Research on Seaweeds and Mollusks

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Hurtado-Ponce AQ. 1995. Research on seaweeds and mollusks, pp. 199-208. In: Bagarinao TU, Flores EEC (eds) Towards Sustainable Aquaculture in Southeast Asia and Japan. SEAFDEC Aquaculture Department, Iloilo, Philippines.

Abstract

Research on seaweeds focused on the carrageenan-producing *Kappaphycus alvarezii* and the agar-producing *Gracilaria* spp. Growth of *K. alvarezii* was better on horizontal lines than on vertical or cluster lines from bamboo rafts. All morphotypes (brown green, and red) grew faster at 50 cm than at 100 cm below the water surface, but the green morphotype showed better carrageenan properties. A socioeconomic survey of *K. alvarezii* farming in Panagatan Cays, Antique revealed that a farmer has an average annual production of 3 tons/ha (dry) with the fixed bottom and hanging longline methods.

Three species of *Gracilaria* in natural beds in lloilo showed monthly variations in biomass and agar quality; *G. heteroclada* had the highest biomass and gel strength. When this species was grown in tanks, growth and agar sulfate content were influenced by the interaction of light, salinity, and nutrients. Enriched and unenriched stocks of *G. heteroclada* differed in agar quality. When *G. heteroclada* was grown with the tiger shrimp *Penaeus monodon* in extensive ponds, the highest growth rate and production were obtained at the seaweed stocking density of 250 g/m^2; this was in November when average water temperature, transparency, and salinity were low. Salinity tolerance varies among *Gracilaria* species.

Oyster (*Crassostrea iredalei*) and mussel (*Perna viridis*) farming in Western Visayas were assessed in 1992 in terms of the culture methods, socioeconomics, marketing, and profitability. A more localized survey of oyster and mussel fanning was conducted through rapid rural appraisal in two coastal towns in 1993. A farmer-participatory study followed in 1994 for the culture of oysters, mussels, seaweeds, and rabbitfishes in a river mouth in Dumangas, lloilo. Green mussel, brown mussel (*Modiolus metcalfei*), and seaweeds transplanted to Dumangas from Capiz have reproduced. In another study, the green mussel was tested as a biological filter in tiger shrimp ponds; shrimps stocked with mussels grew better than those without.

A nationwide survey on the *Placuna placenta* fishery in 1993 showed 27 remaining 'kapis' beds; many others have been depleted due to excessive gathering, pollution, siltation, and trawling. Broodstocks are being developed to produce 'kapis' seed for grow-out and restocking. For the first time at AQD, adult donkey-ear abalone *Haliotis asinina* from the wild spawned naturally in laboratory tanks. Juvenile abalones can be successfully grown on *Gracilaria* or abalone diet.

Introduction

Six seaweed genera were prioritized for research at AQD during the ADSEA meeting in 1991: *Eucheuma, Kappaphycus, Gracilaria, Gelidiella, Porphyra,* and *Sargassum.* But the studies conducted in 1992-1994 focused only on *Kappaphycus* and *Gracilaria.* Among mollusks, the slipper oyster *Crassostrea iredalei,* green mussel *Perna viridis,* window-pane oyster *Placuna placenta,* pearl oysters *Pinctada* spp., and the abalones *Haliotis* spp. were ranked as top priorities for research. No studies on *Pinctada* were proposed during the period.

Studies on the growth, production, carrageenan quality, and proximate composition of the different morphotypes of *Kappaphycus alvarezii* were done to ascertain the best strain for cultivation and for use as feed ingredient. Simple economic analysis allowed comparison of the profitability of the various methods of cultivation. Studies on *Gracilaria* aimed at selecting the best species or strain for culture and agar extraction. Growth under various culture conditions was assessed together with salinity tolerance and agar quality.

Oyster and mussel farming and the fishery for windowpane oyster were assessed to determine problems and recommend ways for improvement. The green mussel was tested as a biofilter in an effort to develop a technology for cleaning effluents from intensive shrimp ponds. Another major effort was to artificially propagate the windowpane oyster and the local abalone for grow-out culture or restocking in areas where these species have been depleted.

Studies on *Kappaphycus alvarezii*

Chromosome number

Samples of *Kappaphycus alvarezii* from Panay and Guimaras islands were examined for chromosome counts with an aceto-iron-haematoxylin-chloralhydrate stain. At late diakinesis stage, the chromosome count was n=32 and the chromosomes were bar-shaped and 3 μm long (H Yabbu, personal communication).

Socioeconomics of farming

Located west of Caluya Island, Antique, Panagatan Cays is an incomplete atoll with a shallow reef flat 1,300 hectares wide. Panagatan was colonized six years ago by seaweed planters from nearby islands including Mindoro and Panay. About 15-20 hectares are now used for seaweed culture. A survey of the farming practices of *K. alvarezii* planters was conducted in November 1993 and May 1994 to determine the status, production, and problems of seaweed farming in the area (Hurtado-Ponce, unpublished). November is the peak of the planting season and May is the harvesting season of seaweeds in the Philippines. Some 43 seaweed planters (72% of all planters in Panagatan) were interviewed with a structured questionnaire. Seaweed farming is the main livelihood of 93% of the people in Panagatan; fishing is done mainly for home consumption.

Individual planters farm areas of 280-17,500 m^2 at stocking densities of 0.5 kg/m^2. Most farmers (79%) plant two morphotypes (brown and green), and 70% use a combination of the fixed bottom method and the hanging longline method of culture. An initial investment of P2,500 (US$1 = P25) can provide a monthly income of P2,600. Seaweeds are harvested after 45 days of culture and used to seed larger areas. After another 60-90 days, the seaweeds are totally harvested and dried. From three to six harvests are made in one year. Yearly production ranges 0.3-12 tons/ha. Farmgate prices range P4.50-7.50/kg. During the peak season (March-May), 100-150 tons of dried seaweeds are sent to Cebu on big sailboats. Epiphytes, grazers, typhoons, and thallus whitening were the major problems reported by the farmers.

Experimental cage culture

Kappaphycus alvarezii seedlings were cultured in cluster, vertical, and horizontal lines inside floating cages tied to a bamboo raft (Hurtado-Ponce 1994). Juvenile groupers (*Epinephelus* sp.) were stocked in the cages to control grazers. After 45 days, the seaweeds on the horizontal lines showed the highest specific growth rate (5.3% per day) and production (1204-1533 g/m line). After 120 days of culture, 68% of the groupers survived and reached mean weights of 297 grams.

Carrageenan properties

Three morphotypes (brown, green, and red) of *Kappaphycus alvarezii* were grown 50 cm and 100 cm below the water surface then examined for carrageenan properties and proximate composition (Hurtado-Ponce, in press). When grown at 50 cm deep, the green morphotype was significantly different from the brown and red in all carrageenan properties except sulfate content (Table 1). When grown at 100 cm deep, the green morphotype differed only from the brown. The three morphotypes did not differ in proximate composition, except in ash content and nitrogen-free extract.

Studies on *Gracilaria*

Stock assessment in Iloilo, Panay Island

The influence of some environmental factors on biomass and agar quality was studied for 12 months in *Gracilaria changii* from Guimbal, *G. rubra* from Concepcion, and *G. heteroclada* from Estancia and Zarraga (Pondevida 1993). For all species, the biomass varied monthly but no correlation was found between biomass and temperature, pH, turbidity, nutrients, and salinity at different study sites. However, phosphate was positively correlated with the biomass of *G. heteroclada* in Estancia, and rainfall was negatively correlated with the biomass of *G. changii* in Guimbal and *G. heteroclada* in Zarraga.

Table 1. Carrageenan properties of three different morphotypes of *Kappaphycus alvarezii* grown at two depths. Values are means±SE (n=2). Data from Hurtado-Ponce (in press).

Water depth Morphotype	Yield (%)	Gel strength (g/cm^2)	Gelling temp. (°C)	Melting temp. (°C)	Viscosity (cps)	Sulfate (%)
50 cm						
Brown	8.5±2.7	1.0±0	4.3±0.5	30.0±1.5	23.0±2.0	20.6±0.9
Green	4.7±0.6	131.0±8.0	17.3±1.3	67.5±0.5	34.5±1.5	15.2±0.4
Red	10.8±0.3	7.5±4.5	8.6±1.6	46.5±0.5	25.5±0.5	15.7±0.3
100 cm						
Brown	7.5±0.3		3.0±0	69.0±0.7	30.0±2.0	34.5±1.5
22.2±0.7						
Green	4.8±2.4	56.5±11.5	12.7±1.5	47.5±0.5	28.0±0	15.7±0.2
Red	11.6±1.3	64.0±11.0	13.9±0.1	53.5±0.5	24.0±1.0	15.9±0.9

Experimental tank culture

Gracilaria heteroclada was grown in fiberglass tanks in enriched or unenriched seawater at stocking densities of 500, 1000, and 2000 g/m^2 (Hurtado-Ponce, unpublished). Pulses of 2 mM NH_4C1 and 0.2 mM KH_2PO_4 were provided for 12 hours at night. Growth was significantly higher at the stocking density of 500 g/m^2 in both enriched and unenriched seawater.

In another experiment, *G. heteroclada* was grown in outdoor or indoor tanks, at either 15, 25, or 35 ppt salinity, and with or without 5.58 μM urea enrichment (Pondevida 1993). Seaweeds at 15 ppt in outdoor tanks with urea enrichment grew significantly better than the rest. Thus, *G. heteroclada* is tolerant of low salinity.

Tank-grown *G. heteroclada* was transplanted to Dumangas for farming (Hurtado-Ponce, unpublished). After two months, the farmers were able to harvest and sell the seaweed. The presence of unwanted algae was a problem.

The salinity tolerance of four other species of *Gracilaria* (*G. changii, G. fastigiata, G. firma,* and *G. tenuistipitata*) from Sorsogon was tested in concrete tanks (SR Ferrer, personal communication). Preliminary results show that salinity tolerance and growth rates differ by species.

Pond culture with tiger shrimp

The tiger shrimp *Penaeus monodon* was stocked at 2,500/ha and 5,000/ha together with *Gracilaria heteroclada* planted at 250, 500, and 750 g/m^2 in the 'rice-planting' method and at 500 g/m^2 in the longline technique. During the 5-month culture period, growth and production of the seaweed varied monthly and with the seaweed stocking density. Highest average growth rate (3.1% per day) and production (873 g/m^2) of *G. heteroclada* was obtained at the stocking density of 250 g/m^2 during November when average temperature was 29.5°C, salinity was 24 ppt, water tansparency was 74%, and water depth was 83 cm (Hurtado-Ponce, unpublished).

Agar quality

Species of *Gracilaria* grown under different conditions were tested for agar quality. Wild stocks of *G. heteroclada* from Estancia and Zarraga yielded agar of higher gel strength than *G. changii* and *G. rubra* (Pondevida 1993). Harder gels are highly priced in the international agar market. Agars with gel strength of 600 g/cm^2 or more are considered bacteriological grade agar.

Salinity affected the gel properties of *G. heteroclada* grown in outdoor or indoor tanks, with or without urea enrichment. Seaweed grown at 25 ppt produced agar with significantly higher gel strength and gelling and melting temperatures but lower agar yield and sulfate content than those at 15 and 35 ppt (Pondevida 1993).

Several studies were done to manipulate and possibly improve the gel properties of *G. heteroclada.* Seaweed grown at a density of 2,000 g/m^2 in tanks with enriched seawater produced agar with significantly higher gel strength, and higher gelling and melting temperatures than those grown at 500 and 1000 g/m^2 (Hurtado-Ponce, unpublished). In unenriched seawater, gel properties did not vary with stocking densities.

The two species *G. heteroclada* and *G. changii* have gel strengths of more than 600 g/cm^2 and are thus of potential commercial importance. Two methods of alkali treatment were tested on these species (de Castro 1993a). In Treatment I, the seaweeds were pretreated with either 1, 3, or 5% NaOH for 30-60 min at 85-90°C. In Treatment II, crude extracted agar was treated with either 5, 10, or 15% NaOH for 3 days at room temperature. Significant differences in gel strength were found (Table 2), but either alkali treatment may be used for *G. heteroclada* and *G. changii.* Treatment II is a modification of the standard method used for *Polycavernosa* spp. in Thailand; it can be used for reprocessing of crude agar extracted at the village level.

The agar yield and gel strength of *G. heteroclada* cultured in cages at different depths (25, 50, and 100 cm) varied monthly. Seaweeds grown at 25 cm deep had higher agar yields and gel strength (TR de Castro, personal communication).

Table 2. Gel strength (mean±SE) of two *Gracilaria* species under different alkaline treatments. Data from de Castro (1993a).

Treatment	NaOH (%)	Duration	Gel strength (g/cm^2) *G. heteroclada*	Gel strength (g/cm^2) *G. changii*
I	1	30min	463 ± 4.2	379 ± 8.9
	3	30min	516 ± 1.6	538 ± 7.9
	5	30min	642 ± 11.9	574 ± 5.5
	1	60 min	632 ± 8.7	357 ± 1.3
	3	60 min	568 ± 4.6	644 ± 3.4
	5	60 min	444 ± 3.2	414 ± 4.8
II	5	3 days	439 ± 3.3	783 ± 5.3
	10	3 days	639 ± 11.9	469 ± 4.9
	15	3 days	542 ± 5.6	657 ± 16.6

Studies on Oyster *Crassostrea iredalei* and Green Mussel *Perna viridis*

Socioeconomics of farming in western Visayas

The socioeconomics, technical status, marketing, and profitability of oyster and mussel farming in Western Visayas were assessed in a 1992 survey (GPB Samonte, personal communication). Oyster and mussel farms are located among fish capture devices in rivers and bays. About 73% of the oyster farmers and 81% of the mussel farmers have farms with areas less than 1,000 m^2. Oyster and mussel farming in western Visayas is dependent on the natural spatfall — almost year-round for oysters, but seasonal for mussels. Four methods are used to culture oysters: stake (most common), bottom, rack hanging, and raft hanging; the raft method is the most cost-efficient. Mussels are cultured on stakes, at the bottom, and on rafts; the stake method is the most cost-efficient. Unpaid owner and family labor is an essential input in oyster and mussel farms. The production costs are minimal and affordable by small-scale fishermen. Mussel farmers had higher net farm income than oyster farmers. Oyster and mussel farmers belong to the marginalized sector of society. The average mussel or oyster farmer in the study was 44-45 years old, married with 5-6 children, and had an elementary education, 8-9 years of farming experience, and a household income of P20,500-28,700 in 1990 (US$1 = P25). Farmers have no legal claim to the farm lots; most of them own their houses but not their home lots.

A localized technical and socioeconomic assessment was made of oyster and mussel culture in Binaobawan, Pilar, Capiz and Lakaran, Dumangas, Iloilo in 1993. Rapid rural appraisal was conducted to determine the condition of the resources and the livelihood and socioeconomic situation of the villagers, particularly the oyster and mussel farmers (WG Gallardo, personal communication). Fishing is the major livelihood in both villages. In Lakaran, all residents are engaged in oyster fanning by the rack hanging method. In Binaobawan, 77% of the villagers are engaged in oyster and mussel fanning; oysters are cultured by the bottom method and mussels by the platform method. Production of oysters in Binaobawan could be increased by adapting the method used in Lakaran.

Market-size green mussels and the brown mussel *Modiolus metcalfei* were transplanted from Capiz to Lakaran for culture by the oyster farmers there (KG Corre, personal communication). Five months after transplantation, spats of green mussels were found attached to nearby bamboo poles and oyster and mussel shells.

Green mussels as biological filter in shrimp ponds

Work in Thailand and elsewhere have suggested that shrimp pond effluents may be cleaned by biological filters such as filter-feeding mollusks and nutrient-absorbing seaweeds. Green mussels were tested as biological filter in ponds with tiger shrimps stocked at $5/m^2$. The mussels prevented excessive growth of phytoplankton and an increase in suspended solids. Water transparency was higher in shrimp ponds with green mussel than those without. After a 98-day culture period, shrimps in ponds with mussels had significantly higher body weight than those without mussels, but survival and production were not significantly different (KG Corre, personal communication).

Studies on the 'Kapis' *Placuna placenta*

Fishery

A nationwide survey of the windowpane oyster or 'kapis' fishery was conducted to assess the present status (WG Gallardo, personal communication). There are 27 'kapis' beds in the Philippines, six of which are the major sources. 'Kapis' stocks are declining and most beds are already depleted due to excessive gathering, pollution, siltation, and trawling. 'Kapis' shells support an open access fishery; anybody can gather shells by handpicking in shallow areas, compressor diving in deeper areas, and dredging. To prevent the depletion of the 'kapis' resource, several measures are recommended: establishment of sanctuaries, ban on trawling and other destructive fishing methods, strict enforcement of existing regulations, community-based fishery management, and further research on seed production, restocking, and transplantation (WG Gallardo, personal communication).

Seed production

To provide 'kapis' seed for grow-out and restocking, broodstocks are being developed for eventual spawning and seed production in the hatchery (JM Ladja, personal communication). Wild-caught 'kapis' were induced to spawn after intragonadal injection of 1 ml of 2 mM serotonin solution. The larvae developed to early pediveliger stage. 'Kapis' broodstocks kept in tire rays at a river mouth showed more mature gonads than those held in laboratory tanks. Broodstocks fed a 3:1 combination of of the microalgae *Isochrysis galbana* and *Tetraselmis tetrahele* developed more mature gonads than those fed a 1:1 combination (JM Ladja, personal communication).

Studies on the Donkey-Ear Abalone *Haliotis asinina*

Studies on the reproductive biology of the local abalone were initiated in 1993 on specimens collected from Panagatan Cays, Antique (EC Capinpin, personal communication). As of May 1994, the 150 specimens collected had shell lengths of 4.8-9.6 cm. The specimens ranged in gonad development from immature to fully mature.

Abalones collected from Panagatan Cays were maintained in fiberglass tanks for spawning and seed production trials. Since March 1994, abalones have spawned continuously on a semilunar cycle (M Hosoya, personal communication). Juvenile abalones ranged 1.5-2 cm after three months.

Juvenile abalones were reared for 120 days in plastic baskets inside fiberglass tanks with flow-through seawater. They were fed *Gracilaria heteroclada, Kappaphycus alvarezii,* or a commercial diet for Japanese abalone. Growth of the local abalone was best on *Gracilaria* and worst on *Kappaphycus* (EC Capinpin, personal communication).

Conclusion

Studies at the SEAFDEC Aquaculture Department have focused on the biology, culture, and agar quality of several *Gracilaria* species. Growth and production of *Gracilaria heteroclada* are higher in tanks than in ponds. Nutrient enrichment during the culture period enhances growth and improves agar quality. Salinity tolerance varies by species. Alkali treatment of the raw material improves agar quality.

Oyster farming and mussel fanning are important livelihoods for marginal fisherfolk in many towns in western Visayas. Income for the fisherfolk could be improved with government and private support, in terms of policy, credit, culture and post-harvest methods, and infrastructure. Green mussel is a potential biofilter in intensive shrimp ponds. The local abalone is relatively easy to spawn and rear in the laboratory. Seed production of the windowpane oyster may soon be feasible.

Editors' Addendum

The following other papers on seaweeds and mollusks were published by SEAFDEC AQD researchers during the past three years:

- Culture of *Gracilaria:* Lavilla-Pitogo (1991), Hurtado et al. (1992c), de Castro and Guanzon(1993),
- Culture of *Kappaphycus:* Hurtado-Ponce (1992a), Samonte et al. (1993)
- Biology and gathering of seaweeds: Luhan et al. (1992), Hurtado-Ponce et al. (1992a, b), Hurtado-Ponce(1993)
- Post-harvest processing of seaweeds: Hurtado-Ponce (1992b, c), de Castro (1993b, c, d)
- Biology of *Placuna placenta:* Gallardo et al. (1992)

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