The duration of the common fishery rights of Hegurajima Island, the Nanatsujima Islands and Yomeguri reef (Common Nos. 9–12) and of the conservation coastal fishing ground off Wajima City (a fishing ground in which the Ishikawa Prefecture Fisheries Cooperative carries out the removal of harmful animals and plants, the release of seed and so on). [S39, S33]
- Fiscal 2023–2027 (Reiwa 5–9): The efforts for the revitalisation of remote island fisheries by the fishing community of Hegurajima Island (the plan under the national grant for the revitalisation of remote islands; includes the conservation of seaweed beds). [S35]
- 16 November 2025: The underwater camera survey of Hegurajima Island and the Nanatsujima Islands in the Doyukai report (the date the photographs were taken). [S1]
- 20 January 2026: Announcement of the prefecture's initial budget for fiscal 2026. Under "support for the rebuilding of ama fishing" (3.5 million yen), it supports activities to protect seaweed beds, such as removing wood that has flowed in and propagating seaweeds. The content is dealt with in R7-B26. [S38]
- March 2026: Issue of the Doyukai report (on the 24th). The report of the programme commissioned by the Fisheries Agency stated that the Conservation Group plans to begin, from fiscal 2026, the production of kajime seed (seaweed seedlings), the transplanting of parent seaweeds and seed, and the cleaning of mud from the rocks (R7-B26). [S1, S13]
- 3 July 2026: Breath-hold diving for turban shells and abalone began around Hegurajima Island (about 130 ama; a voluntary limit of up to 30 kg of turban shells per person in 1 day; ama fishing is dealt with in R7-B25). [S46]
- 4 September 2026: The study committee (1st meeting) for the prefecture's new "Ishikawa Fisheries Promotion Vision". A vision looking ahead about 10 years is scheduled to be drawn up with fiscal 2026 as the target for completion, and the committee members include the chair of Wajima's association for the preservation and promotion of ama fishing. The material gives "climate change (rising water temperature, decline of seaweed beds, change in fish species)" as 1 of the changing circumstances, and places "conservation and effective use of seaweed beds" among the pillars of the present measures. The target fiscal year of the present Vision (2017) is fiscal 2026. [S14, S3]

5. What is not yet known

Things for which there are no figures

- We found no figures for the numbers of sea urchins or of fish that eat seaweed in the deep water of the offshore islands (water deeper than 25 m). We also found no records of the water temperature at the seabed in the deep water of the islands. [S1, S2]
- We found neither the cover values for each point at the islands in July 2019 nor the course of change in the deep water of the islands between 2019 and 2025. The report's comparison is a comparison in words of 2

points in time. The report of the prefecture's survey of fiscal 2019, and the dates on which its images were taken, have also not been made public. [S1, S2]

- Yomeguri reef has no field survey points for 2025, and its area is a value from images alone. We also found no values for the uplift and tsunami at the Nanatsujima Islands and Yomeguri reef. [S1, S9, S10]
- The Conservation Group's report that tsuruarame had decreased at Hikariura in 2023 has not been made public, and there is only the quotation in the Doyukai report. [S1]
- We found no shares by reason, such as warming, feeding damage, the decrease in the nutrients of the sea, and the tsunami, within the decline in the deep water of the islands. The report also cites an overseas paper (2025) showing a decrease in nutrients in the deep water of the Sea of Japan, but this paper has not checked its content. [S1]
- We found no source showing the results of the enhancement grounds that the prefecture built at Hegurajima Island and the Nanatsujima Islands, or of the placing of parent seaweeds. We also found neither the results of the survey of seaweed beds throughout the prefecture that the Bed Vision scheduled for fiscal 2024, nor the report of the prefecture's survey after the earthquake (the "R7–R8 survey" [Reiwa 7–8]). [S2, S30, S14]
- We found no continuous official statistics on the catch of abalone and turban shells in Wajima City. There are only the values for 2 years (1983 and 2014) in the public relations magazine of a prefectural body, and the table for Hegurajima port for fiscal 2015–2020 in the border islands plan. [S4, S34]

Limits of the comparisons

- The comparison of the same points at the islands is between different seasons. July 2019 is close to the period of thick growth and November 2025 is the period of regrowth, and the Sargassum species have not been compared. For tsuruarame, it is judged from the sori that the effect of the timing is small. The origin of the records of 2019 is not written, and the comparison is not in figures for each point but in words. [S1]
- The 3 surveys of the area of the islands' seaweed beds differ in the water depth surveyed, in how beds in deep water were found, and in the timing of the images (Table 2). Fiscal 1990–91 covered only water shallower than 20 m; fiscal 2019 also counted beds in water deeper than 20 m, using an underwater camera from a boat and a scanning sonar; and after the earthquake, what is counted is down to about 20 m, as far as can be seen in the images, plus the places where beds were found in the field. The prefecture states that the increase in area from fiscal 1990–91 to fiscal 2019 is due mainly to the difference in survey methods. This paper considers that part of the difference between fiscal 2019 and after the earthquake may also be affected by the difference in how beds in deep water were found (this paper's view). [S1, S2]
- The correctness of the identification by satellite (82.3%) is a value checked against the 355 points that were also used to build the training examples, and it is a value for the whole of the sea surveyed. No value of the correctness for the islands alone is given. The report states that there was a tendency for errors to be many in the beds on the offshore side. Yomeguri reef has no field points for 2025. [S1]
- Between the value before the earthquake (fiscal 2019) and the values after the earthquake (2024–2025) fall about 4 years before the earthquake (longer than that, depending on the date on which the earlier images were taken), the earthquake, and 2023 and 2024, which were warm years in the record. Within this difference, the change from before the earthquake and the change due to the earthquake cannot be separated (this paper's view). The report also states that this survey was not made immediately after the disaster, and that a comparison with the time just before the earthquake and the heavy rain has not been made sufficiently. [S1, S11]
- The 32 people interviewed include fishers of the Uchiura coast, and the shares are not values for Sotoura or the islands alone. [S1]
- The Japan Meteorological Agency's values by sea area are values for a wide sea that includes the sea off the Noto Peninsula, and are not the water temperature in the deep water of the islands of Sotoura (chapter 4).

[S11]

- The disappearance of tsuruarame at Ossaka in Noto Town and in Tsukumo Bay, and the southern sea urchins, are examples from the Uchiura coast and do not serve as a basis for Sotoura. [S20, S21]
- The wording "barren ground (isoyake)" differs between materials. The prefecture stated in 2017 that no large-scale barren ground had been confirmed, the national guidelines treat the conspicuous barren ground of the northern Sea of Japan as local, the overall summary of the Doyukai report states that no decline of seaweed beds through conspicuous feeding damage is known in Noto, and the Ministry of the Environment's 2003 survey treats the deep water of Hegurajima Island as a seaweed bed that has not become a crowd of sea urchins. On the other hand, the ama reported barren ground at the Nanatsujima Islands (posted in 2020), and the local group was worried about barren ground advancing from deep water. The extent (large-scale or local), the way the word is defined (offshore barren ground is easy to misjudge), the kind of basis (an account or a survey) and the timing differ. This paper has written what has been confirmed as "the decline of the tsuruarame beds in deep water", and has used "barren ground (isoyake)" with a note of whose word it is. The same researcher is involved in the national guidelines, the overall summary of the Doyukai report and the Ministry of the Environment's survey mentioned here ("Reliability and the standpoint of the materials"). [S3, S15, S1, S37, S7, S6]
- The landings at Hegurajima port in fiscal 2020 are a value for the year in which the novel coronavirus disease spread, and reasons other than the decline of seaweed beds may also enter (this paper's view). [S34]

Figures that disagree

- The year in which the abalone catch of Wajima was largest is 1983 (41 t) in the public relations magazine of the prefecture's Fisheries Research Center (2017), and 1984 in the news report of June 2026 (citing Wajima City and others). The magazine writes of the abalone catch of Wajima City and the news report of the amount of abalone landed off Wajima, and it is not known whether the range counted is the same. [S4, S45]
- The amount of landings at Hegurajima port is 155–361 t in fiscal 2015–2020 in the table of the border islands plan, but the main text of the same plan states that it has moved between 200 and 300 t over the last 5 years and is about 1/2 of that of 10 years earlier. The main text appears to be wording left over from before the revision (this paper's view), and this paper has used the values in the table. [S34]
- The area of the islands' seaweed beds differs between materials (Table 2). The Ministry of the Environment's pages on the important marine areas give the extent of the seaweed beds as 4.5 km^2 (450 ha) at Hegurajima Island and 2.1 km^2 (210 ha) at the Nanatsujima Islands, values close to those of fiscal 1990–91, but the year and method of the survey are not written. [S12, S2, S1]
- The year of the Ministry of the Environment's 7th seaweed bed survey is July 2003 in the overview of the report (p. 340) and in the sample codes, and 8 July 2004 in the survey date and the cutting-and-collection field on the Hegurajima Island page, so that it disagrees within the report. [S37]
- The upper-limit water temperature at which tsuruarame grows differs between the values cited by the report of the Noto researchers (gametophyte 28°C, sporophyte 27°C) and the figure in the presentation by the researcher of the Marine Ecology Research Institute (male gametophyte around 29°C, female gametophyte around 30°C, young sporophyte around 27°C; reading of the figure). This appears to be a difference in how the stages of growth are divided and in the reading of the figure (this paper's view). [S20, S17]
- The rise in the sea surface temperature of the south-western Sea of Japan is 1.56±0.30°C per 100 years in the value of the Doyukai report and 1.57±0.30°C in the Japan Meteorological Agency's 2026 announcement. The report's value is the value of the previous year's announcement. [S1, S11]
- The extent of the seaweed beds for which the Conservation Group concluded an agreement is 80.5 ha in the Bed Vision and 81 ha in the report of the programme commissioned by the Fisheries Agency. These appear to be the area of the same agreement, rounded (this paper's view). [S2, S13]

- The wording of the reasons differs from place to place even within the same report. For Hegurajima Island it is the disturbance of the seabed at the time of the earthquake and environmental change such as warming coming together; for the Nanatsujima Islands it is environmental change caused by warming and the like; and the conclusion gives it as the result of the climate change of recent years and the force of the water from the tsunami at the time of the earthquake and the uplift of the terrain coming together. All are presumptions, and the size of each reason is not shown. [S1]

Reliability and the standpoint of the materials

The reliability differs from item to item. That, before the earthquake, the prefecture acknowledged a declining trend in the seaweed beds of parts of Hegurajima Island and the Nanatsujima Islands is written in the prefecture's plan (the Bed Vision), and the reliability can be said to be high. That fishers and ama were speaking of the decrease in kajime kelps and shellfish since before the earthquake also points the same way in the material of the local group, the site of the national programme and the news reports. However, the places that declined and their extent are shown only by marks at several places on the figures of the islands and in words, and the amount is not known, so the reliability is medium. That, after the earthquake, the runs of places dense in tsuruarame decreased in the deep water of the islands is the result of 1 survey that looked at the same points with an underwater camera, but the season differs and the origin of the records of 2019 and the values for each point are not shown, so the reliability is medium. For the decrease in area seen in satellite images (Hegurajima Island −55.6%, Nanatsujima Islands −75.5%, Yomeguri reef −78.3%), the method is written in detail, but for 2 of the islands the images are from 2024, and the difference in how beds in deep water were found and the errors on the offshore side remain, so the reliability is medium to low. Among these, the value for Yomeguri reef has no field points for 2025 and is from images alone, so the reliability can be said to be low. The direction, that what decreased was mainly the beds in deep water that include kajime kelps, matches the underwater camera comparison. The reasons for the decrease are all the report's presumptions, and there is no source showing the size of each reason, so the reliability can be said to be low. We found no source showing that the decline at the islands is due to feeding damage by sea urchins. That the shellfish of Wajima had been decreasing since before the earthquake points the same way in the values of the public relations magazine of a prefectural body (the name of the underlying statistics is not written), the material of the local group, the table for Hegurajima port in the border islands plan, and the news reports, but no continuous official statistics have been found, so the reliability is medium. The rise in the water temperature of the Sea of Japan is based on the observations of the Japan Meteorological Agency, and the reliability can be said to be high. However, there is no source that applies it to the water temperature in the deep water of the islands. The disappearance of tsuruarame and the overwintering of southern sea urchins on the Uchiura coast are based on the reports of a research institution, and the reliability as examples from the Uchiura coast is medium, but they do not serve as a basis for Sotoura. The cases from Japan and abroad are based on papers and the national guidelines, and cannot be applied to Sotoura as they stand.

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 (this paper also cites articles of the Hokkoku Shimbun). The head of the survey team is Daisuke Fujita, president of the Japan Seaweed Association; the satellite analysis was handled by a surveying company (Kokusai Kogyo), the diving survey by a survey company (the limited company Shizen Kankyo Chosa), and the interviews by Ryoko Ishikawa of the Wajima Seaweed Lab, and people from the prefecture's Fisheries Division and Fisheries Research Center took part as observers. Daisuke Fujita is the author of the 2002 report that is the origin of the wording on barren ground cited by the national guidelines, and his name is also listed as a specialist engineer of the organisation that carried out the Fisheries Agency's commissioned survey (2026) on building seaweed beds in step with the rise in seawater temperature. The national guidelines (2021) state that

they were revised with the advice of Daisuke Fujita and others, and Daisuke Fujita, as chair of the study committee of the Fisheries Agency's commissioned programme, also wrote the preface to the guidelines. In the Ministry of the Environment's 7th seaweed bed survey, which surveyed Hegurajima Island before the earthquake, he is 1 of the people responsible for the survey of Hegurajima Island and the Nanatsujima Islands. He is also listed in the report of the programme commissioned by the Fisheries Agency (March 2026) as a member of that programme's evaluation and study committee. For this reason, the wording on barren ground, the national guidelines, the Ministry of the Environment's survey of Hegurajima Island, the overall summary of the Doyukai report and the 2 reports of the Fisheries Agency cannot be said to be mutually independent confirmations. The authors of Ling et al. (2015), cited as a case from around the world, also include D Fujita of Tokyo University of Marine Science and Technology. The report of the Fisheries Agency's commissioned survey gives Daisuke Fujita as a former associate professor of Tokyo University of Marine Science and Technology, but whether this is the same person is not written in the materials. Ryoko Ishikawa is the writer of the Conservation Group's material from before the earthquake, and is also the leader of the interview team of the report. Takahiko Ikemori of the prefecture's Fisheries Research Center is the author of the 2017 article in the public relations magazine and of the report on the tsuruarame of the Uchiura coast, and is also an observer of the report's survey. The fiscal 2019 areas in the report are based on the data of the same prefectural survey as the Bed Vision, and the values before the earthquake in the 2 materials are values of the same survey. The origin of the records of the points in July 2019 is not written. The report of the Conservation Group's survey of 2023 has not been made public, and there is only the quotation in the report. The news reports convey briefly what the ama and the head of the island's district saw and said, and each is the account of one person. The Ministry of the Environment's 7th seaweed bed survey is a single survey. For the English-language papers, we read only the abstracts. However, for the California case we also checked the names of the species in the main text, and for Ling et al. (2015) we also checked the list of authors. For the Iki paper, we read the abstract and the beginning and the discussion of the main text.

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 from attaching (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 seaweed beds itself and the efforts to protect and bring back seaweed beds (the removal of sea urchins, the placing of parent seaweeds, and enhancement grounds), and the restoration of seaweed beds overlaps with the publisher's field of business. This paper also touches on the area of the islands' seaweed beds measured from satellite images, and on its reliability. 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 Sotoura are as follows (as of 5 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 for the prefecture's (Commerce, Industry and Labour Department, Industrial Policy Division) "survey project for attracting start-ups to Noto" (fiscal 2025 [Reiwa 7]) (September 2025). 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). Many of the materials that this paper cites are plans and materials of the prefecture, and the prefecture's Fisheries Division and Fisheries Research Center took part as observers in the survey of the Doyukai report. 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 Sotoura, and whose representative director and senior managing director is a member of the study 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. This paper cites the report on conservation activities submitted by the same cooperative. The Wajima branch of the same cooperative has also joined the Wajima Satoumi Conservation Group taken up in this paper, 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, and Nanao Bay is dealt with in R7-A (Nanao Bay) of this series. In Sotoura (Shika Town, Wajima City and the north coast of Suzu City as far as Jike), the publisher is not active. On the study committee for the prefecture's new Fisheries Promotion Vision that this paper cites, 1 of the members is a person from Kanazawa University. The name of Atsumasa Nakamura does not appear in the list of members of this committee or in the list of the survey team of the Doyukai report. With Hiroshima University, the publisher has participated since October 2025, as one company in a consortium, in a research centre of the university (JST COI-NEXT). Michio Imai, the publisher's co-representative CEO, has served since 1 November 2026 as a researcher (part-time) at a research institute of the same university (the institute for the future of ocean and maritime affairs) (concurrently with his post as the publisher's co-representative CEO). In addition, the publisher joined joint research under the Town & Gown initiative of Kure City and Hiroshima University (an initiative in which the city and the university work together) (the research period is October 2025 to August 2026, with the contract concluded in March 2026). This joint research is funded by a research grant from Kure City, and the publisher received an allocation of research funds from that grant (April 2026). It has also been selected for the research grant from Kure City for the 2nd year (from September 2026). The authors of the materials that this paper cites include no one from Hiroshima University. This paper does not use the data or results of this joint research. 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, 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 Sotoura (fishery cooperatives, local groups 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 6 November 2026. Working mainly from materials of the national government and the prefecture, peer-reviewed papers and reports of research institutions, we used figures that a separate researcher had checked against the very materials listed as sources (for the English-language papers, the abstract only; for the California case, the names of the species alone were also checked in the main text; where we used a value that has not been checked, we have indicated this in the text). Among the figures that materials quote from other studies, there are some that we have not checked back to the original study, and we have marked these "quoted" in the text. Values that this paper calculated from the values in the sources are written as "this paper's calculation", values counted from the tables of points as "this paper's count", and things read from figures as "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 by organisations, guidance with little description of method, presentations at meetings; D = news reports.

ID	Source (publisher, year)	Type	Reliability	Chapters used
S1	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 im - pacts 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 comparison of the islands is on pp. 35–37, the points at the islands in Table 3-8, the areas of the islands in Tables 3-10 and 3-11, and the overall summary on p. 204)	Report	C	Chapters 1–5
S2	Ishikawa Prefecture: Ishikawa Prefecture Seaweed and Seagrass Bed Vision (Ishikawa Prefecture plan for building seaweed and seagrass beds) (in Japanese) (March 2022. This paper's "Bed Vision". The areas of the islands are in Table 2 [p. 7 of the PDF], the decline and treatment at the islands on pp. 29–31 of the PDF, and the figures of the islands on pp. 33–34 of the PDF)	Plan	A	Chapters 1–5
S3	Ishikawa Prefecture: Ishikawa Fisheries Promotion Vision (pp. 33–40) (in Japanese) (June 2017)	Plan	A	Chapters 1, 2, 4, 5
S4	Takahiko Ikemori (Ishikawa Prefecture Fisheries Research Center): Placing par - ent seaweeds of kajime (tsuruarame) (in Japanese) (Fisheries Research Center newsletter No. 51: 9–10, January 2017. The underlying statistics for the catch are not stated)	Explanatory	C	Chapters 1–3, 5
S5	Ishikawa Prefecture: Comprehensive fisheries infrastructure improvement project plan for the Kaga–Noto Sotoura area (Ishikawa Prefecture) (R4–R8) (in Japanese) (2022. This paper's "Sotoura fisheries infrastructure plan")	Plan	A	Chapter 2
S6	Ryoko Ishikawa (Kaiyo Planning Co., Ltd.): On the efforts of the Wajima Satoumi Conservation Group (in Japanese) (no date stated. The PDF was created in February 2016)	Explanatory	C	Chapters 1–3, 5
S7	Information site of the measures to bring out the multiple functions of fisheries (hitoumi.jp): Introduction of activity organisations: Wajima Satoumi Conservation Group (Wajima City, Ishikawa Prefecture) (in Japanese) (posted 29 September 2020. The site of a Fisheries Agency programme)	Explanatory	C	Chapters 1–3, 5
S8	Ishikawa Prefecture Noto Marine Center: Annual report "Monitoring survey on the rocky coasts of Ishikawa Prefecture" in Report of the Noto Marine Center No. 28 (2022) (in Japanese) (Hegurajima Island was surveyed on 8–9 June 2022. Tables 2-1 and 2-2)	Report	B	Chapter 2
S9	Ishikawa Prefecture and the council for the reconstruction of Noto's fishery-re - lated ports: Reconstruction policy for Noto's fishery-related ports (in Japanese) (drawn up in August 2024. The PDF on the site is the version amended in December 2024. The values for each fishing port are provisional values. Hegurajima fishing port is on p. 6)	Plan	A	Chapters 1, 2, 5
S10	Japan Meteorological Agency: Results of the field survey on the tsunami by the Japan Meteorological Agency Mobile Observation Team in the "2024 (Reiwa 6) Noto Peninsula Earthquake" (in Japanese) (material. 26 January 2024. The survey was on 11–20 January. Preliminary values)	Announcement	A	Chapters 1, 2, 5
S11	Japan Meteorological Agency: Marine diagnosis report "Long-term trend of sea surface temperature (seas around Japan)" (in Japanese) (announcement of 5 March 2026. Data up to 2025. Includes the data by sea area)	Statistics	A	Chapters 1, 4, 5

ID	Source (publisher, year)	Type	Reliability	Chapters used
S12	Ministry of the Environment: marine areas of high importance from the view - point of biodiversity (coastal areas), around Hegurajima Island; around the Nanatsujima Islands (in Japanese) (no date of publication on the pages)	Material	A	Chapters 2, 3, 5
S13	JF Zengyoren (National Federation of Fisheries Co-operative Associations) and others: Fiscal 2025 (Reiwa 7) survey report of the commissioned programme supporting measures to strengthen the productivity of fishing grounds and the multiple functions of fisheries (in Japanese) (a programme commissioned by the Fisheries Agency, March 2026. The state of the seaweed beds of Wajima is in Table 1-5-1 on p. 17, the removal of sea urchins on p. 26, and the plan for fiscal 2026 on p. 144)	Report	A	Chapters 3–5
S14	Ishikawa Prefecture: Study committee for drawing up the new "Ishikawa Fisheries Promotion Vision" (in Japanese) (materials of the 1st meeting; list of committee members, 4 September 2026. The decline of seaweed beds is on p. 11 of the materials. The figures for seaweed beds are values for the whole coast of the prefecture)	Meeting	A	Chapters 2, 4, 5
S15	Fisheries Agency: Guidelines for Measures against Barren Ground (Isoyake), 3rd edition (in Japanese) (March 2021. This paper's "national guidelines". The def - inition is on p. 18, the types and misjudgement on p. 20 and p. 26, and the summary by sea area on pp. 62–66)	Guidelines	A	Chapters 1–5
S16	Daisuke Fujita: The present state of barren ground (isoyake) (in Japanese) (Fisheries Engineering 39(1): 41–46, 2002. Report article)	Report	B	Chapters 2, 5
S17	Masasuke Baba (Marine Ecology Research Institute): Growth responses and distribution shifts of large brown algae due to warming (in Japanese) (presen - tation at the fiscal 2021 [Reiwa 3] national council on measures against barren ground [isoyake], 1 March 2022. On the Fisheries Agency's site)	Presentation	C	Chapters 2, 5
S18	Setuo Kiyomoto et al.: Long-term changes up to the disappearance of the beds of seaweeds of the kajime family off Waka, Iki Island, north-western Kyushu (in Japanese) (Nippon Suisan Gakkaishi 87(6): 642–651, 2021. The abstract and the beginning and the discussion of the main text were checked)	Paper	B	Chapter 2
S19	Fisheries Agency: Fiscal 2025 (Reiwa 7) report of the commissioned fisheries infrastructure improvement survey programme, "Study and survey on the preparation of seaweed beds in response to the rise in seawater temperature" (in Japanese) (Fisheries Infrastructure Development Center, Japan Fisheries Research and Education Agency and others, March 2026. The provisional ver - sion is on pp. 3–4, and Iki on p. 4)	Report	A	Chapters 2, 3, 5
S20	Takahiko Ikemori and Yukimasa Higashide: Standing crop and species compo - sition of the Sargassum beds on the east coast of the Noto Peninsula (in Japanese) (Report of the Noto Marine Center 29: 15–17, 2023. An example from the Uchiura coast)	Report	B	Chapters 2, 4, 5
S21	Hiroaki Arakawa et al. (Noto Marine Center): First record of long-spined sea urchins (gangaze and its relatives) that overwintered on the coast of Toyama Bay (Report 29: 25–32, 2023); The state of establishment of arasaki-gangaze in Tsukumo Bay (Report 30: 73–76, 2025) (in Japanese) (examples from the Uchiura coast)	Report	B	Chapters 4, 5
S22	Ling et al.: Global regime shift dynamics of catastrophic sea urchin overgrazing (Philosophical Transactions of the Royal Society B 370, 20130269, 2015. The abstract and the list of authors were checked)	Paper	B	Chapters 2, 3, 5
S23	Filbee-Dexter and Scheibling: Sea urchin barrens as alternative stable states of collapsed kelp ecosystems (Marine Ecology Progress Series 495: 1–25, 2014. Review article. Abstract only checked)	Paper	B	Chapter 2

ID	Source (publisher, year)	Type	Reliability	Chapters used
S24	Ling et al.: Overfishing reduces resilience of kelp beds to climate-driven cat - astrophic phase shift (PNAS 106(52): 22341–22345, 2009. Abstract only checked)	Paper	B	Chapter 2
S25	Wernberg et al.: Climate-driven regime shift of a temperate marine ecosystem (Science 353(6295): 169–172, 2016. Abstract only checked)	Paper	B	Chapter 2
S26	Rogers-Bennett and Catton: Marine heat wave and multiple stressors tip bull kelp forest to sea urchin barrens (Scientific Reports 9, 15050, 2019. CC BY. The abstract and the names of the species in the main text were checked)	Paper	B	Chapter 2
S27	Krumhansl et al.: Global patterns of kelp forest change over the past half-cen - tury (PNAS 113(48): 13785–13790, 2016. Abstract only checked)	Paper	B	Chapter 2
S28	Kumagai et al.: Ocean currents and herbivory drive macroalgae-to-coral com - munity shift under climate warming (PNAS 115(36): 8990–8995, 2018. Abstract only checked)	Paper	B	Chapter 2
S29	Muraoka et al.: Effects of the 2011 Great East Japan Earthquake and tsunami on two kelp bed communities on the Sanriku coast (Fisheries Oceanography 26(2): 128–140, 2017. CC BY. Abstract only checked)	Paper	B	Chapter 2
S30	Ishikawa Prefecture: Fisheries environment improvement project, Kaga and Noto Sotoura district (general): plan drawing (in Japanese) (June 2026. The construction period is fiscal Reiwa 4–13 [2022–2031])	Plan	A	Chapters 1, 3–5
S31	Wajima district regional fisheries revitalisation committee (ama subcommittee): Plan for Revitalising Fishing Communities (Hama Plan) (in Japanese) (fiscal 2015–2019. The PDF was created in March 2016. This paper's "ama subcom - mittee's plan")	Plan	A	Chapters 2, 3
S32	Wajima regional fisheries revitalisation committee: Plan for Revitalising Fishing Communities (Hama Plan) (3rd phase) (in Japanese) (fiscal 2025–2029)	Plan	A	Chapter 3
S33	Ishikawa Prefecture Fisheries Cooperative (coastal fishing ground management body): report on the state of implementation of conservation activities by the coastal fishing ground management body (waters off Wajima City. for fiscal 2023 (Reiwa 5); for fiscal 2024 (Reiwa 6)) (in Japanese) (posted by the prefecture)	Report	A	Chapters 3, 4
S34	Ishikawa Prefecture: Plan on the maintenance of local communities in Ishikawa Prefecture's specified inhabited remote border island areas (in Japanese) (drawn up in September 2017, revised in September 2022. This paper's "border islands plan". The table for Hegurajima port is on p. 8)	Plan	A	Chapters 2, 3, 5
S35	Ministry of Land, Infrastructure, Transport and Tourism: projects and the like stated in the project plan for the grant for the revitalisation of remote islands and related grants that are to be carried out in the fiscal year concerned (Ishikawa Prefecture, Hegurajima Island. fiscal 2023 (Reiwa 5); fiscal 2025 (Rei - wa 7)) (in Japanese)	Material	A	Chapters 3, 4
S36	Ishikawa Prefecture: on the state of implementation of the project under the grant for supporting the revitalisation of remote island fisheries (Wajima City, Hegurajima Island community. fiscal 2009 (Heisei 21); fiscal 2014 (Heisei 26)) (in Japanese)	Material	A	Chapter 3
S37	Biodiversity Center of Japan, Nature Conservation Bureau, Ministry of the Environment: 7th National Survey on the Natural Environment: report of the shallow-sea ecosystem survey (seaweed bed survey) (in Japanese) (September 2008. The coast around Hegurajima Island and the Nanatsujima Islands is on pp. 110–111, and the overview of the Sea of Japan side on p. 340)	Report	A	Chapters 2, 5
S38	Ishikawa Prefecture: Main projects of the initial budget for fiscal 2026 (Reiwa 8) (in Japanese) (20 January 2026. The support for the rebuilding of ama fishing is on p. 7 of the PDF)	Budget	A	Chapter 4

ID	Source (publisher, year)	Type	Reliability	Chapters used
S39	Ishikawa Prefecture: Ishikawa sea area fishing ground plan (in Japanese) (as changed on 30 June 2026. Common fishery rights Common Nos. 9–12)	Material	A	Chapters 2, 4
S40	Hokuriku Chunichi Shimbun: The survey of the fishing grounds of the Nanatsujima Islands, and the account of an ama (in Japanese) (6 October 2024, Chunichi Shimbun Web. The survey of 20 August 2024)	News	D	Chapter 2
S41	Hokuriku Chunichi Shimbun: The survey of the fishing grounds of Hegurajima Island, and the tsunami damage on the island (in Japanese) (7 October 2024, Chunichi Shimbun Web. The survey of 21 August 2024)	News	D	Chapter 2
S42	Bunshun Online (Taro Hagami): The ama fishing of Wajima before the earth - quake, and the decrease in abalone (in Japanese) (7 April 2024)	News	D	Chapters 2, 3
S43	Hokkoku Shimbun: The start of breath-hold diving by the ama of Wajima (2025) (in Japanese) (1 July 2025)	News	D	Chapter 2
S44	Hokkoku Shimbun: The making of fertiliser from sea urchins by the ama of Wajima (in Japanese) (30 November 2025)	News	D	Chapter 3
S45	Hokkoku Shimbun: The new ama of Wajima, and the removal of sea urchins (in Japanese) (23 June 2026. The value for abalone landings is according to Wajima City and others)	News	D	Chapters 2, 5
S46	Hokkoku Shimbun: The start of breath-hold diving for turban shells and abalone at Hegurajima Island (2026) (in Japanese) (4 July 2026)	News	D	Chapters 2, 4

Related materials: R2 Seaweed and seagrass beds and the living things of the sea, R7-A04 The decline of the Sargassum beds of Nanao Bay, R7-B01 Earthquake uplift on the Sotoura coast, R7-B02 The active faults just off the coast, and preparing for the next earthquake and tsunami, R7-B07 The total die-off of living things in the intertidal zone and on shallow rocky reefs, and their recovery afterwards, R7-B08 Shallow seaweed beds dried out by uplift, and the decrease in the area of seaweed beds in Sotoura, R7-B09 Mud and turbidity that keep entering from river mouths (the seaweed and seagrass beds and rocky-shore fishing grounds of the Wajima coast), R7-B10 The decline of the offshore-side seaweed beds of the Sotoura coast of Suzu (tsunami or winter waves), R7-B12 High summer water temperature (the shallow sea of the Sotoura coast), R7-B13 The mass die-off of abalone and turban shells, and the fall in catches that continues for some years, R7-B25 The ama fishing of Wajima (numbers, resumption and the handing on of skills), R7-B26 Rebuilding the local activities that protect the seaweed beds of Wajima, R7-B27 Hegurajima Island and the Nanatsujima Islands (the fishing grounds of the offshore islands and life on the islands), I1 List of assessments