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Feeding of Abalone Juveniles with Two Species of *Sargassum*
(*Sargassum cristaefolium* and *Sargassum polycystum*)

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The species preference, growth and survival rates of juveniles of *Haliotis asinina* fed with two species of *Sargassum i.e.,Sargassum cristaefolium* and *Sargassum polycystum,* were evaluated over a 75 day culture period. Proximate composition of the two species of *Sargassum* was also determined. The test organism preferred *S. cristaefolium* (80%) more than *S. polycystum* (20%). Growth rate in terms of shell length and weight as well as the survival rate did not differ significantly among juveniles fed with two species of *Sargassum*. Protein content of *S. polycystum* (6.26%) is higher than *S. cristaefolium* (3.45%)

Abalone is a highly valued marine mollusk with very high export potential. It is present in Philippine waters and inhabits rocky reef coast areas facing the outer sea. The Philippines is considered as one of the major producers of abalone from capture fishery. Other countries with commercial fishery of abalone are Japan, Korea, the Pacific Coast of North America, South Africa, Australia, New Zealand and Mexico. The Philippines is showing a consistent increase in abalone production in contrast with other abalone producing countries where abalone production is decreasing (FAO, 1996). In 1991, the Philippines exported nearly 300,000 kg of live and processed abalone worth over US$2 million to Australia, US and Asian countries. Two years later, this volume nearly doubled to 500,000 kg worth US$3.6 million. From 1993 to 1996, Philippine abalone capture fishery production has increased from 122 mt to 448 mt . No data are available from 1997 to present except in 1998 with 190 mt (FAO, 2000).

In Japan, the annual catch of abalone is about 4,000 t. Japan also imports about 1,000 t of fresh, frozen and refrigerated abalone annually from China, Korea and New Zealand and another 1,000 t of canned abalone and several hundred tons of processed abalone from Australia. In addition, Japan exports several dozen tons of dried abalone to Hong Kong and Taiwan (Surtida, 2000).

Demand and prices for premium abalone products have risen steadily during the last few years, creating an economic environment in which abalone aquaculture is becoming increasingly attractive as a financial investment (Surtida, 2000).

The species of abalone with good potential for a viable tropical abalone aquaculture is *Haliotis asinina.* It is the fastest growing abalone in the world and has a delicate flavor and has a convenient size for banquets, making it ideal for aquaculture. *H. asinina* is ready for the market in less than a year, compared to five years for some temperate species (Surtida, 2000).

In the Philippines, juveniles of *Haliotis asinina* reach the marketable size within one year after release. The fast growth of this species and the abundant supply of seaweeds (i.e., *Sargassum, Gracilaria*) which are used as food by abalone in contrast with other countries, is an advantage in considering it for aquaculture and sea ranching.

The increase in demand and prices for abalone products has been steady since 1991, making abalone increasingly attractive as a financial investment to fishfarmers all over the world. Filipino fishfarmers have shown interest in abalone culture, but so far, no commercial farm is operating. The high market demand and high value of abalone will encourage fishermen to gather huge amounts of abalone, which will ultimately end the depletion of the resource as experienced by other countries.

The depletion of abalone in the coastal areas of the country has been a major concern, thus, a need to enhance the production of abalone through aquaculture and sea ranching. The most critical element to any culture endeavor is that of nutrition which is also dependent on the availability of food.

Several studies had been conducted on the culture of abalone with focus on the diet from postlarva, juveniles and adult stages of abalone using different species of diatom and macroalgae had been conducted by Chen (1996), Fleming et al. (1995), Viana et al. (1996), Kawamura et al. (1995), McShane et al. (1994), Ebert et. al. (1989), Chen (1989), Hahn (1989), Yoo (1989), Huges (1986), and Uki et al.(1985).

The post-larval abalone fed on the following four diatom species: *Achnanthes brevipes var. intermedia, A. longipes, Cocconeis scutellum var. parva and Cylindrotheca closterium* supported high growth rates and high digestion efficiencies. These results suggest that the differences in growth rates were due primarily to the differences in the digestion efficiency of the abalone fed on the diatom species (Kawamura et al., 1995). Chen (1996) stated that newly settled juveniles feed on benthic diatoms and green microalgae but switch to eating seaweeds after formation of the first respiratory pore. Small abalone prefers soft seaweeds to hard seaweeds.

Several studies have reported the dietary value of various macroalgae for growth of temperate abalone species (Sakai, 1962; Kikuchi et.al, 1967; Uki et.al., 1986; Sato and Notoya, 1988; Mercer et al., 1993; Stewart and Brown, 1994; Fleming, 1995) but few for tropical species (Singhagraiwan, 1991; Capinpin and Corre, 1996; Tahil and Juinio-Menez,1999; Bautista-Teruel and Milanena, 1999; Fermin, 2002).

The grow out culture of abalone in the open sea is dependent on the availability of macroalgae. Findings of Tahil and Juinio-Menez (1999) on the natural diet of *H. asinina* showed that abalone prefers red algae to brown algal species. Their observation showed that 72.2% of which are red algae (Rhodophyta) such as Laurencia, Hypnea, Amphiroa and Coelothrix were found in the gut contents of all size groups of abalone.

In Ilocos coastal waters, brown algae such as *Sargassum* are abundant. This study was designed to look into the species preference of abalone juveniles on two *Sargassum* species, i.e., *S. cristaefolium* and *S. polycystum* as well as their growth and survival.

Material and Methods

Abalone juveniles with shell length of 21-23 mm were obtained from UP-MSI, Bolinao, Pangasinan. The abalones were transported for eight hours to Nagabungan Bay, Pasuquin, Ilocos Norte (Fig. 1), using a styrofoam box with wet foam as matting. Iced seawater were placed at the four corners of the box in order to maintain low temperature during transport.

Six plastic perforated cages measuring 1 m x 1 m x 0.3 m each were submerged at 5 m depth in the reef area of Nagabungan Bay. The abalones were put in a net bag to prevent escape before placing them inside the cages with a stocking density of 58 pieces per cage at water temperature of 27.8 – 32.8°C, salinity at 32-34 ppt and dissolved oxygen 5.58 – 6.98 mg/L.

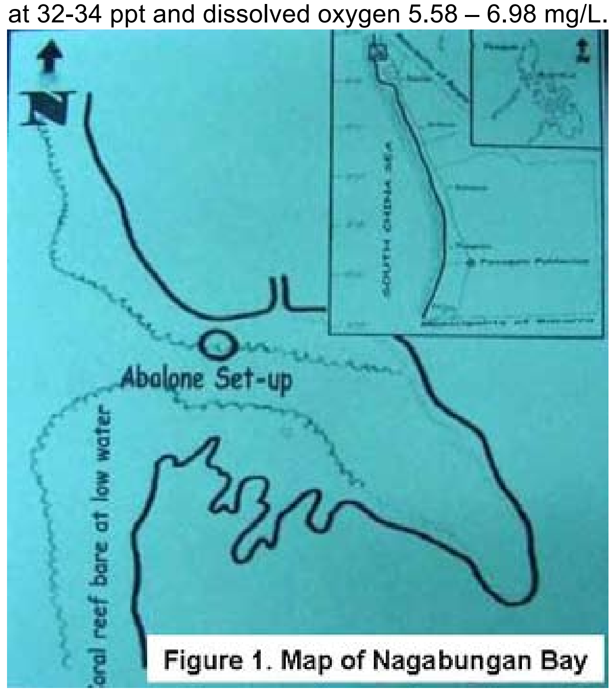

Figure 1. Map of Nagabungan Bay

Eighteen pieces of abalone of uniform size (30%) in each cage were tagged for the monitoring of growth parameters. Adhering a plastic material on top of the abalone shell was done during tagging. The tagged abalones were used in monitoring the growth of abalone every 15 days. Growth parameters measured were shell length using a vernier caliper and weight using a weighing scale.

The abalones were fed with two species of *Sargassum* (*S. cristaefolium and S. polycystum).* Treatment 1 used *S. cristaefolium* and Treatment 2 used

S. polycystum with three replicates each. Each cage was given equal weight of 2 kg of *Sargassum* every 15 days and the food consumption was determined which is expressed as:

$$F_c = F_o - F_f$$

Where F_c = actual *Sargassum* consumption in 15 days, F_o = original weight of *Sargassum* offered, F_f = final weight of *Sargassum* after 15 days. The *Sargassum* was immediately replaced with 2 kg of fresh fragments as the original weight offered. It is assumed that any change in weight of *Sargassum* as a result of growth in the cages will cancel out.

The UP Pilot Food Plant, Quality Control Laboratory of the College of Home Economics, conducted analysis on the proximate composition of the two species of *Sargassum*.

Data were analyzed by Paired Comparison of Means (t-test) using the SPSS Statistical Package. The mean weight (g) of *Sargassum* consumed for the two species: *S. polycystum* and *S. cristaefolium* by the abalone juveniles, length (mm) and weight (g) and survival rates were subjected to t-test.

Results and Discussion

Findings showed that *S. cristaefolium* is more preferred than *S. polycystum* by the abalone juveniles of *H. asinina*, resulting in a highly significant difference on the amount consumed using t-test as shown in Table 1. The consumption of *S. cristaefolium* by abalone juveniles per cage in every 15 days sampling for the 75 days culture period ranged from 1,150 to 1,633 g, while that of *S. polycystum* ranged from 217 to 503 g. However, in the case of of *S. cristaefolium*, a decrease in Sargassum consumption was observed from 60 to 75 days due to the escape of some of the abalones from the cages as a result of breakage. The abalone juveniles fed more voraciously on the fronds of *S. polycystum* than *S. cristaefolium* as shown in Fig. 2.

Comparison on the shell length and final weight of abalone juveniles fed with *S. cristaefolium* and *S. polycystum* showed no significant difference using the t-test. During the 75 days culture period, those fed with *S. cristaefolium*, 6.67 g -± 1.79 while 4.31 g ± 1.79 was observed for those fed with *S. polycystum*. Mean survival rate also showed no significant difference between abalones fed with *S. polycystum* (99%) and *S. cristaefolium* (98%).

The insignificant difference on the growth rate of abalone juveniles fed with two species of *Sargassum* despite the highly significant difference on the amount consumed for *S. cristaefolium* (80%) and *S. polycystum* (20%) might be due to the difference on the protein content of *S. polycystum* of 6.26% while that of *S. cristaefolium* with only 3.45% as shown in Table 3. Uki et al. (1986) reported a high growth rate of abalone juveniles fed with macroalgae when the protein content was high. Hahn (1989) stated that in the formulation of artificial diet, protein content is one of the major considerations in providing the nutritional requirement for the growth of any organism like abalone. The artificial feed must contain protein content sufficient to produce an excellent growth rate. The study of Capinpin and Corre (1996) reported the importance of diet quality on the growth rate of *H. asinina* juveniles. Their findings showed that diets with higher protein and fat contents, i.e., *Gracillaria heteroclada* and artificial diet for abalone, resulted in faster growth than those fed with lower protein, i.e., *Kappaphycus alvarezii,* which showed steady and little changes in daily growth rates. Mercer et al. (1993) stated that high levels of protein (>15%), lipid (3-5%) and carbohydrates (20-30%) in algae are essential for optimal growth rates of abalone. Bautista-Teruel and Millamena (1999) also reported that better growth rates of abalone fed the formulated diets in terms of weight gain, increase in shell length and specific growth rate than those fed the control diet (seaweeds). This result may be ascribed to the higher protein content and more balanced amino

Table 1. Mean weight (g) of Sargassum consumed by *H. asinina* juveniles every 15 days of culture.

Culture Period (days)	*S. polycystum**	*S. cristaefolium**	Significance
15	217 ± 17	1,150 ± 17	**
30	250 ± 17	1,267 ± 17	**
45	350 ± 44	1,633 ± 44	**
60	383 ± 12	1,350 ± 12	**
75	503 ± 45	1,195 ± 45	**

* – Means of replicate groups ± SEM
** – Highly significant at 1% level of significance

Figure 2. ***Sargassum polycystum*** **and** ***Sargassum cristaefolium*** **before and after feeding.**

Table 2. Mean length (mm) of *H. asinina* juveniles fed with *S. cristaefolium* and *S. polycystum*.

Culture Period (days)	*S. polycystum**	*S. cristaefolium**	Significance
15	26.26 ± 1.29	28.37 ± 1.29	ns
30	26.79 ± 1.46	28.79 ± 1.46	ns
45	27.24 ± 1.27	29.77 ± 1.27	ns
60	27.81 ± 1.35	29.52 ± 1.35	ns
75	28.83 ± 0.64	29.99 ± 0.64	ns

* – Mean of replicate groups ± SEM
ns – non significant at 5% level

Table 3. Mean weight (g) increment of *H. asinina* juveniles fed with *S. cristaefolium* and *S. polycystum*.

Culture Period (days)	*S. polycystum**	*S. cristaefolium**	Significance
15	2.64 ± 0.96	3.92 ± 0.96	ns
30	3.31 ± 1.32	4.89 ± 1.32	ns
45	4.01 ± 1.02	5.94 ± 1.02	ns
60	4.02 ± 1.73	6.49 ± 1.73	ns
75	4.31 ± 1.79	6.67 ± 1.79	ns

* – Means of replicate groups ± SEM
ns – non significant at 5% level

Table 4. Proximate composition of *Sargassum cristaefolium* and *Sargassum polycystum*.

Parameters (%)[a]	*Sargassum polycystum*	*Sargassum cristaefolium*
Moisture content	75.08	79.3
Protein	6.26	3.45
Ash	8.15	7.18
Crude fat	0.13	0.14
Crude fiber	7.98	7.13
Carbohydrates[b]	2.4	2.8

[a] Nielsen, S. S. 1998. Food Analysis 2nd ed. Aspen Publishers, Inc., Maryland, USA
[b] Calculated by difference

acid profile of the formulated feed. Abalone needs a sufficient amount of good quality protein for growth and the amount of protein in seaweeds may not have been sufficient to support the rapid growth. Tahil and Junio-Menez (1999) stated that quality and efficiency of artificial diets are determined largely by composition and the identification of the natural food components are very important in the preparation of the most efficient diet for abalone. The optimum protein level in a casein based diet was determined to be 20 to 30% by Uki et al. (1986). Britz (1996) found that the growth rate of *Haliotis midae* increased with an increase in protein content from 27 to 47%. Britz (1996) also reported that a dietary protein level higher than 20 to 30% may be required to achieve maximum growth rate. Since the consumption of protein in monogastric animals is influenced by their requirement for energy, accurate definition of this protein level requires more information about their enegetic requirements (Smith, 1989)

The results of the experiment show that the rate of growth of abalone is not solely dependent on the quantity of *Sargassum* consumed but also on the protein content. The abalones were feeding more on the *S. cristaefolium* (80%) than *S. polycystum* (20%) but the growth in terms of length and weight did not differ significantly. It is assumed that if the abalones consume more *S. cristaefolium* (with 3.26% protein) than *S. polycystum* (6.26% protein), high seaweed consumption can compensate for the lower protein content, thus, growth of the abalone fed with lower protein content (*S. cristaefolium*) did not differ significantly from those fed with higher protein content (*S. polycystum*).

The survival rate of abalone juveniles fed with *S. cristaefolium* and *S. polycystum* was 98% and 99.6%, respectively, and did not differ significantly. The high survival rate observed is similar in other studies conducted on the culture of abalone in baskets with 85 to 90%, which is in contrast to abalones released to the sea bottom with only 35 to 40% survival rate (Yoo, 1989). Bautista-Teruel and Milamena (1999) reported a high survival rate from 85 to 95% of *H. asinina* juveniles fed with natural food and formulated diets cultured for 90 days. The high survival rate of abalone is an indication of a balance of nutrients in the diets although the low protein content in the natural food may not have been enough to sustain comparable growth of abalone with those fed with the prepared diet.

In conclusion, this study showed that *Sargassum* can be used as feed for abalone. However, the *Sargassum* species (i.e., *S. polycystum*) with the highest protein content should be selected to promote better growth. The results of the present study are important in the choice of suitable *Sargassum* species for feeds to be used on the grow out culture and the development of artificial feeds for abalone culture. However, more studies should be conducted on the presence of growth stimulants or growth inhibitors in *S. polycystum* and *S. cristaefolium*.

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