Effects of the size of abalone (*Haliotis discus hannai*) seeds stocked in sea cages on growth

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Introduction

Over the past 20 years, Korean abalone aquaculture has increased rapidly, with 24,126 tons produced in 2023, which amounted to USD 390 million. Abalone farming on land, which was mainstream until the late 1990s, failed to meet market demand due to high production costs and difficulty in mass production. Therefore, abalone cage farming began to spread in the early 2000s to meet market demand and became a catalyst for rapidly increasing abalone farming production. The rapid increase in output through sea cages led to the development of abalone seed production technology and the establishment of a mass production system for seeds. Furthermore, the seed culture farm developed an early seed abalone production technology to produce the large seeds required for sea cages, which allows seed collections to begin in February. In addition, we supply high-protein mixed feed to promote the growth of abalone seeds, with the mixed feed showing superior growth compared to seaweed. Moreover, owing to the recent development of abalone seed production technology, larval abalones are collected in the spring. Seeds measuring more than 3 cm long are produced in November of the same year and supplied to sea cages. However, the increase in the size of abalone seeds supplied to cages is causing an increase in seed prices, adding to the economic burden on abalone fishermen. Thus, many studies have been conducted to improve abalone growth characteristics. Presently, most studies have conducted abalone breeding with the goal of rapid growth, such as selective breeding of abalone considering genetic diversity, production of triploid abalone for sterility, and improvement of growth and survival rates through hybridization. Hence, the size of abalone seeds stocked in sea cages has been increasing over the past 10 years. However, it has yet to be verified whether the size of seeds initially introduced into the cage positively affects overall growth and productivity during long-term cultivation in sea cages. In other words, an abalone is an invertebrate with very slow growth, and it is not clear how much influence its growth early in its life cycle has until it becomes a mother. However, sea cage fish farmers continue to purchase large seeds at higher costs and stock them in cages despite the lack of clear information on how the initial growth of abalone affects the overall growth of abalone's life cycle. Therefore, this study classified Pacific abalone (*Haliotis discus hannai*) seeds produced in a seed culture farm by size, stocked them in sea cages, and observed their growth over a long period to investigate the effect of seed size on productivity.

Methods

Experimental species

- Pacific abalone were purchased from a seed producer in Wando-gun, Korea.
- Spat sizes A (3.2– 3.6 cm), B (2.9–3.2 cm), C (2.6–2.9 cm), and D (< 2.6 cm) were stocked in sea cages (since mass mortality occurred 1 month after stocking, D was excluded from the experiment).
- Growth and survival rates were examined on days 100, 200, 500, and 722 of stocking.
- Growth was measured by randomly sampling 30 animals from each sea cage.
- The survival rate was calculated by collecting and counting dead animals when measuring growth and calculating the number of surviving animals.

Abalone farming process

- In producing seeds, abalone seeds that passed the trochophore stage were attached to a tank rich in diatoms and with sufficient attachment substrate.
- Afterward, it continuously provides clean seawater through perfect filtration using a sand filter. In addition, to maintain an appropriate water temperature, the water temperature was adjusted using a heater or cooler, and dissolved oxygen was maintained at an appropriate range using liquid oxygen.
- Initially, food was supplied using diatoms; artificial feed provides food after about 3 months of rearing.
- A complete water change was performed daily to prevent the food from spoiling.
- Due to the large seawater flow in the offshore cages, nets were cleaned twice a year, and seaweed was supplied monthly.

Results & Discussion

1. Seed production and sea cage farming

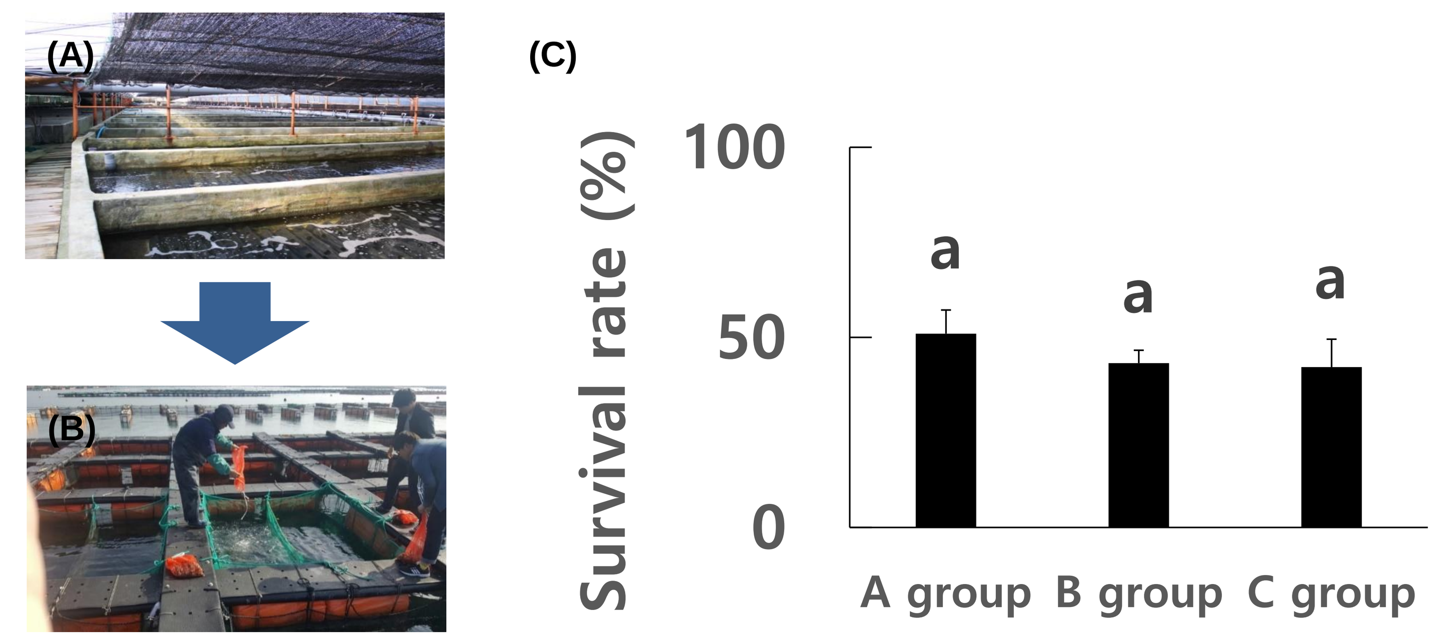


Fig 1. (A) Juvenile abalones that had passed the trochophore stage and entered the appressoria stage were produced in land-based seed production plants up to around 3 cm in length. (B) Abalone seeds produced around 3 cm in size were transported to sea cages and grown under the same conditions used by actual abalone farms. (C) No significant difference was observed in the survival rates between groups A, B, and C.

Juvenile abalones that had passed the trochophore stage and entered the appressoria stage were raised in a land-based seed production facility. Individuals that had grown to around 3 cm were selected by size: A (3.2–3.6 cm), B (2.9–3.2 cm), C (2.6–2.9 cm), and D (< 2.6 cm). Afterward, they were stocked in sea cages for each experiment and reared for 722 days. No significant difference in the survival rate was observed between groups.

2. Abalone stocking and management process

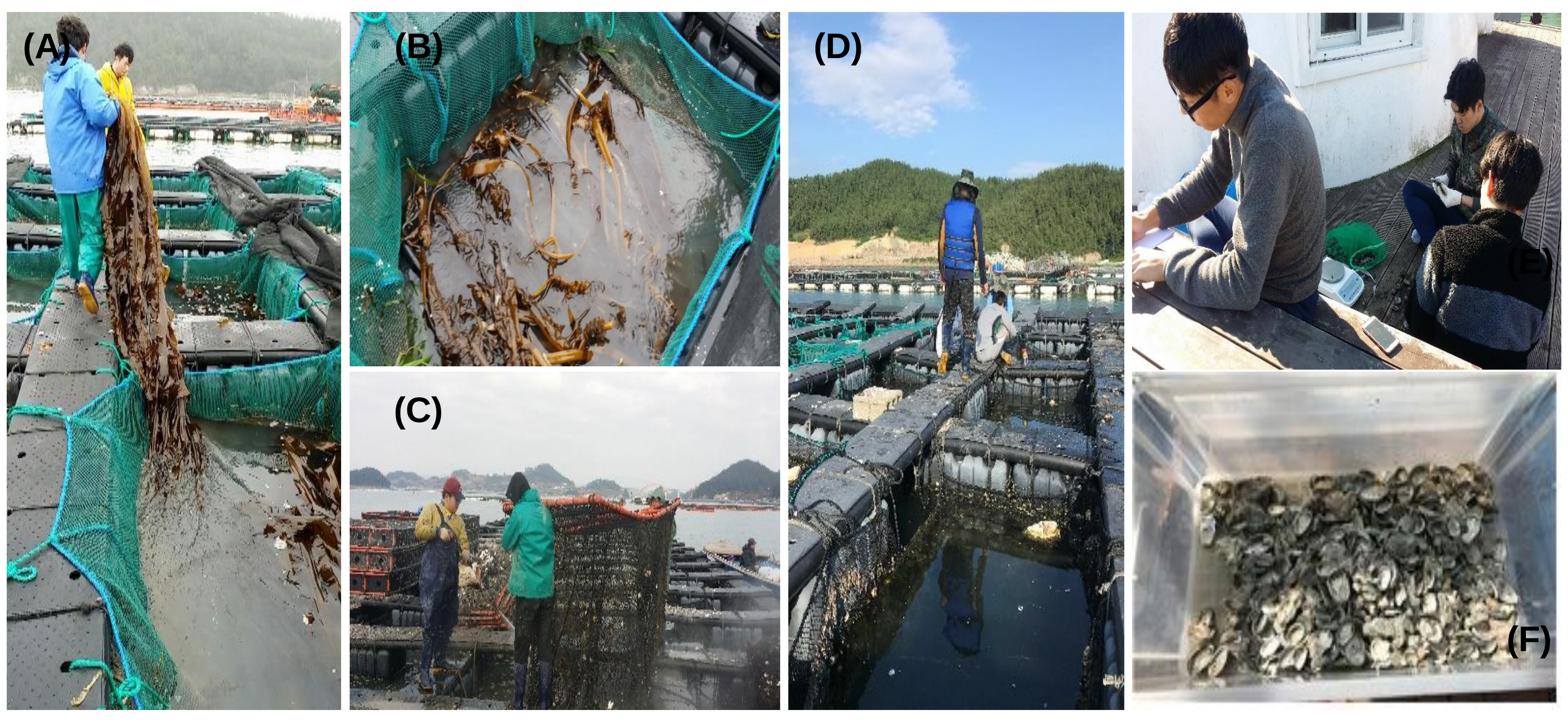


Fig 2. (A) Supplying seaweed after spat seed stocking. (B) Feeding process after feeding seaweed. (C) Activities to investigate the sea environment. (D) Daily size and weight abalone measurements. (E) Collection after death in sea cages.

Since it is difficult to control changes in the sea environment in offshore waters, observation of those changes is essential; thus, a preliminary site survey is necessary.

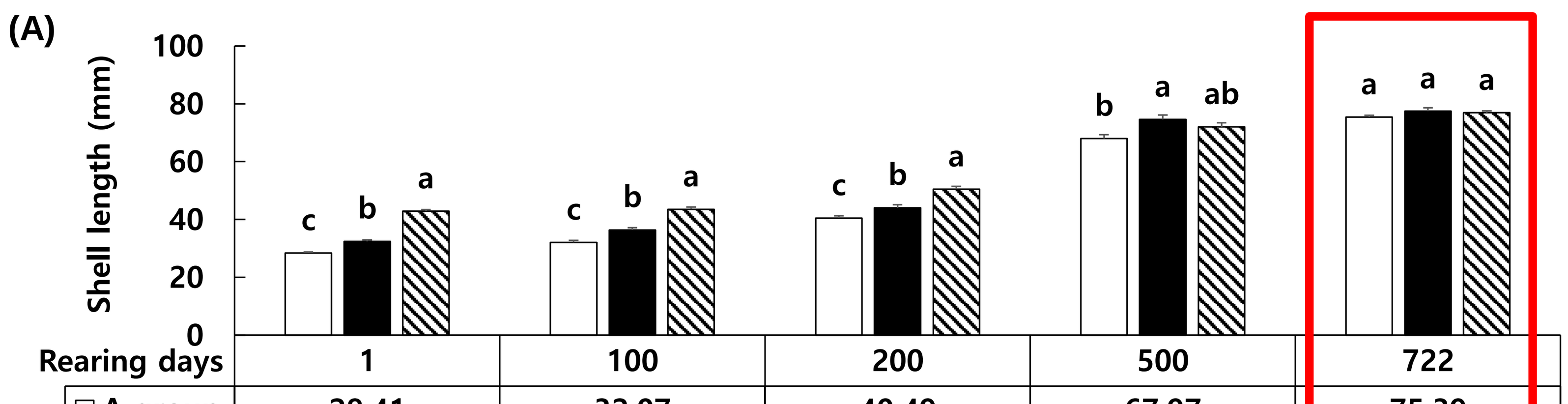
Sea cages were installed in locations suitable for abalone breeding, and an appropriate amount of food was supplied in advance. After abalone seeds of each size were stocked, nets were cleaned twice a year, and seaweed was supplied monthly due to the large flow of seawater in the offshore cages. Dead individuals were collected to determine the survival rate, and considering the uniformity of the experiment, all work was performed manually.

3. 722-day changes in marine environment

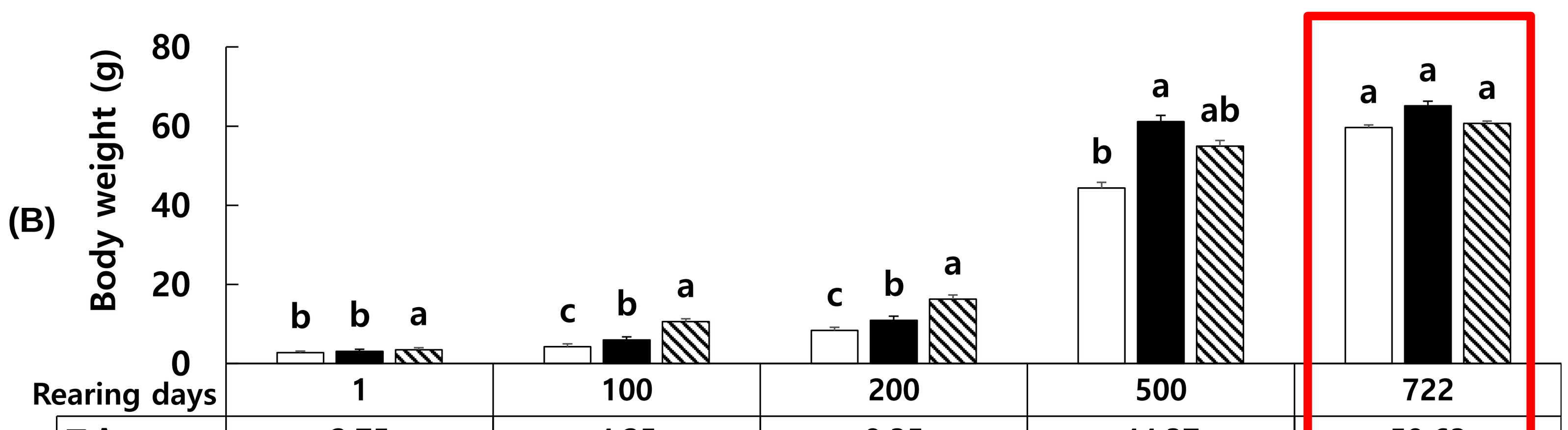
Table 1. Individuals were stocked in sea cages after passing the seed production stage and sorted by seed size. Then, on days 1,100, 200, 500, and 722, water temperature, salinity, dissolved oxygen, and pH values were measured alongside growth using YSI (YSI 5908, Xylem, USA).

Days \ Factor	Water temperature (℃)	Salinity (psu)	Dissolved oxygen (mg/L)	pH
1	19.4	32.76	7.56	7.91
100	9.6	32.65	11.13	7.42
200	19.4	33.42	7.59	7.21
500	12.6	32.54	10.28	7.21
722	15.9	32.88	8.14	8.56

4. Growth changes during breeding



Rearing days	1	100	200	500	722
□ A group	28.41	32.07	40.49	67.97	75.39
■ B group	32.44	36.4	44.06	74.57	77.44
▧ C group	42.86	43.55	50.44	72.03	76.94



Rearing days	1	100	200	500	722
□ A group	2.75	4.25	8.35	44.37	59.63
■ B group	3.11	5.96	10.91	61.13	65.13
▧ C group	3.5	10.58	16.3	54.94	60.67

Fig 3. (A) After the seed production, seedlings grow from days 1 to 722, depending on the stocking in sea cages. (B) Weight increases from days 1 to 722 also depend on stocking in sea cages after seed production.

The size of seeds farmed in sea cages was divided into groups A (3.2–3.6 cm), B (2.9–3.2 cm), C (2.6–2.9 cm), and D (< 2.6 cm) based on length. Salinity and pH were adjusted during the experiment period. A constant value was maintained, and water temperature and dissolved oxygen showed seasonal changes but were at levels suitable for raising abalone. As a result of rearing for 722 days, the survival rate showed no significant difference among the experimental groups, except for group D, which was excluded from the experiment due to many early deaths occurring during cage placement. As for seed growth, the initial size difference gradually narrowed as the rearing period became longer after stocking in sea cages, and there was no significant difference between groups A, B, and C after 722 days.

Conclusion

In conclusion, the initial seed stocking size does not appear to affect productivity during long-term rearing.

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