Large-Scale Open-Water Aquaculture System

1 Introduction: Background Factors

The production of seafood is expected to expand on the back of the continued growth predicted for the global population, with demand for food also increasing in step. Given that the harvest of wild-caught fish has plateaued internationally, including in Japan, aquaculture production will be needed to make up the difference (see Figure 1). The sustainable development of aquaculture is an urgent issue, with large-scale open-water aquaculture systems being needed to form part of the solution.

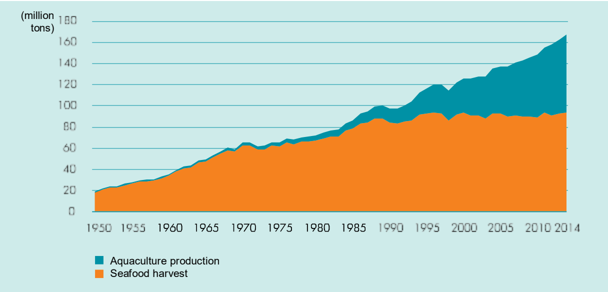

Figure 1 Global seafood harvest and aquaculture production (Source: "The State of World Fisheries and Aquaculture, 2016", United Nations Food and Agriculture Organization (FAO))

2 Large-Scale Open-Water Aquaculture System

In a large-scale open-water aquaculture system, fish are farmed in large quantities under conditions of high waves and strong tidal currents. The system is made up of two sub-systems: [1] Several large cages in which the fish are raised, and [2] Automatic fish feeding system (see Figure 2).

In Japan, most aquaculture takes place in sheltered coastal waters where waves are relatively small and with better access from the land where it is easier to work. Unfortunately, there is only a limited sea area suitable for such operations and it is recognized that such sites are largely already taken.

Also, most coastal aquaculture operations are run by private farmers using small-scale cages (around 10 m × 10 m × 10 m), making them unsuitable for a large scale production. In fact, the current situation raises numerous concerns, including water pollution due to uneaten feed, excreted waste from the fish, and the consequent problems with fish health, something that is exacerbated by the slow circulation of seawater (or the low rate of water exchange) in inshore waters. Labor shortages are another constant concern due to the need for experienced workers and the hazardous nature of the workplace.

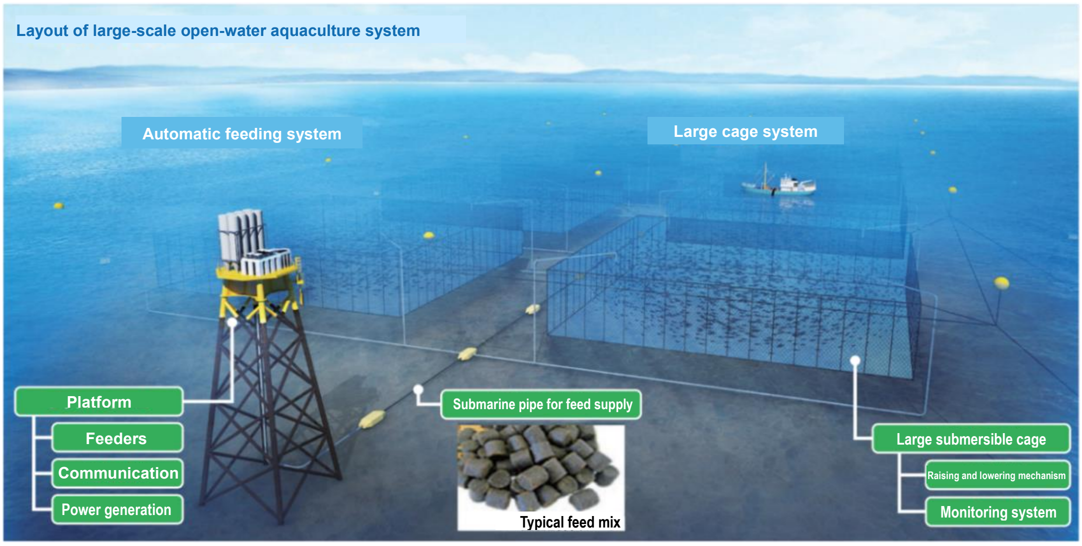

Figure 2 Layout of large-scale open-water aquaculture system

In contrast, large-scale open-water aquaculture systems use large cages of 50 m × 50 m × 20 m and are intended for offshore locations where there is a relatively fast flow of water (it is assumed that a typical site would have a depth of around 60 m and a maximum significant wave height of 10 m). By enabling new developments in waters that have not previously been used for aquaculture (see Figure 3) and through the use of measures such as automation to increase productivity, these systems provide a large scale and efficiency for corporate operators (see Table 1).

Table 1 Benefits of large-scale open-water aquaculture system

New sites	Ability to withstand harsh seas and currents enables operation in waters where aquaculture was not previously possible.
Scale	Production in bulk is achieved through the use of large cages approximately 50 times the size of those used currently.
Labor saving	Operation with less or no staff is possible using technologies such as automated feeding. This reduce wage costs and addresses issues of labor shortages.

3 Technological Breakthrough

Large cage system

The development of the large cage system drew on Nippon Steel Engineering's experience in technology for offshore structures such as oil and natural gas platforms. Unlike structures that are fixed to the seafloor, however, cages floating on the sea surface must be able to withstand wave and current force. Furthermore, because Japan experiences frequent natural events such as typhoons, cages need to be able to submerge below the surface of the sea in order to withstand winds and waves that are more severe than in inshore waters.

To assess the effects of waves and water currents, numerous simulations were conducted to analyze a wide variety of parameters using scale models and computational techniques. The results indicated that performance would be adequate for open water environments, including that the required strength could be achieved along with reliable raising and lowering of submersible cages despite their size, approximately 50 times larger than those used currently. This technology could possibly provide a pathway to higher fish production.

Automatic feeding system

In Japan, the conventional way of feeding is conducted using feeding vessels and the fish are fed either by hand or machine. In open waters, on the other hand, where conditions can be extreme, the concern is that vessels may not be able to access the sea for days at a time due to bad weather and would interfere with the scheduled fish growth. To solve this problem, Nippon Steel Engineering has devised an automatic feeding system that uses a submarine pipeline through which fish feed can be supplied directly to the cages. The system draws on the company's expertise in the conveyance of pulverized coal at steel plants.

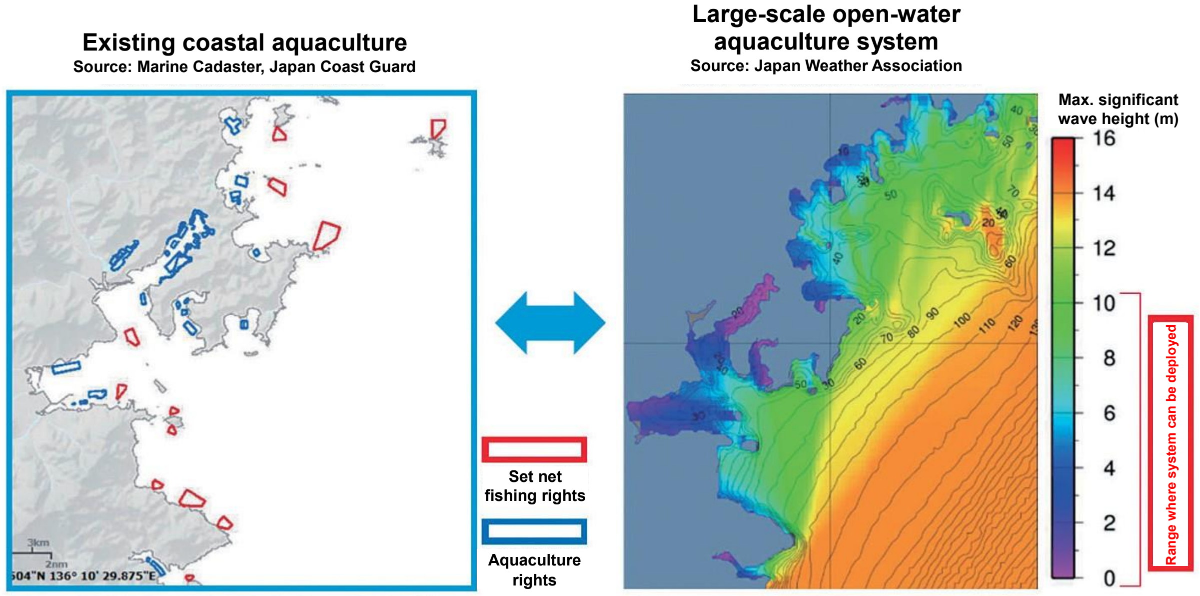

Figure 3 Comparison of existing inshore range and new expanded range

However, the pelletized feed used in aquaculture differs from the pulverized coal and could be easily broken during long conveyance due to its fragileness. As this will be wasted because the fish fail to recognize it as food, the best way to transport the feed without damage is an issue to be addressed. Furthermore, because the feed size preference and the feeding behavior differs largely between fish species, there is a recognized need to be able to control the timing and rate of feed supply to suit the difference according to the species. To determine the operating conditions needed to satisfy these criteria for feed transportation, a trial pipeline was built on land and used to assess the disintegration rate for a variety of different feeds under different transportation conditions. Thus, the optimal conditions for conveying feed were achieved successfully.

This culminated in the successful completion of an automatic feeding system made up of a submarine pipeline and a platform on which the storage silos and feeders were installed. The system contributes to higher production efficiency and lower costs by supplying enough feed without interruption and by lightening the human workload.

4 New Initiatives

Nippon Steel Engineering is now developing a production management system (see Figure 4) that can provide an optimal feed supply under various different conditions by using underwater cameras and other sensors to perform continuous monitoring of the farm environment and other factors such as fish growth and behavior (see Table 2). In order to determine the best rate and quantity of feed, machine learning models will be achieved and applied to analyze this data.

Table 2 Examples of data collected by production management system

Environmental	Water temperature, current, wave height, dissolved oxygen concentration, salinity, air temperature, hours of sunlight, etc.
Fish growth	Fish count, weight, appetite, etc.
Feeding	Feed quantity and timing, etc.

This enables the feed quantity to be adjusted dynamically based on factors such as fish growth and appetite, thereby reducing the feed conversion ratio (FCR), the weight of feed administrated divided by increased fish weight, and significantly cutting the cost of feed, which accounts for about 70% of production cost. This also may turn the individual aquaculture skills into a common resource that can be shared and passed on. These outcomes should improve returns on investment and help to transform aquaculture into a growth industry.

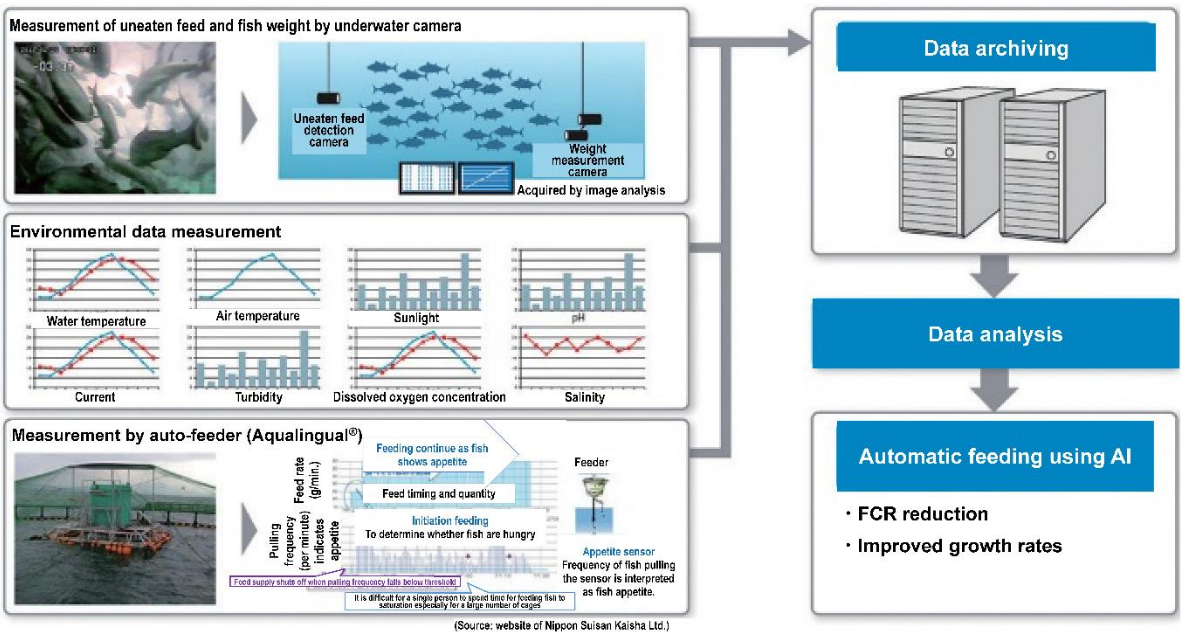

Figure 4 Production management system

5 Future Plans

Good progress is being made on preparations for the construction of the first commercial large-scale open-water aquaculture system through participation in the demonstration project in Sakaiminato City, Tottori Prefecture, the demonstration project in Owase City, Mie Prefecture and the (still ongoing) project "R&D matching funds on the field for Knowledge Integration and innovation" run by the Bio-oriented Technology Research Advancement Institution of the National Agriculture and Food Research Organization.

Awareness is spreading that the development of previously untapped offshore waters represents a breakthrough in aquaculture. Momentum for action is building in both government and industry, one example of which was the fisheries industry policy reforms being undertaken by the Fisheries Agency identifying offshore aquaculture as one of the initiatives for turning aquaculture into a growth industry. Beyond the modernization of Japanese aquaculture and its role as part of the country's "sixth sector industrialization" lies a grand vision of meeting the public expectations of global markets and contributing to the future of humanity. Nippon Steel Engineering intends to take on the burden of this vision and its associated responsibilities, and to continue its work on developing better aquaculture systems.

For more information, please contact:
Aquaculture System Business Department
Business Solution Center
TEL (03) 6665-2638