GROW-OUT OF ABALONE *Haliotis squamata* IN FLOATING CAGES FED DIFFERENT PROPORTIONS OF SEAWEED AND WITH REDUCTION OF STOCKING DENSITY

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ABSTRACT

Abalone is a herbivore marine animal which feeds on seaweed. Abalone culture has a good prospect in terms of price, market share and simple culture technique. Thus, a study was conducted with the aim of finding out an effective and efficient abalone culture technique in terms of feed use and density. In this study, a 42 cm diameter plastic container with a 22 cm height was used. Three vertically arranged containers were used as the experimental group which were put into a net box and hung onto a raft so that the containers were placed in a 4 m depth below the sea surface. The juvenile of abalones being used came from a hatchery production that has been adapted to cages environment with *Gracilaria* sp. and *Ulva* sp. feed. The initial density of abalones was 450 for each container, with the initial weight of 2.6-3.2 g and the 2.5-2.7 cm shell lengths. The abalones were fed with *Gracilaria* sp. and *Ulva* sp. seaweeds with different *Gracilaria* sp./*Ulva* sp. proportions, i.e. 100/0% (A); 80/20% (B); and 60/40% (C) as the treatments. Each treatment consisted of two replications. After three months of rearing period, densities of abalones were reduced to be 190 for each experimental unit. Weight and shell length of abalones were measured every month by measuring 25 abalone samples from each experimental unit. The result of the experiment showed that the increase in the *Ulva* sp. proportion in the feed increased the growth of abalones and decreased the feed conversion. Feeding with *Gracilaria* sp./*Ulva* sp. proportion of 60%/40% allowed the best growth of abalones. The decrease of abalone density in the experimental unit after three months of rearing also produced an increase in their growth.

KEYWORDS: abalones *Haliotis squamata*, grow-out, seaweed proportion, rearing density

INTRODUCTION

Abalones (*Haliotis* sp.) are marine animals who are herbivorous and mostly feed on seaweed of red algae (*Gracilaria*), brown algae (*Lamnaria*), and green algae (*Ulva*) (Setyono, 2004). Abalone farmers are likely to culture abalone by feeding macroalgae such as brown algae *Laminaria japonica* or *Undaria* because of their easy farm management and availability (Cho & Kim, 2012). Depending on the species, abalones can become a competitive commodities whose culture is to be developed because of their high economic value and are one of the export commodities. The price of abalones could be US$ 33/kg and varied according

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to their species (Fermin *et al*., 2009). There are about 100 species of abalone world-wide (Jia & Chen, 2001) and seven species are found in Indonesia (Setyono, 2006). World demand of abalones increases as the increase in demand on a variety of protein sources (Littay, 2005). Global aquaculture production of abalone has continued to increase from 292,000 tons in 2005 to become 395,000 tons in 2011 (FAO, 2013), and is expected to keep increasing.

The supply of abalones in Indonesia still comes from the nature (Directorat General of Fisheries Product Processing and Marketing, 2008). The increase in intensity of abalone catch in the nature parallels to the increase in demand in the market and people are fearful that this will become over exploitation and will disturb population of abalone in the nature. For this reason, since a couple of years ago efforts were made to develop the culture starting from the development of the seed production of abalones in hatchery. The development of seed production technique of abalone *Haliotis squamata* at Institute for Mariculture Research and Development, Gondol, Bali has started since 2007 and at present the technology of mass seed production has been established (Rahmawati *et al*., 2009; Rusdi *et al*., 2011; Susanto *et al*., 2012). The availability of seed supply from hatchery makes it possible to develop the way how to grow-out the abalone. Roughly there are two methods to develop this, i.e. in a pond culture (land based) and the culture by using a raft in the sea (Jia & Chen, 2001). For optimal growth, abalones need good water quality, so the land based culture needs a high water exchange (200%-2,400% per day) to keep the good water quality. This causes a high operational cost (Badillo *et al*., 2007). In the culture of abalone in the sea, PVC (polyvinyl chloride), washbasin or plastic basket can be used as shelter to which abalones attach and then they are put into a closed net bag hung on to a raft.

Some factors need to be considered in the culture of abalones which are suspected to have an effect on their growth, which include the surface area of the shelter that is good enough for abalones that attach to the shelter and suitable feed. Cho & Kim (2012) reported that growth of abalone *Haliotis discus hannai* Ino is affected by feed type and temperature, but feed type had a stronger effect than temperature. The surface area of the shelter is directly related to the density, so that this density needs to be adapted regularly by reducing the density for the period of rearing to optimize their growth. Depending on the species, the growth of abalones is relatively slow that it needs a relatively long time to get the market size (Stickney, 2000). The information on the culture technique for abalone *H. squamata* that meets the current standard is not yet available, thus there is a need to develop it to accelerate the development in the business of abalone aquaculture. This study was aimed at finding out an effective and efficient abalone culture technique in a floating cage that is related to the density and feed use.

MATERIALS AND METHODS

Rearing Methods

The floating raft for raising abalones was made of 10 m x 10 m wood. As the substrate for them to attach themselves 30 liter plastic washbasin with 42 cm diameter and 22 cm height was used. On the vertical side of the washbasin, four holes with 10 cm diameter were cut. One of the experimental unit consisted of three washbasins which were vertically arranged and were put into a net bag to prevent abalones from going out of the washbasin. Each experimental unit had 1.0 m^2 substrate surface area and was hung on to a raft so that it was put at a depth of 4 m below the sea water surface. The juvenile of abalones used for the experiment came from hatchery of Institute for Mariculture Research and Development, Gondol, Bali. Before being used in this experiment, the juvenile abalones were adapted to the floating cages environment in the sea first and were fed with seaweed consisting of *Gracilaria* sp. and *Ulva* sp.

Experimental Design

In this experiment the initial density of juvenile abalone in each experimental unit was 450 pcs, with the juvenile weight of 2.6-3.2 g and shell length of 2.5-2.7 cm and shell width of 1.6-1.8 cm. The juvenile was fed with fresh seaweed mixture of *Gracilaria* sp. and *Ulva* sp. with different proportions as treatments, i.e. the proportion of *Gracilaria* sp./*Ulva* sp. 100%/0% (treatment A); 80%/20% (treatment B); and 60%/40% (treatment C). Every treatment consisted of two replications. The feed was put into the washbasin through the hole on the vertical side every three days with the amount in proportion to the abalone feeding response.

The rest of the feed in every three days was measured to know the real amount of feed consumed by the abalones.

After three months of rearing period, in which the abalones have reached a weight of 7-8 g, density reduction of abalone was done in which every experimental unit was divided into 2 and the density of abalone became 190 pcs per experimental unit. The feeding with the proportion of *Gracilaria* sp./*Ulva* sp. according to the initial treatment was continued until the end of the experiment.

Data Analysis

To know the growth of the abalones, their weight, shell length, and shell width were measured monthly by random sampling of 25 abalones from each experimental unit. The growth of abalones as indicated by the increase in weight and the percentage of weight gain, feed conversion ratio, and survival of abalones was calculated using the following formulae.

Total weight increase (g) = Final weight (g) – Initial weight (g)

Percentage of weight gain = (Final weight – Initial weight) x 100/Initial weight

Feed conversion ratio = The total of feed consumed (g)/Total of abalone biomass increased (g)

Survival rate (%) = Final number of abalones (pcs) x 100/Initial number of abalones (pcs)

The data on the growth, feed conversion ratio and survival rate were analyzed using analysis of variance (ANOVA) and differences between the tested treatments were analyzed using Tukey test at 95% level of confidence. As the supporting data, water quality parameters such as temperature, water transparency and salinity were also measured.

RESULT AND DISCUSSION

Average weight and shell length of abalones for two periods of rearing is shown in Figure 1. The different proportion of *Gracilaria* sp. and *Ulva* sp. in the feed caused different abalone growth response. On Tables 1 and 2, data on growth response of abalones fed with *Gracilaria* sp. and *Ulva* sp. with different proportions for three months of rearing period-1 and three months of rearing period-2 are shown. In both rearing periods the feed proportion of *Gracilaria* sp./*Ulva* sp. had a significant effect ($P<0.05$) on final weight, weight gain, and abalone shell length as growth parameters. Abalones that were fed with *Gracilaria* sp. only (100%) produced the lowest growth. Increasing the proportion of *Ulva* sp. in the feed increased abalone growth with the highest growth obtained from abalones fed with mixture of 60% *Gracilaria* sp. and 40% *Ulva* sp.

Increase in *Ulva* sp. proportion in feed tended to give a better growth response. This result is similar to that reported by Rahmawati *et al*. (2008) in which the best growth of abalone *H. squamata* was obtained on abalones fed with *Ulva* sp. compared to that fed with *Gracilaria* sp. or *Euchema* sp. Green algae *Ulva* sp. was also preferred because of its soft texture. Rusdi *et al*. (2010) reported that the feeding with a mixture of *Gracilaria* sp., *Ulva* sp., and *Sargassum* sp. gives the best growth in rearing of abalone *H. squamata* broodstocks compared to the feeding of *Gracilaria* sp., *Ulva*

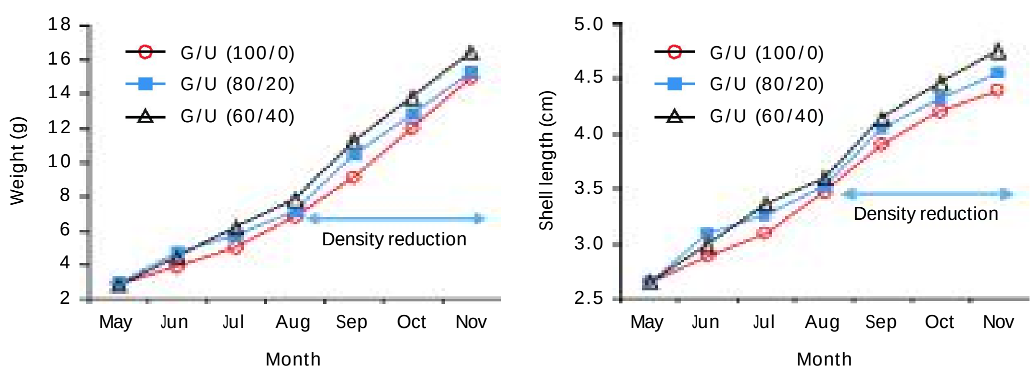

Figure 1. Weight and shell length of abalone *Haliotis squamata* fed different proportion of *Gracilaria* sp. (G) and *Ulva* sp. (U) during six months rearing period

Table 1. Final weight, total weight increase, percent weight gain, shell length, survival rate, and feed conversion ratio of abalone *Haliotis squamata* fed different proportion of *Gracilaria* sp. and *Ulva* sp. during the first three months of feeding period-1[1)]

Proportion of *Gracilaria* sp./ *Ulva* sp. (%)	Final weight (g)	Total weight increase (g)	Weight gain (%)	Shell length (cm)	Survival rate (%)	Feed conversion ratio
100/0	6.70±0.14^{a}	3.65±0.07^{a}	120.0±10.7^{a}	3.44±0.08^{a}	85.2±2.4^{a}	20.8±0.5^{a}
80/20	7.05±0.21^{a}	4.10±0.01^{b}	139.3±10.0^{b}	3.52±0.04^{b}	96.0±5.7^{b}	18.9±0.3^{a}
60/40	7.75±0.21^{b}	4.95±0.20^{c}	176.8±7.6^{c}	3.60±0.06^{b}	100.0±0.0^{b}	15.6±0.9^{b}

[1)] Initial weight of abalone was 2.6-3.2 g, with shell length of 2.5-2.7 cm. Values in the same column followed by the same superscript letters are not significantly different (P>0.05)

sp. or *Sargassum* sp. alone. Abalone *H. laevigata* juveniles are reported to have the best growth with *Ulva* sp. feeding (Daume *et al*., 2007).

The degree of seaweed preference may varies from abalone species to another. Setyono (2006) reported that *H. asinina* prefers *Gracilaria* sp. However, the growth of abalones fed with *Gracilaria* sp. is almost the same as those fed with *Ulva* sp., and the best growth is obtained in abalones fed with a mixture of five seaweeds including *Gracilaria* sp. and *Ulva* sp. Alcantara & Noro (2006) reported that abalone *H. diversicolor* cultured in a floating basket in the sea grow better by feeding them with *Sargassum fusiforma* and *Ulva pertusa*. Another experiment has been conducted by Perez-Estrada *et al*. (2012) to test the growth response of abalone *Haliotis fulgens* fed with rehydrated seaweed *Egregia menziesii*, *Egregia arborea*, *Macrocystis pyrifera (*brown algae), *Porphyra perforate* (red algae) and *Ulva* sp. (green algae). This experiment showed that rehydrated *Egregia menziesii*, *Macrocystis pyrifera*, and particularly, *Porphyra perforata* were more efficient in promoting growth compared to those rehydrated *Ulva* sp. and *E. arborea*. In terms of feed consumption, *H. diversicolor* is reported to prefer brown algae *Sargassum fusiforma* to green algae *Ulva perfuse* (Alcantara & Noro, 2005). Abalone *H. iris* prefer to consume seaweed of brown algae to red algae or green algae (Cornwall *et al*., 2009). The light condition during the rearing of abalone has an effect on the feed consumption which in turn has an effect on the growth. Garcia-Esquaivel *et al*. (2007) reported a higher consumption rate of abalone *H. fulgens* feed in the night time and the highest is in the continuous dark condition.

Survival rate of abalones in rearing period-1 is influenced by the proportion of *Gracilaria* sp./*Ulva* sp. in their feed (Table 1). The highest is obtained in abalones fed with combination of 60% *Gracilaria* sp. and 40% *Ulva* sp. While in rearing period 2 the proportion of *Gracilaria* sp./*Ulva* sp. does not have a significant effect on survival rate of abalone (Table 2). Abalone

Table 2. Final weight, total weight increase, percent weight gain, shell length, survival rate, and feed conversion ratio of abalone *Haliotis squamata* fed different proportion of *Gracilaria* sp. and *Ulva* sp. during the second three months of feeding period-2[1)]

Proportion of *Gracilaria* sp./ *Ulva* sp. (%)	Final weight (g)	Total weight increase (g)	Weight gain (%)	Shell length (cm)	Survival rate (%)	Feed conversion ratio
100/0	14.48±0.30^{a}	7.78±0.21^{a}	116.0±2.2^{a}	4.40±0.05^{a}	90.2±4.4^{a}	22.8±1.0^{a}
80/20	15.45±0.29^{b}	8.40±0.18^{b}	119.2±1.0^{b}	4.56±0.04^{b}	90.1±3.7^{a}	18.1±0.5^{b}
60/40	17.48±0.60^{c}	9.73±0.31^{c}	125.5±2.3^{c}	4.76±0.07^{c}	87.0±2.4^{a}	16.1±1.6^{c}

[1)] Values in the same column followed by the same superscript letters are not significantly different (P>0.05) deaths occur because of disease infection. The laboratory analysis shows that there is an infection caused by *Vibrio* sp. bacteria marked by the presence of mantel epithelium and digestive tract epithelium erosion with much mucus and degradation as well as the presence of mantel muscular abscess.

Feed conversion ratio of abalone is influenced by the *Gracilaria* sp./*Ulva* sp. proportion in the feed (Tables 1 and 2). The best feed conversion is 15.6 in rearing period 1 and 16.1 in rearing period 2 obtained in abalones fed with combination of 60% *Gracilaria* sp. and 40% *Ulva* sp. Feed conversion ratio is the proportion of feed (wet weight) fed by abalones and abalone biomass increase (wet weight) during rearing period. The smaller the feed conversion value can show that the feed is used more efficiently by abalones for their growth, or better feed quality. In this experiment, the addition of *Ulva* sp. as feed increased abalone growth. This shows that *Ulva* sp. is a better feed for abalones to support their growth. Green algae *Ulva* sp. has a higher protein and fat content than *Gracilaria* sp. (Table 3). This supports a better growth in abalones fed with a higher proportion of *Ulva* sp. In addition to a higher protein and fat content, *Ulva* sp. also has a softer texture compared to *Gracilaria* sp. that it is more digestible and produces more digested energy. Zhanhui *et al*. (2010) reported feed conversion ratio and growth in shell length of abalone *Haliotis discus hannai* improved by feeding a mixed seawed of fresh kelp *Laminaria japonica* and the red algae *Gracilaria lemaneiformis*. Abalones spend about 25%-30% of their digestible energy (DE) for respiration depending on the species (Donovan & Carefoot, 1998; Gomes-Montes, 2003), and the rest (70%-75%) for other needs including growth. Ganmanee *et al*. (2010) reported more detail data on energy utilization by abalone *Haliotis asinina* reared in a semiclosed recirculating land-based system and fed artificial diet. In their experiment it was found that 33.2%-42.5% of obtained energy used for metabolism, 37.4%-45.8% for growth and only 0.8%-1.8% was used for ammonia excretion.

Density is one of the factors that have an influence on abalone growth. In a high density abalones tend to attach in clusters on the substrate and overlapping one another. A decrease in density in the experimental unit after three months of rearing period-1 was intended to give enough space for abalones to attach to the washbasin wall. In the time of density reduction for each experimental unit, the average weight of abalones had reached 6.7-7.8 g. The result of the experiment in rearing period-2 after density reduction is shown in Figure 1. The density reduction did not only give more space to abalones to be able to attach on the washbasin surface, but also give opportunity to use feed available optimally to produce an increase growth rate. Abalone density is related to space and feed was reported by Setyono (2007) in which the best density for grow-out of juvenile abalone *H. asinina* with 3.0-3.9 cm length was 80 pcs/square meter. Huchette *et al*. (2003) reported the abalone *H. rubra* growth decrease by 14%-52% when the density was increased by 2-60 times. While the three times density increase for abalone *H. discus hannai* raised in floating net baskets produced a growth 26% lower (Jee *et al*., 1988). Abalone density also directly influences access to feed in the culture system. This is related to the abalone's behavior that tends to attach in clusters on a substrate or shelter (Day *et al*., 2004).

An observation of the parameter of water quality includes temperature, salinity, and water transparency during the rearing period showed that the temperatures ranged from 27.3°C-30.8°C, salinity from 32.6-35.2 g/L and water transparency from 9-11 m. Septory *et al*. (2012) reported population of abalone *Haliotis squamata* at several natural habitat develop well at water temperature and salinity of 25°C-30°C and 32-38 g/L, respectively. Growth and

Table 3. Protein and lipid contents of *Gracilaria* sp. and *Ulva* sp.

	***Gracilaria* sp.**	***Ulva* sp.**
Moisture (%)	88.2	81.8
Crude protein (% dry matter)	9.5	17.7
Lipid (% dry matter)	1.5	2.7

survival of abalone *H. squamata* are influenced by water salinity. Rusdi (2013) reported the best growth of juvenile abalone *H. squamata* is obtained at salinity of 30-35 g/L, while high survival was obtained at salinity of 25-35 g/L. Feed consumption of juvenile green abalone *H. fulgents* is also influenced by temperature and markedly higher at 25ºC than 20ºC. However, even the feed consumption was higher at 25ºC, but FCR and growth of this abalone was better at 20ºC (Garcia-Esquivel *et al*., 2007). Water temperature between 12ºC and 20ºC was reported physiologically optimal for growth of South African abalone *Haliotis midae*. At higher temperature between 20ºC and 24ºC growth and feed consumption of abalone *Haliotis midae* declined markedly (Britz *et al*., 1997). Another study on the effect of temperature on growth of red abalone *Haliotis rufescens* found the optimum temperature for good growth of thie abalone was 17.8ºC (Steinarsson & Imsland, 2003).

CONCLUSION

Increase in the proportion of *Ulva* sp. in feed increases abalone growth and decreases feed conversion ratio. Feed with the proportion of *Gracilaria* sp./*Ulva* sp. at 60%/40% gives the best growth of abalone *H. squamata*. Decrease in density of abalone in the experimental unit after three months of rearing period stimulates the growth rate of abalone.

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