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 (Laminaria), 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
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 Iino 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 m² 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...
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)

<table>
<thead>
<tr>
<th>Proportion of Gracilaria sp./Ulva sp. (%)</th>
<th>Final weight (g)</th>
<th>Total weight increase (g)</th>
<th>Weight gain (%)</th>
<th>Shell length (cm)</th>
<th>Survival rate (%)</th>
<th>Feed conversion ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>100/0</td>
<td>6.70±0.14(a)</td>
<td>3.65±0.07(a)</td>
<td>120.0±10.7(a)</td>
<td>3.44±0.08(a)</td>
<td>85.2±2.4(a)</td>
<td>20.8±0.5(a)</td>
</tr>
<tr>
<td>80/20</td>
<td>7.05±0.21(a)</td>
<td>4.10±0.01(b)</td>
<td>139.3±10.0(b)</td>
<td>3.52±0.04(b)</td>
<td>90.0±5.7(b)</td>
<td>18.9±0.3(b)</td>
</tr>
<tr>
<td>60/40</td>
<td>7.75±0.21(b)</td>
<td>4.95±0.20(c)</td>
<td>176.8±7.6(c)</td>
<td>3.60±0.06(c)</td>
<td>100.0±0.0(c)</td>
<td>15.6±0.9(b)</td>
</tr>
</tbody>
</table>

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. laevidgata 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 perforata (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 perforata (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)

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

2) Values in the same column followed by the same superscript letters are not significantly different (P>0.05)
Grow-out of abalone *Haliotis squamata* in floating cage ... (I Nyoman Adiasmara Giri)

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 seaweeds 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>
<thead>
<tr>
<th>Gracilaria sp.</th>
<th>Ulva sp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>88.2</td>
</tr>
<tr>
<td>Crude protein (% dry matter)</td>
<td>9.5</td>
</tr>
<tr>
<td>Lipid (% dry matter)</td>
<td>1.5</td>
</tr>
</tbody>
</table>
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 25°C than 20°C. However, even the feed consumption was higher at 25°C, but FCR and growth of this abalone was better at 20°C (Garcia-Esquivel et al., 2007). Water temperature between 12°C and 20°C was reported physiologically optimal for growth of South African abalone Haliotis midae. At higher temperature between 20°C and 24°C 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 this abalone was 17.8°C (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.

**REFERENCES**


Grow-out of abalone *Haliotis squamata* in floating cage ... (I Nyoman Adiasmara Giri)

Haliotis asinina (Reeve, 1846) juveniles. Pusat H. squamata. Pusat Penelitian dan Haliotis refes-


