REGENERATION OF KELP FORESTS USING SEA URCHIN SHELLS IN SHAKOTAN, JAPAN

By Tomohiro Asakawa

Shakotan, a small fishing town in western Hokkaido, was faced with a problem which sea urchin harvesters all over the world will be familiar with: roes becoming smaller and more inferior in quality as the urchins over-forage on depleting kelp forests. At the same time, the industry in Shakotan had to find a way to dispose of urchin shells left behind after roe harvesting. The town developed an environmentally sustainable and unique solution to these problems. Urchin shells were used to make an underwater fertilizer which successfully regenerated kelp growth; sea urchins returned to feed on the kelp, and the roe production increased by 48% with improved quality.

Sea urchin shells are usually regarded as waste

Though not specifically mentioned in statistics, various studies have estimated the global production of sea urchins in 2018 to be about 63 000 tonnes, based on data contained in FAO's FishStatJ-Software for Fishery and Aquaculture Statistical Time Series. Of importance in its trade is the quality of the roe *(uni)* which is extracted from the sea urchins, and which is a popular delicacy in Japan. Global demand for sea urchin roe has also been increasing in recent years.

The ability of urchins to thrive in the wild and therefore produce high quality roe is dependent on maintaining a delicate balance with their food sources, one of the most important being kelp, which is a species of large brown alga. Kelp forests have a vital role in providing not only food and shelter to urchins and other marine species, but also in atmospheric carbon absorption and oxygenating the oceans. However, sea urchin populations tend to expand at an unsustainable rate as they forage on kelp, resulting in barren forests. This is an issue in many fishing grounds in Japan and other countries such as Norway, Canada, Australia, and the US, where the sea urchins become underfed and produce poor grade roe that is not viable for commercial harvesting.

Shakotan's innovative approach

Shakotan, a small fishing town in western Hokkaido with a population of 1 883, faced this problem. The local industry produced 20 tonnes of high-grade sea urchin roe in FY2019. However, roe production became inconsistent due to the sea urchins continuously feeding on the kelp forest and causing it to shrink. The urchins on the deserted kelp beds become underfed and deficient in nutrition; consequently, the proportion of sea urchins yielding poor quality roe continued to increase. At the same time, roe harvesting produced huge industrial wastes including about 100 tonnes of sea urchin shells, the disposal of which had to be addressed by fishers and processors. Sea urchin shells are rich in nutrients, including nitrogen and phosphorus.

The industry in Shakotan responded with an innovative project aimed at maintaining its output of good quality roe as well as utilizing the dried sea urchin shells. Rather Rather than discarding the shells, the town developed a unique underwater fertilizer whose application to deserted rocky shores successfully reproduced kelp *(Saccharina japonica var.religiosa)*. In the experiment, kelp on the treated rope grew 1.3 to 3.7 times faster than on untreated rope. Sea urchins returned to feed on the kelp, and the roe production increased by 48% with improved quality. Overall, the system recreated a complete and sustainable life cycle of kelp and sea urchin with zero emission and blue carbon while at the same time, reducing industrial waste. This project was categorized as an initiative to "Promote Utilization of Fishery Waste," in which the Japanese government provided funding to assist local revitalization.

Production of the underwater fertilizer

The fertilizer, consisting of crushed sea urchin shells and natural latex, adds nutrients which improve the growth of kelp beds in the area, including for *Hosomekombu* kelp (*Saccharina japonica var. religiosa)*, which is a natural feed for sea urchin. It is low in cost to manufacture, and fishers can produce it efficiently. The town experimented with two types of fertilizer; one involving ropes treated with the fertilizer for

kelp farming, and another was in blocks which were placed on rocks to regenerate kelp forests to attract sea urchins.

Experiments were carried out to determine the effectiveness of the sea urchin underwater fertilizer in regenerating kelp growth. In these trials, ropes treated with the fertilizer mix were lowered into the water at the test sites.

Conventional kelp farming in Hokkaido uses ropes. Wild kelp is harvested to collect seedlings on threads in the on-shore facility. When the seedlings grow 3-5 millimeters after about 40 days, farmers attach the threads to ropes and place the ropes in the oceans for commercial farming.

The production process is as follows:

- Crush sea urchin shells to powder and keep in fresh water for one hour;
- Immerse cotton ropes in this liquid for one hour and dry;
- Apply separately prepared dried sea urchin shell powder mixed with natural latex liquid to the ropes; and
- Before the liquid dries, apply the powder once more to the ropes and dry.

For fertilizer production in blocks to be placed on the rocky shores, the town selected natural latex as a solidifier because microorganisms break it relatively quickly, integrating it into the raw material cycle. Mix crushed sea urchin shells with 2-3 times the amount of freshwater-diluted natural latex. The mixture is placed into containers such as buckets, then dried naturally.

The sea urchin shells are crushed and then mixed with natural latex

The mixture is placed in containers such as buckets, then naturally dried.

Cotton rope treated with dried sea urchin shell powder and latex

Treated ropes were lowered into the water at the test sites

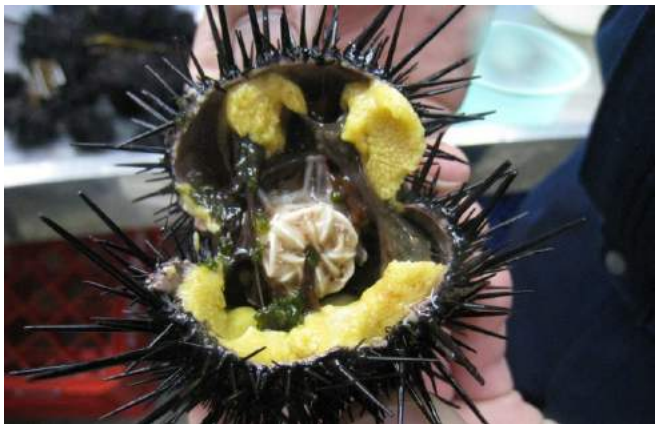
Kelp growth at experimental site

Before experimenting, after obtaining the consent of the local fishery cooperative, the fishers discussed the handling of the experiment plan under the relevant laws and regulations with the government agencies of Hokkaido and the town. They also reported to the Japan Coast Guard. In December 2019, fishers placed fertilizer blocks on barren rocks in the selected test area. By March 2020, a kelp forest had grown within a $5m^2$ area, and each blade length was about one metre. Two months later, sea urchins started feeding on the kelp.

A similar experiment was conducted in the same month, but this time in waters where kelp spores were scarce to determine the fertilizer's effectiveness in a different environment. In March 2020 at this second test area, no kelp growth was observed, indicating the limitation of the fertilizers in waters where there are insufficient kelp spores.

In July 2020, sea urchins were harvested from the two areas. In the first area (fertilized ground), 53 sea urchins weighing 3.26 kg produced 0.76 kg of high-quality roe, representing a gonadal somatic index (GSI) of 23.3%. Meanwhile, 52 specimens weighing 3.06 kg harvested from the non-fertilized ground, produced 0.48 kg of roe with 15.7% GSI. The results indicated that sea urchin grown in the fertilized ground had 1.48 times more GSI against the roe from urchins in non-fertilized ground. In other words, the fertilizer resulted in about 50% more production as well as higher quality roe.

Harvesting the sea urchins amid the regenerated kelp growth



High quality roe from sea urchin harvested in the first fertilized area

Over two years, the fishers also studied the growth of cultured kelp using ropes treated with sea urchin shell fertilizer. In May 2019, treated ropes resulted in 48.3 kg kelp, whereas untreated ropes produced only 13 kg of growth. By June 2020, the kelp growth had risen to 59.7 kg for the treated ropes against 46.3 kg on untreated ropes. This experiment proved that the nutrients in sea urchin shells effectively increase the production of farmed kelp. Town officials were encouraged to apply the fertilizer to more kelp beds where sea urchins had destroyed the kelp forest.

A blue carbon farming future for Shakotan

The sea urchin shell fertilizer reduces industrial waste, has no negative impact on the shore environment, is low-cost and easy to manufacture by fishers, flexible in size and shape, and does not require any special machinery for placement. The kelp forest also helps in sequestering carbon dioxide. Moreover, the town officials are proud to see the revitalization in the shore environment. In 2020 and 2021, 11 districts outside Hokkaido experimented with growing cultured marine plants, including *Undaria* sea mustard, employing Shakotan's technology.

A Shakotan town executive said, "At first, we were skeptical about the effect of sea urchin shell fertilizer, but we saw that the experiment was successful in regenerating the kelp forest. In the future, we would like to continue such activities to make sea urchin fishing sustainable and to protect the environment with blue carbon."

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