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Symposium mini review

## Recent Challenges for Developing Barnacle Aquaculture Techniques in Japan

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### Abstract

More than ten species of barnacles are distributed in the market worldwide. In Japan, they have high potentials as tourism and fishery resources. Small scale aquaculture has been conducted in Aomori prefecture, Japan, since about 20 years ago. However, it needs high quality of skills and only a few fishermen are engaged in the aquaculture. Authors and colleagues have made efforts to develop novel techniques by using Japanese species to achieve efficient production of spats in hatchery and well-shaped barnacles with flat bottoms, by which each individual is easily harvested from the substratum. In addition, there has been increasing interest in developing efficient aquaculture techniques of barnacles worldwide since the resources are declining because of overexploitations. While further efforts are needed, our studies will contribute to activate the local tourism and economies, as well as conserving resources.

### Introduction

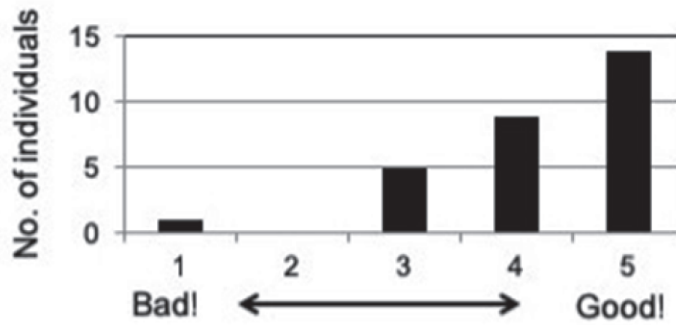
Thoracican barnacles (hereafter referred as barnacles) are sessile crustacean that dominate many intertidal and subtidal environments. Barnacles consist of two orders, Pedunculata (goose barnacles) and Sessilia (acorn barnacles). Goose barnacles attach themselves by means of a stalk while acorn barnacles lack the stalk and their shells directly attach to the substratum. Today, more than ten species of barnacles are distributed in the market worldwide and most of them are consumed by local communities (López *et al.*, 2010; 2012a). A goose barnacle *Pollicipes pollicipes* ‘percebes’ is popular in Iberian Peninsula (López *et al.*, 2010; 2012a). The production of this species is 300 to 500 tonnes / year in recent years (López *et al.*, 2010), and resources are decreasing because of the overexploitation (Jacinto *et al.*, 2011; Carvalho *et al.*, 2017). An acorn barnacle *Austromegabalanus psittacus* ‘picoroco’ is harvested by local fishermen with average landings of 200 t/y in Chile (López *et al.*, 2010). It is also suggested that overexploitation driven resource decline occurs in this species (López *et al.*, 2012b). Such resource declines increased interest to the aquaculture of barnacles (Franco *et al.*, 2015; 2017; López *et al.*, 2012b). However, López *et al.* (2010) reported that aquacultures of barnacles are conducted

only in acorn barnacles in progress at a pilot or a semi-industrial level. The large-scale production of barnacles by aquaculture depends on the optimization of spat collection from the wild and/or the development of mass production techniques for larvae (López *et al.*, 2010).

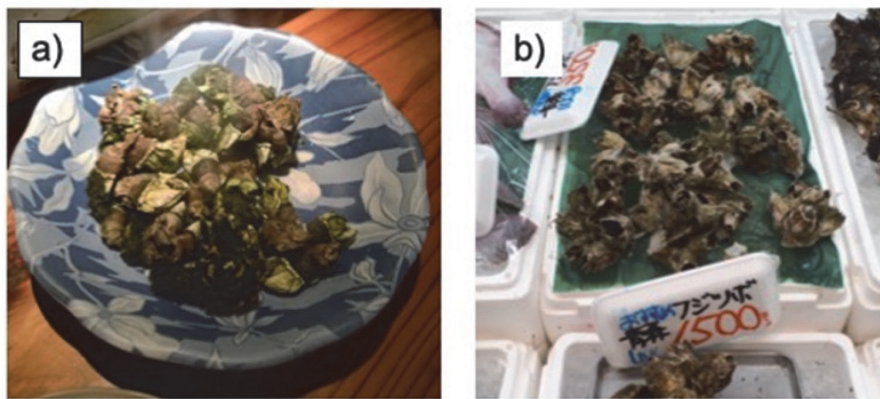
Both acorn and goose barnacles are commercially viable in Japan (López *et al.*, 2010; Oshino, 2006). Recently, authors and colleagues made efforts to develop barnacle aquaculture techniques with using Japanese barnacles. In this paper, we introduce recent topics involved in barnacle aquaculture in Japan.

### Potency of barnacles as tourism and fishery resources in Japan

Barnacles have high potentials to be a popular food sources for Japanese people because of the good taste (**Fig. 1**) while it is less common at present. A goose barnacle, *Capitulum mitella* ‘kamenote (**Fig. 2a**)’ is exploited by local fishermen in western part of Japan (Oshino, 2006). In Aomori prefecture (northeast part of Honshu, Japan), small scale aquaculture of an acorn barnacle *Balanus rostratus* ‘mine-Fujitsubo (**Fig. 2b**)’ has been conducted by suspended systems with using spat that produced in the ocean (Tsurumi, 2015). This species



**Fig. 1.** Result of taste test of an acorn barnacle *Megabalanus rosa* 'aka-fujitsubo' conducted in Ehime, Japan in 2015 (Tsurumi, unpublished).



**Fig. 2.** Commercially viable barnacles in Japan. (a) *Capitulium mitella* 'kamenote' served at a restaurant in Wakayama, Japan. (b) *Balanus rostratus* 'mine-fujitsubo' at a market in Aomori.

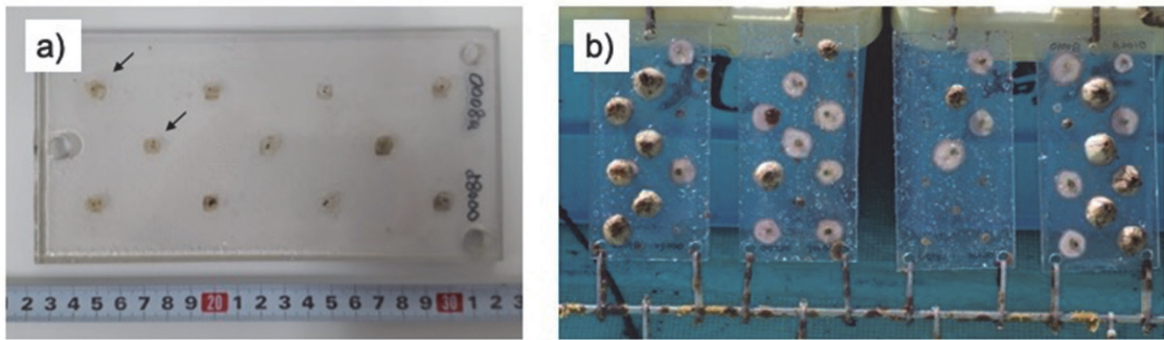
distributes north part of Japan and is known as “one of the eight delicacies” in Aomori. Selling price of this species can be 7,000 yen/kg (Tsurumi, 2015; 2016) and therefore, it has potentials to activate the tourism and the economy in Aomori and neighboring areas (Sanriku region that consists of Aomori, Iwate, Miyagi prefectures): if 30% of the tourists who stay at least one night in Sanriku eat two barnacles, the estimated sale is up to 2.7 - 5.5 billion yen/year.

### Recent progress in barnacle aquaculture techniques in Japan

*Balanus rostratus* was recognized as potential food sources by a local chef and has spread in Aomori in 1990s (Tsurumi, 2015). This species has, then, suffered heavy exploitation pressure in 1990s and the resources have declined (Tsurumi, 2015). In 2000s, studies have been conducted to verify the feasibility of *B. rostratus* aquaculture in Mutsu Bay (Nakanishi *et al.*, 2003), and Okkirai Bay, Iwate (Kado *et al.*, 2009a). Today, most *Balanus rostratus* individuals in the market are from the aquaculture in Mutsu Bay. However, it needs skills of highly experienced persons to collect spat in the wild even though ecological properties, such as reproductive season and seasonal patterns of larval distribution, of *B. rostratus* were well studied in Shizugawa Bay, Miyagi (Yamauchi *et al.*, 2007) and Mutsu Bay in Aomori (Kado *et al.*, 2009b). Only a few fishermen are, therefore, engaged in the aquaculture (Tsurumi, 2016).

To promote the aquaculture by fishermen, development of mass production techniques for larvae and spat is necessary. We have succeeded in producing mass culture of larvae in 500 L tanks by feeding *Skeletonema costatum*, and production of spat (Tsurumi *et al.*, 2015). However, there are still problems to be solved for the consistent production. It is suggested that optimizing lipid condition is important for the cultures of planktonic crustaceans (Yamada *et al.*, 2017). Recently, authors and colleagues identified lipid profiles during the ovary maturation process in *B. rostratus* (Yamada *et al.*, 2019). Such efforts may contribute to improve the larval culture conditions.

Barnacle larvae show gregarious settlement (Clare, 2010) that causes variabilities in adult shell morphologies due to density-dependent effects. In addition, it is practically impossible to separate individuals from each other. Unit of barnacles in the market is, therefore, mass of individuals on a plate (**Fig. 2b**), which likely leads to decrease the likelihood of purchases by tourists and persons who want to buy just one or two individuals. To solve the problem, we have developed a novel technique to produce barnacles that are uniform in morphology with flat bottoms by which each individual is easily harvested from the plate (Tsurumi, 2016). In this technique, plates are covered with silicone paint with making uncovered spots at regular intervals (**Fig. 3a**). Because the paint inhibits the settlement of barnacle larvae, settled larvae on the silicone-free spots can grow without competition with neighboring individuals (**Fig. 3b**). In addition, the paint inhibits the fouling of other organisms during the culture in



**Fig. 3.** Novel plates to produce well-shaped barnacles. (a) A plastic plate covered with silicone paint. Arrows indicate silicone-free spots. (b) Adult barnacles attached on the plates and cultured in the ocean. Bottom of each barnacle individual is flat and it is easily harvested by inflecting the plate.

the ocean, which drastically reduces the maintenance cost of the plates. It is possible to re-attach the harvested barnacles with flat bottoms to protecting sheets by keeping them in sea water for a day, which reduces the risk of damages during transportation.

Similar efforts have also been made to develop the aquaculture systems in another acorn barnacle *Megabalanus rosa* ‘aka-Fujitsubo’ which distributes western part of Japan (Oshino, 2006; Tsurumi, 2015). Thus, barnacles can be important tourism and fishery resources all over Japan by improving larval culture conditions as well as establishing the business models.

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