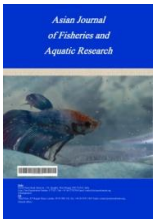

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Aquaculture Recovery in Shizugawa Bay, Japan: Post Tsunami Recovery

Peter W. Wilson[1,2*], Tanya L. Park[3], Beatrice Harrison-Day[4], Davis Hinton[5], Laura Nilssen[5], Matthew Rose[5] and Stuart Isles[5]

[1]The King's Institute, The King's School, Parramatta, NSW 2151, Australia.
[2]School of Biological, Earth and Environmental Sciences, University of New South Wales, NSW 2052, Australia.
[3]OCP Architects, Surry Hills, Sydney, Australia.
[4]School of Biological Science, University of Tasmania, Sandy Bay Campus, 7000, Tasmania, Australia.
[5]Institute for Marine and Antarctic Studies, University of Tasmania 7000, Tasmania, Australia.

Authors' contributions

This work was carried out in collaboration among all authors. Author TLP supervised the study aurhor, BH-D wrote the first draft of the manuscript. All authors managed the analyses of the study and literature searches. Author PWW wrote the final draft. All authors read and approved the final manuscript.

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ABSTRACT

This report outlines a study undertaken at Minamisanriku, a small coastal village on the East Coast of Honshu, Japan, in late 2018. The area relies heavily on fisheries and aquaculture for economic stability. While there, scientists, community leaders and individuals involved in the fisheries and aquaculture industry were interviewed to gain a qualitative understanding of the impacts of the 2011 tsunami caused by the Great East Japan Earthquake, particularly on the oyster industry and aquaculture in general in the region.

The tsunami completely disrupted aquaculture operations, with a 93% loss of infrastructure. Consequently, stakeholders were presented with an opportunity to restructure in some way as they rebuilt the industry. The resulting 66% reduction in some species densities within aquaculture lots has subsequently led to increased sustainability and increased product quality. Those gains,

**Corresponding author: Email: pwilson@kings.edu.au;*

paired with reduced material cost and efforts, have together resulted in a more socio-ecologically responsible aquaculture operation. This operation now generates at least same amount of revenue as pre-tsunami.

Keywords: Aquaculture; fisheries; tsunami; Japan.

1. INTRODUCTION

This article looks at how the local fishermen have been able to restructure the aquaculture industry following the devastating tsunami. Rather than simply rebuilding as before, a more sustainable approach was taken and the results have proved that approach to be very successful.

The focus of the study outlined below is the redevelopment of the aquaculture industry in Shizugawa Bay, Minamisanriku, Japan following the 2011 tsunami caused by the Great East Japan Earthquake (as illustrated in Fig. 1).The focus is on oysters particularly. With 93% of fishing equipment and aquaculture-related infrastructure washed away as a result of the tsunami, the region faced catastrophic damage to the aquaculture industry (Moaka, 2018). This created a unique challenge to the industry, that is, to start again or to disappear.

Our study site was the 46.8 km^2Shizugawa Bay, just south of Minamisanriku. This the town historically has been deeply involved in the production of seafood products for consumption and exportation. Prior to the disaster however, the Bay ecosystem was suffering as a result of high density placement of the racks, intensive sea-farming. Discussions had already taken place locally regarding the restructuring of the Bay's aquaculture infrastructure in order to minimize stress caused to the natural ecosystem.

Highlighting the Shizugawa Bay aquaculture industry both prior to, and following the tsunami allows for analysis of the regeneration of the industry. We demonstrate here how it has successfully redeveloped itself from ecological, economic and social points of view. While using Shizugawa Bay as a platform to show the redevelopment, it does have to be noted that other aquaculture regions that were affected may have regenerated differently and the redevelopment of Shizugawa Bay may not be directly applicable to every local region affected by the tsunami.

2. MATERIALS AND METHODS

Shizugawa Bay is on the East Coast of Japan, along the Sanrikuria Coast, facing the Pacific Ocean. The aquaculture industry in the Shizugawa Bay began as a small-scale operation and with advancements of equipment such as synthetic rope in the 1970's, fishing became simpler and more lucrative. More people were fishing and so making more money and this resulted in a fishing boom from the late 1970s (until 2011) [2].

By 2009, the area was densely packed with aquaculture, ranging from finfish farming, seaweed cultivation to shellfish cultivation. This then began to have adverse effects on the products, including the fact that oysters took up to three years to harvest. This long growth cycle meant the oysters needed more nutrients and required more labor and economic input to create the final product. As mentioned, pre-tsunami the fishermen had established that the Bay was overcrowded (as shown in Fig. 2), but creating a solution was not immediately obvious to the local stake holders. The fishermen and local interested parties were motivated and were interested in managing the coastal area, but this was seen as a long and difficult process to redevelop (Moaka, 2018), [3]. The fisherman, Mr Moaka, joked, "they say that they would need a tsunami to wash away the area so that they could start again". The slow and steady decline in total gross weight of oysters harvested can be seen in Fig. 2.

With the 2011 tsunami, enormous damage was caused to the aquaculture industry and the opportunity to start again arose [4]. More than 93% of fishing equipment and infrastructure washed away. Only 132 of the 2194 boats of the aquaculture fleet remained [4], (Moaka, 2018). Fig. 3 demonstrates the loss in oyster facilities in the Bay immediately after the tsunami (from 1400 down to less than 50) and the subsequent growth back again. However, the growth has not been designed to have the number of facilities ever to be back at pre-tsunami levels.

Compounding the loss of the entire aquaculture industry of the Bay was the significant population decline that followed the disaster, both from the lives lost in 2011 and from migration away from the area given the lack of employment and disaster impact. This created a 29% population loss in Minamisanriku (from 17,500 pre-disaster

to 13,000 post disaster, KYODO [5], *Japanese times)*.

Following the 2011 earthquake and tsunami, Miyagi Prefecture and the town of Minamisanriku were both provided with a unique opportunity for complete aquaculture redevelopment. With fishermen already representing a small percent of coastal communities, when coupled with an aging population of fisherman and only small numbers of successors coming through to continue the aquaculture industry, this turning point in redevelopment was critical in insuring that the aquaculture industry even continued after the disaster [3]. Seven years (i.e. by 2018) into the redevelopment of the aquaculture industry, the changes can be illustrated and explained to some extent by a closer look [6].

Fig. 1. The devastating damage in the region of Minamisanriku, Japan. Photograph from Daily Mail newspaper [1]

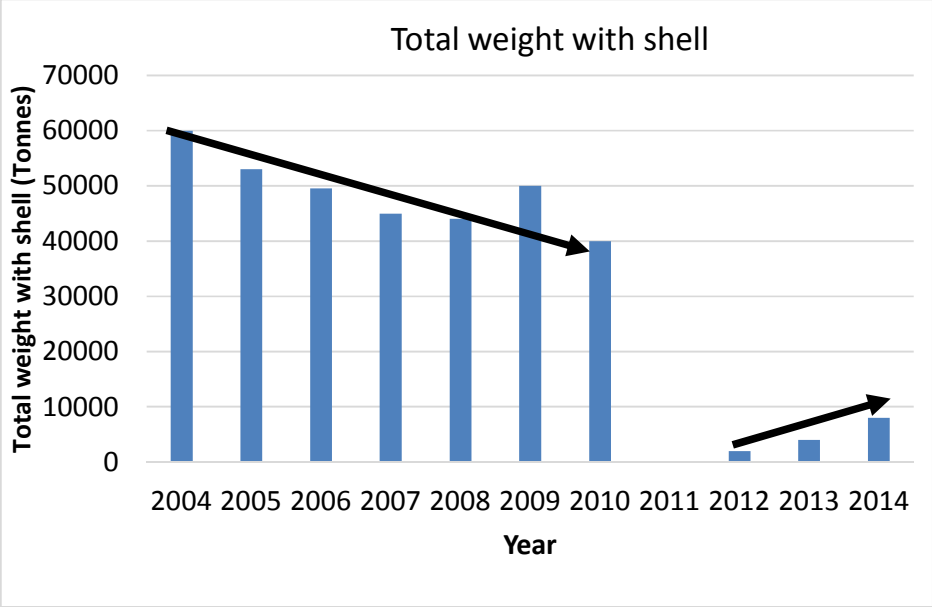

Fig. 2. Total gross weight (i.e. with shell) of oysters farmed in the Bay steadily declining up until the tsunami in 2011. The few years immediately after the tsunami saw a growth (at a higher percentage than the equivalent decline had been)

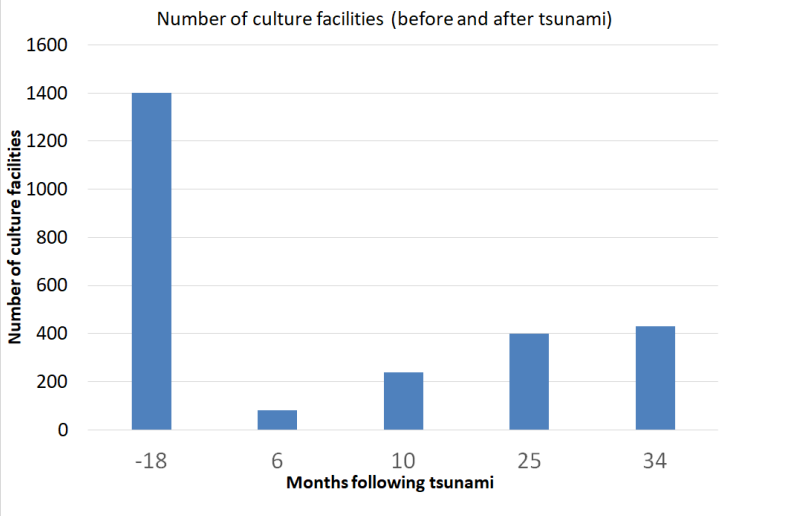

Fig. 3. Comparing February 2009 to Jan 2014, (i.e. 18 months before tsunami to 34 months post tsunami) the ⅔reduction in number of culture facilities is evident (1400 down to 420)

3. RESULTS AND DISCUSSION

The redevelopment of the oyster industry initially created tension as fishermen's shares in the leases were all revoked and then numbers reduced and re-allocated equally. The Prefecture gives rights to the Fishery Union, the Union in turn allocates to individual fishermen the number of lines/racks. There is a historical tendency for fishermen and co-ops to hold onto these leases for many years. Certain areas were considered better, or worse, with respect to aquaculture. For example, edge of plots were thought to be the best due to the extra nutrients available to them.

After the disaster, some people who had so called "better" lots had to give them up and start again. The opportunity created meant that there would be no further "better" plots, as the new aquaculture was significantly more spread out.

The success of this redevelopment can best be demonstrated through the product created after the restructure (see Figs. 4 and 5). With oysters as the best example, the net weight of oysters has dramatically increased and has (by 2018) resulted in a one year growth cycle instead of the previous three year cycle, causing a higher turnover and overall higher quality (see Fig. 3) [7]. Indeed, since 2011, the price of oysters has gone up and fishermen have overall made more profit (than pre-tsunami). The less dense spreading of racks meant fewer racks and so less work as well as faster harvest and production.

The number of salmon farmed in the Bay has remained the same, but the salmon nets have generally moved closer to land. There are better nutrients closer to the land because of the river output and there is better water quality in the region due to the reduced amount of aquaculture [8].

The re-modelling of Minamisanriku allowed for its aquaculture products to gain the Aquaculture Stewardship Council (ASC) in 2016, the first in Japan, only five years after the disaster [9]. The ASC represents environmentally and socially responsible seafood. The ASC has given the product more authority in the Japanese market, as buyers are more aware in recent years of the ethical considerations that have gone into the product. This was a significant stepping-stone for sustainable aquaculture across Japan, with over 67 ASC granted fishery leases in Japan (the majority are in the Miyagi prefecture) as of late 2020.

The aquaculture industry did not change specifically to get ASC but rather it changed for the benefit of future generations and for the positive effects managing aquaculture gave them [10,11]. This example of the success of an aquaculture industry after a natural disaster, with the industry now considered more sustainable and producing a better product than before, may not be unique globally, but is certainly a model to be highlighted.

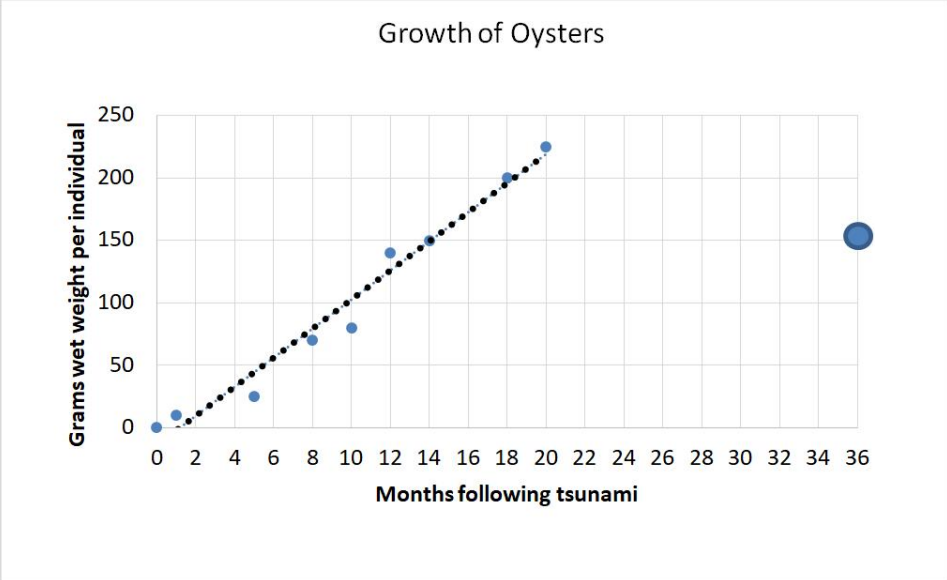

Fig. 4. Individual oyster size as a function of time (as of 2018). The blue dot is average size after 36 months, prior to the disaster

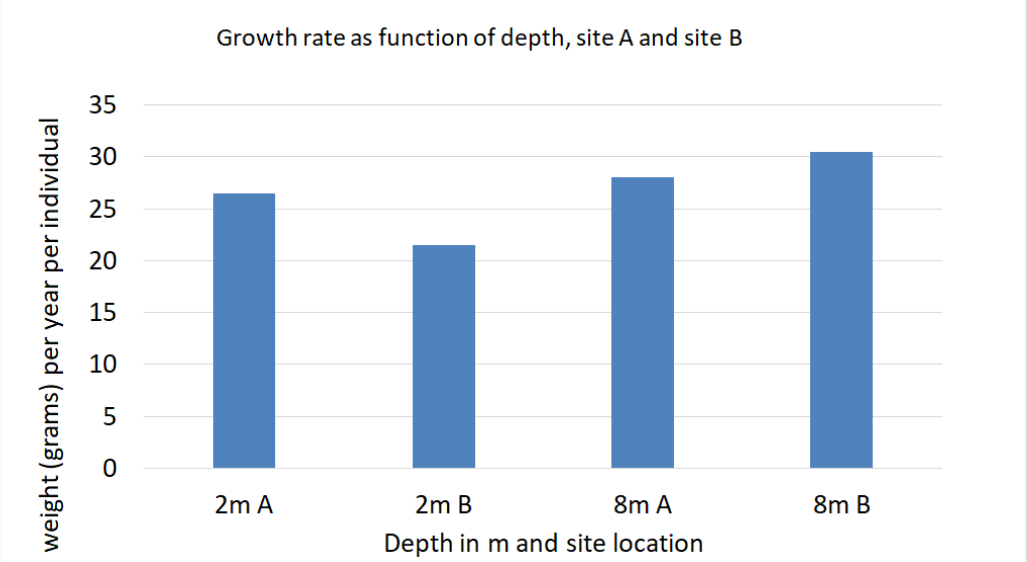

Fig. 5. Growth rate as function of depth from site A and site B. Both sites are well within the Bay and the actual latitude and longitude of sites is immaterial to this discussion. Measurements (taken in February, 2014) indicate that a depth of 8m below the surface adds weight to individuals at a faster rate that at a depth of 2m below the surface.

4. CONCLUSION

The redevelopment of the aquaculture in Minamisanriku since the 2011 tsunami caused by the Great East Japan Earthquake has been seen as successful in the eyes of the local fishermen and people of Shizuguwa Bay. Through first-hand experience and anecdotal evidence we have briefly reviewed the redevelopment process which occurred. The success of the aquaculture is measured through the increased price, the increased quality of product and the fact that an industry which could easily have collapsed after

the disaster has managed to return, stronger and smarter than before.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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