Growth of the rabbitfish *Siganus randalli* Woodland in relation to the feasibility of its culture on Guam

by

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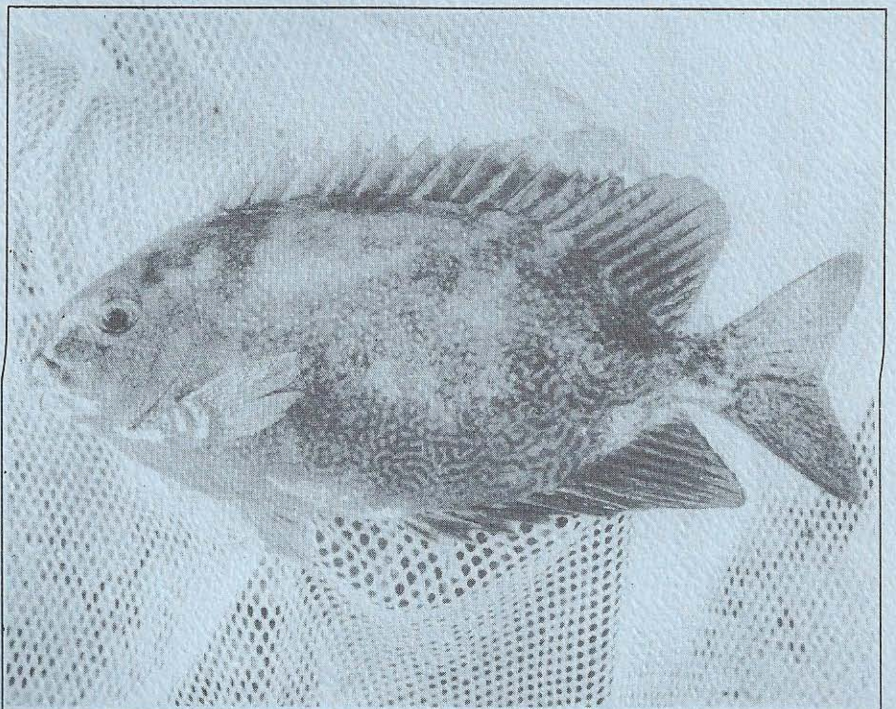

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INTRODUCTION

Rabbitfishes belong to the genus *Siganus* of the family Siganidae (Woodland, 1990). Siganids are herbivorous marine and brackishwater fishes that are found throughout the Indo-West Pacific (Woodland, 1983), and the more common species are the objects of traditional subsistence and commercial fisheries throughout this region. There has been interest in the culture of these fishes in ponds or cages in several areas (Duray, 1990; Tacon et al., 1990; Tawada, 1991) including Guam and Micronesia (Nelson, 1988), and siganids are one of the groups identified by the Pacific Aquaculture Association as being of interest for aquaculture development within Micronesia. The work described here was undertaken to provide useful information about rates of growth, production, and the efficiency of feed conversion for evaluating the potential of siganid production in ponds in this region. It was also hoped that this study would provide information to be used to identify areas where additional research is needed.

Our work has focused on *Siganus randalli* (Fig. 1), a species described in the revision of the family by Woodland (1990). This siganid was only recently discovered on Guam but is common in Sasa Bay and the inner portions of Apra Harbor. We chose this species for several reasons: it is one of the larger siganids; it is tolerant of a wide range of salinities; and, most importantly, because we have been successful in spawning this species and rearing the larvae to adults.

The work described here is presented in five sections: 1) production of juveniles for use in growth trials, 2) controlled growth experiments, 3) growth trials in commercial aquaculture ponds, 4) an interview with a commercial farmer experienced at raising siganids in Taiwan, and 5) a summary. The work is a technical report and intended for use by researchers, extension agents, and those involved in aquaculture planning and development at Guam and at other Pacific islands. The work also serves as the final report for a project funded by the Pacific Aquaculture Association.

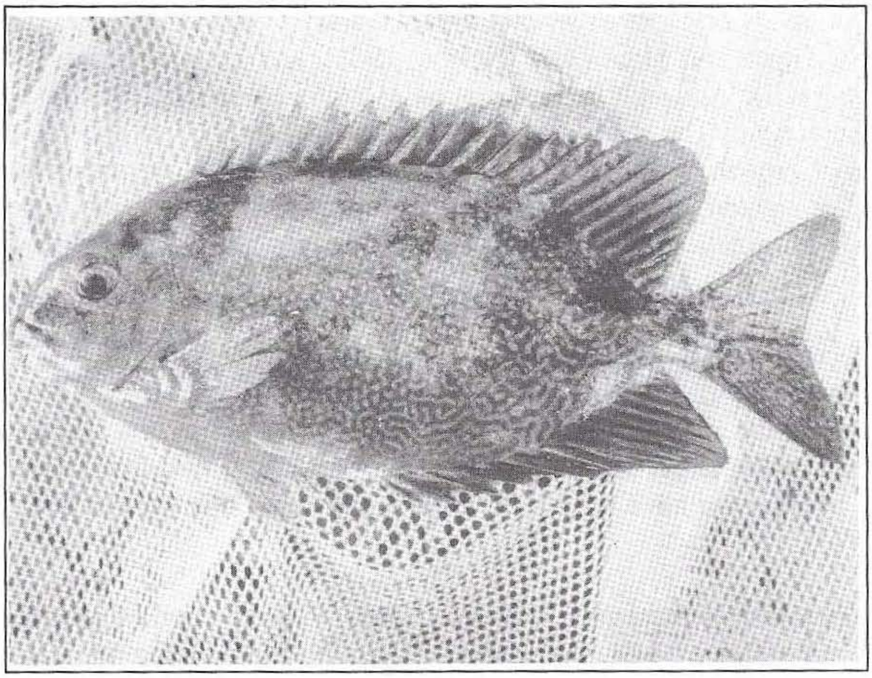

Figure 1. Adult of *Siganus randalli.*

PRODUCTION OF JUVENILES

SPAWNING AND LARVAL REARING

Most of the broodstock were descendants of 13 juveniles of *Siganus randalli* collected from low-salinity waters (6 ppt) of the inner portion of Apra Harbor at Guam. The fish were reared to maturity in a 206-m^2 cement pond, 1 m in depth, at the Guam Aquaculture Development and Training Center. These broodstock were fed pelletized feed at approximately 3 percent of their body weight per day. Progeny from these fish were used to build up the number of broodstock to approximately 300 fish; these formed the pool of individuals from which spawners were selected for the larval-rearing trials described below. Additional *S. randalli* were occasionally captured from around Guam and added to the broodstock.

Spawning

To select spawners, we collected egg samples by cannulating fish that had been anesthetized with MS-222 (tricaine methane sulphonate). Six to eight fish, usually 75% females and 25% males, were placed in either a 2- or a 10-ton tank. If spawning did not occur spontaneously within two days, it was induced by injecting each fish intramuscularly with Human Chorionic Gonadotropin (HCG) at a dose of 1 IU g^{-1}. The fish usually spawned between midnight and dawn.

Like most siganids, this species has demersal, adhesive eggs. The eggs of *S. randalli* are spherical with multiple oil globules (Fig. 2). We placed sheets of corrugated plastic on the bottom of the spawning tanks to collect the eggs. Within a few hours after the larvae hatched, we removed the corrugated sheets, along with any remaining unhatched eggs and the residuum of the hatched eggs.

Larval Rearing

Spawning usually occurs before dawn, with the eggs hatching in the evening at the ambient temperatures (usually between 28-30°C) of the outdoor tanks. The initial larval densities ranged from 20 to 30 l^{-1}. We maintained the flow of seawater into the rearing tanks to provide an exchange rate of 20% of the total tank volume per day. Larval rearing was also conducted in the outdoor tanks.

The day after hatching, phytoplankton (either *Chlorella* sp. or *Nannochloropsis occulata*) was introduced into the larval rearing tanks, at densities of approximately 5×10^5 cells ml^{-1}. During the afternoon of the second day after hatching, small-strain (S-type) rotifers (*Brachionus plicatilis*--obtained from the Brackishwater Aquaculture Center at Phuket, Thailand) were added at densities of 10 to 20 ml^{-1}. In some cases, copepods (*Tisbe holothuriae*) appeared in the tanks during the rearing trials and provided a supplemental feed for the larvae. Twelve to fourteen days after the siganids hatched, newly hatched *Artemia* nauplii were added to the larval rearing tanks at densities of 1 to 2 ml^{-1} and later at 3 to 5 ml^{-1}. After metamorphosis, commercial salmon mash was added to the diet. Similar methods of rearing larval siganids have been used by other investigators (Bryan and Madraisau, 1977; Tawada, 1991; Duray and Kohno, 1988; Soletchnik, 1984; May et al., 1974)

Newly hatched larvae are small (1.4 to 1.8 mm in length) and lack pigmented eyes and a functional mouth (Fig. 2). Approximately 24 hours post-hatching, the eyes become pigmented and the mouth becomes functional (Fig. 3). Soon after the mouth becomes functional the larvae can feed on S-type rotifers. Table 1 provides a generalized summary of the development of *S. randalli* larvae and the associated feeding regime.

Although we were able to rear larvae of *S. randalli* successfully to the juvenile stage, hatchery production was limited and highly variable. A particularly critical period, one in which most of the larval mortalities occurred, is the transition from the yolk-sac stage to first feeding. Work in our laboratory is currently focusing on this transitional stage. Larval mortality during this stage must be reduced in order to achieve the production levels required to support commercial aquaculture.

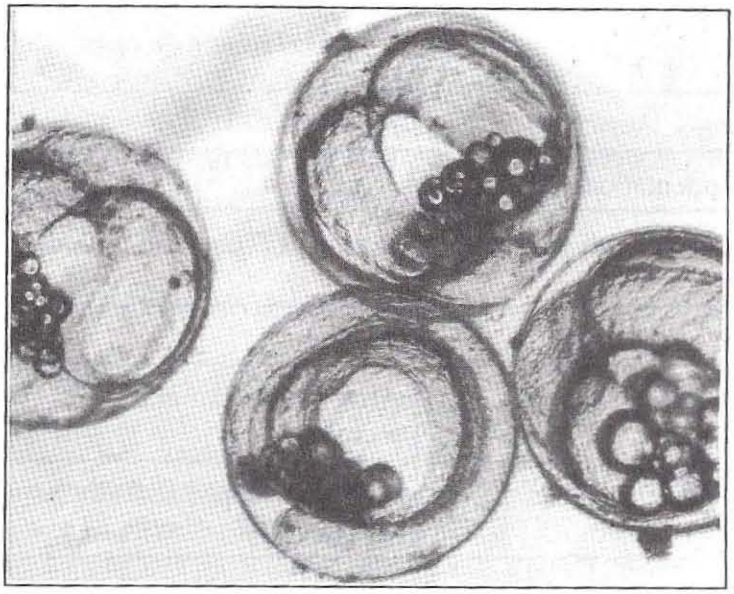

Figure 2. Eggs of *Siganus randalli.*

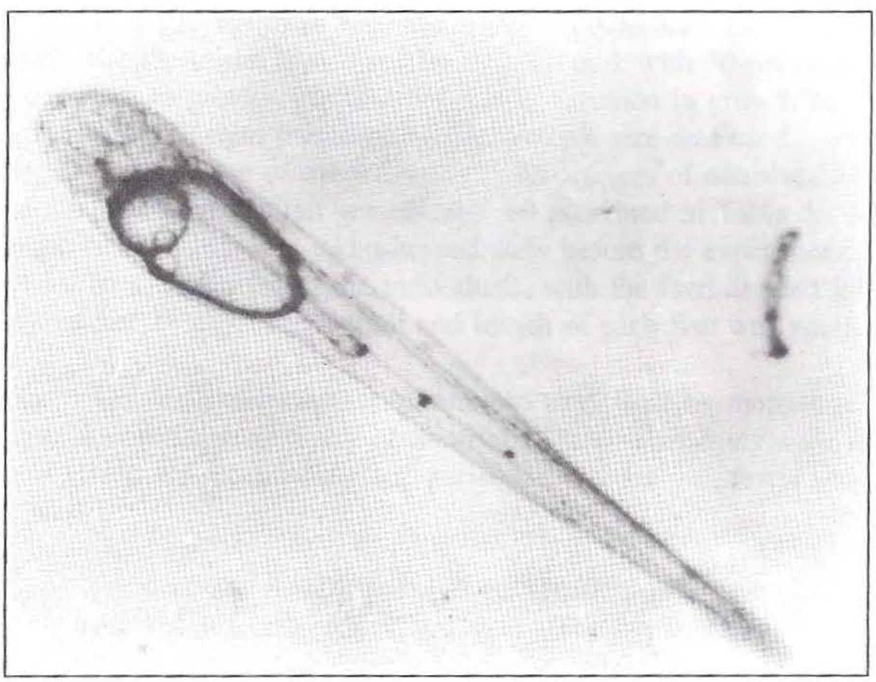

Figure 3. Newly hatched larvae of *Siganus randalli.*

TABLE 1. Generalized pattern of development of *Siganus randalli* and the feeds used at each stage.

TIME AFTER FERTILIZATION	DEVELOPMENTAL STAGE OR EVENT	FEED
12-15 Hours	Hatching	None
36 Hours	Eye Pigmentation	None
50-60 Hours	Functional Mouth and First Feeding	Rotifers (77μm>Rot.>60μm)
80-90 Hours	Yolk-Sac Absorbed	Rotifers
14 Days	Post-Yolk-Sac Larvae	*Artemia* Nauplii and Rotifers
4 Weeks	Brown-Head Stage	*Artemia* Nauplii and Grade III Hatchfry*
5-6 Weeks	Metamorphosis	Hatchfry and Flake Feed
6-8 Weeks	Juvenile	Pelletized Feed

* Hatchfry Encapsulon is a product of Argent Chemical Laboratories.

CONTROLLED GROWTH TRIALS

Initial growth trials were conducted in tanks at the Guam Aquaculture Development and Training Center. These trials allowed an accurate determination of feed conversion ratios, and also allowed us to conduct replicated trials to investigate several factors that might influence the growth of juvenile siganids. The replicated trials included: 1) comparison of two commercial fish feeds with respect to growth, 2) comparison of three feeding rates with respect to growth and apparent feed conversion ratio, and 3) comparison of three feeding frequencies with respect to growth.

MATERIALS AND METHODS

Comparison of diets

We conducted growth trials in tanks to compare two diets currently in use on aquaculture farms and at the Guam Aquaculture Development and Training Center. The diet lower in protein (36% crude protein) was formulated for catfish and is used by commercial producers and for maintenance of our siganid broodstock; the other diet (55% crude protein) was formulated for salmonids and has been used in the production and rearing of juvenile siganids at the hatchery. The composition of the diets is shown in Table 2. Each growth trial was conducted in a set of six 2-ton, flow-through tanks supplied with seawater at a rate of 5 tank-volumes per day.

Two growth trials were conducted to determine the effect of diet on siganid growth rates. For the initial trial, we stocked each tank with 50 juvenile siganids. We planned this experiment to provide information on the variation in growth between fish from this type of experimental design; therefore, a large sample size was used. We randomly assigned each of the six tanks to one of the treatments. The ranges of dissolved O_2, pH, and temperature over the duration of the initial growth trial are presented in Table 3. The weight and standard length of each fish was taken immediately before the experiment. The fish were fed at 9% of the initial total weight of the individuals, with the feed divided into two or three feedings per day. After 21 days, the weight and length of each fish was again determined.

The initial trial was compromised somewhat by mortalities that occurred in three of the tanks on the second day of the trial. These mortalities were attributed to handling stress. As a result, we repeated the comparison, this time with fewer (10) fish per tank and an excess of feed.

We used the BMDP package of statistical programs (BMDP Statistical Software, Inc., Los Angeles, California) for all analyses. The experimental design was that of a nested analysis of variance with fish nested in tank and tank nested in diet. The sample sizes per tank were large enough to allow the use of a one-way ANOVA followed by a Student-Newman-Keuls test to examine differences between tanks.

TABLE 2. Composition of the commercial diets used in the growth trials. The catfish pellets were manufactured by O.H. Kruse Grain and Milling, 3730 Monterey, El Monte, CA 91734. The salmon starter was obtained from Zeigler Bros., Inc., P.O. Box 95, Gardners, PA 17324. The compositions are from the manufacturer's labels.

COMPONENT	CATFISH PELLETS	SALMON STARTER
Crude Protein, Max.	36.0%	55.0%
Crude Fat, Min.	4.2%	15.0%
Crude Fiber, Max.	5.5%	2.0%

TABLE 3. Ranges of dissolved O_2, pH, and temperature during the diet comparison experiments.

	DISSOLVED O_2		pH		TEMPERATURE	
Tank	Low	High	Low	High	Low	High
1	5.4	6.6	7.80	7.87	28.0	31.9
2	5.4	6.34	7.80	8.02	28.0	31.5
3	5.4	6.6	7.79	7.86	28.0	31.8
4	5.2	6.4	7.80	7.84	28.0	31.6
5	5.4	6.41	7.78	7.86	28.0	31.9
6	5.4	6.46	7.87	7.88	28.0	31.6

Because some of the groups in the original trial experienced mortalities, we conducted two alternative analyses of the data. The first consisted of a one-way ANOVA to compare final fish sizes between tanks. The second method was a nested ANOVA conducted on a data set obtained by drawing random samples of 15 records from those of each tank. This reduced the computational intensity required to a level that could be handled with a personal computer (IBM PS/2 386sx) and assured a balanced ANOVA design.

Before performing any of the ANOVAs, we used Levene's Test to check the equality of variances between tanks. Homogeneity of variances is a major assumption of ANOVA.

For the full data set, the differences in variances between tanks were not significant for standard length, but they were for weight. We made several attempts to transform the weight data to achieve homogeneity of the variances but were not successful. Because of this, we statistically analyzed only the data for standard lengths in this trial.

However, for the data set obtained by randomly selecting 15 records, we found the assumptions of homogeneity of variance to be valid for both weight and length. In this case, we used the data on fish weights for statistical comparisons.

Comparison of feeding rates

To determine an optimal feeding rate, we compared the growth of groups of 15 juvenile *Siganus randalli* fed with commercial catfish feed at rates of either 3, 6, or 12% of fish weight per day. Each of nine groups of fifteen fish was held in a separate 2-ton tank supplied with constantly flowing seawater. The tanks were randomly assigned to one of the treatments until each treatment had been assigned three tanks. The duration of the growth trial was 28 days. The ranges of dissolved O_2, pH, and temperature over the duration of the growth trial are presented in Table 4. The mean weights of the fish in each tank at the beginning of the growth trial were compared by one-way ANOVA to verify that there were no significant differences between tanks at the onset of the experiment. At the end of the trial, 10 fish from each tank were randomly selected and weighed to assure a balanced design for the ANOVA model used. A mixed-model ANOVA (BMDP 8V) was used to compare the final weights between treatment groups. In the model, the treatment, or feeding rate, was considered a fixed factor and the tank was considered a random factor. We used a nested ANOVA model with tanks nested in the treatment groups and the fish nested in tanks. Prior to the ANOVA we used Levene's Test to verify variance homogeneity.

Specific growth rates, expressed as percent per day, were calculated for each tank of fish as

$$100\left[\left(\frac{W_f - W_o}{(W_f + W_o)/2}\right)/days\right]$$

where W_f represents the final weight and W_o, the initial weight. The data were also used to calculate apparent feed conversion ratios - the ratio of the dry weight of the food to the wet weight of the increase in fish biomass in each tank. The moisture content of the food was determined by drying samples to constant weight at 50°C in a drying oven.

Comparison of feeding frequency

We compared the growth of groups of juvenile siganids fed either 1, 2, or 3 times per day in a 28-day growth trial. Nine groups of 15 juvenile siganids were each fed with commercial catfish feed at 12% of their body weight per day. Each of nine 2-ton tanks supplied with constantly flowing seawater was randomly assigned to one of the treatment groups until three tanks had been assigned per group. Dissolved oxygen, pH, temperature, and salinity were taken once daily during the experiment and are shown in Table 4. The weights of the individual fish in each tank were taken both at the beginning and at the end of the growth trial. At the end of the growth trial, 14 fish were selected at random from each group to include in the ANOVA. This was necessary because one fish died in each of three tanks, and the BMDP ANOVA program requires a balanced design (equal sample sizes in each cell). The mean weights of the fish in each group were compared with a one-way, mixed-model, nested ANOVA with feeding frequency as a fixed factor, tank (nested in feeding frequency) as a random factor, and individual fish (nested in tank) as a random factor.

TABLE 4. Ranges of dissolved O_2, pH, and temperature during the feeding rate experiments.

	SALINITY		DISSOLVED O_2		pH		TEMPERATURE	
Tank	Low	High	Low	High	Low	High	Low	High
1	25	34	5.50	7.43	7.61	7.88	26.2	28.0
2	25	34	5.70	7.70	7.62	7.88	26.3	28.5
3	25	34	5.00	7.93	7.49	7.80	26.9	28.0
4	25	35	5.80	7.40	7.57	7.82	26.9	28.3
5	25	35	5.20	7.33	7.46	7.84	27.0	28.2
6	25	35	5.30	7.89	7.58	7.83	27.0	28.2
7	25	35	5.40	7.33	7.61	7.88	27.1	28.5
8	25	35	5.60	7.40	7.54	7.91	27.1	28.5
9	26	35	5.40	7.40	7.59	7.88	27.1	28.6

RESULTS

Comparison of diets

Tables 5 and 6 provide summaries of the data for the initial trial. The mean fish weight and the biomass increase were greater for fish in the tanks fed the diet with the higher protein content (salmon starter). One-way ANOVA comparisons of the final standard lengths indicated that significant differences existed between tanks ($F_{5,274} = 15.89$, $p = 0.0000$). We then used post-comparison tests, both the SNK procedure and Tukey's Studentized Range Method, to determine whether any of the tank means differed significantly. The SNK procedure indicated that none of the tanks receiving the same diet were significantly different, but tank means differed between diet groups. Table 7 shows that similar results were obtained with Tukey's test. These results indicate that there was a significant effect of diet on siganid growth and that better growth was achieved with salmon starter than with catfish feed.

We used some of the data from the first trial to calculate apparent feed conversion ratios (FCR). Only the tanks without mortalities (tanks 3, 5, and 6) were used in the calculations of apparent FCR. We calculated apparent FCR as the weight of feed divided by the increase in total fish weight in each tank. Apparent feed conversion ratios for the two tanks fed with salmon starter were 1.74 and 1.51, respectively. Tank 6, fed with catfish pellets, was found to have an FCR of 1.56.

A summary of the data obtained from the second growth trial comparing diets is provided in Table 8. The mean weights of fish in each tank ranged initially from 6.6 to 7.5 g. At the end of the three-week growth trials, mean weights ranged from 18.4 to 21.6 g for the groups fed salmon starter, and from 16.1 to 18.1 g for the groups fed catfish feed. We compared the final weights with a 2-factor, mixed-model, nested ANOVA, with tanks nested in diet. The results, displayed in Table 9, show that there was a significant ($F_{1,54}$=8.7, p=0.042) effect of diet. The conclusion is the same as that derived from the first trial--growth was better with salmon starter. We did not calculate feed conversion ratio (FCR) for this trial because the fish were fed in excess.

<u>Effect of feeding rate</u>

The mean final weights of the juvenile siganids in each tank are shown in Table 10. Mean final weights ranged from 5.03 to 6.08 g; the effect of feeding rate was highly significant ($F_{2,81}$=13.4; p=0.006). Table 11 displays the results of an analysis of variance comparing the final mean weights.

Both feed conversion and growth rate were influenced by feeding rate. Apparent feed conversion ratios (FCR) for each group of fish are shown in Table 12. Values for FCR, corrected for the moisture content of the diet, ranged from 1.2 to 2.7, increasing with feeding rate as shown in Figure 5. Mean specific growth rate increased with feeding rate as shown in Figure 6 . Mean specific growth rates (± standard deviation) were 1.69 (±0.15), 2.25 (±0.23), and 2.98 (±0.22) percent per day in the groups fed, respectively, 3, 6, and 12% of their body weight daily.

<u>Effect of feeding frequency</u>

The results of the growth trial comparing feeding frequencies are shown in Table 13. The mean final weights of the groups of juveniles ranged from 5.1 to 8.6 g, but there were no significant differences between groups attributable to feeding frequency ($F_{2,111}$=0.26; p=0.78) as shown in Table 14.

TABLE 5. Mean initial and final weights (grams) of siganids in a trial comparing the effects of diet on fish growth. The standard errors of the means are given in parentheses. Fifty fish were stocked per tank and were fed at 9% of their initial weight per day. Means with the same superscript did not differ significantly (Student-Newman-Keuls Multiple Range Test, $p>0.05$).

TANK	DIET	INITIAL MEAN WT (g)	FINAL MEAN WT (g)
1	Salmon Starter	4.678	7.064[a] (0.139)
3	Salmon Starter	4.678	6.848[a] (0.131)
5	Salmon Starter	5.122	7.214[a] (0.110)
2	Catfish Pellets	4.888	6.065[b] (0.098)
4	Catfish Pellets	4.674	6.330[b] (0.167)
6	Catfish Pellets	4.428	6.124[b] (0.117)

TABLE 6. Summary of survival and growth of siganids in a growth trial comparing diets (S=Salmon Starter; C=Catfish Pellets).

TANK	DIET	INITIAL COUNT	FINAL COUNT	INITIAL WT (g)	FINAL WT (g)	WEIGHT GAIN (g)
1	S	50	42	233.9	296.7	62.8
3	S	50	50	233.9	342.4	108.5
5	S	50	50	256.1	360.7	104.6
2	C	50	48	244.4	291.1	46.7
4	C	50	40	233.7	253.2	19.5
6	C	50	50	221.4	306.2	84.8

TABLE 7. Summary of the *a posteriori* test of significance of differences in final mean standard lengths of siganids in each of 6 tanks used in a growth trial comparing two diets. Significance levels as determined with Tukey's Standardized Range Method. Fish in tanks 1, 3, and 5 were fed with salmon starter. Those in tanks 2, 4, and 6 were fed catfish pellets. Final sample sizes ranged from 42 to 50 as shown in Table 2. Lengths of fish fed with the salmon starter differed significantly ($p<1\%$) from those fed the catfish pellets

TANK	1	2	3	4	5	6
1	NS	1%	NS	1%	NS	1%
2	1%	NS	1%	NS	1%	NS
3	NS	1%	NS	10%	NS	1%
4	1%	NS	10%	NS	1%	NS
5	NS	1%	NS	1%	NS	1%
6	1%	NS	1%	NS	1%	NS

TABLE 8. Mean initial and final standard lengths (cm) and weights (g) of siganids in a 3-week growth trial comparing two diets fed in excess. Each tank contained ten fish.

TANK	DIET	MEAN SL INITIAL	MEAN SL FINAL	MEAN WT INITIAL	MEAN WT FINAL
1	Salmon Starter	6.500	8.850	7.370	21.566
3	Salmon Starter	6.550	8.510	7.545	20.945
5	Salmon Starter	6.290	8.270	6.558	18.352
2	Catfish Pellets	6.490	8.080	7.435	16.081
4	Catfish Pellets	6.490	8.340	7.417	18.104
6	Catfish Pellets	6.500	8.080	7.329	16.256

TABLE 9. Comparison of final weights of siganids fed two diets with 3 tanks per diet and 10 fish per tank. Feeding was to satiation. A mixed-model, nested ANOVA was used.

SOURCE	ERROR TERM	SUM OF SQUARES	DF	MEAN SQUARE	F	PROB.
Mean	T(D)	20647.6340	1	20647.6340	991.99	0.0000
Diet	T(D)	181.0301	1	181.0301	8.7	0.0420
T(D)	F(DT)	83.2578	4	20.814	5.09	0.0015
F(DT)		220.753	54	4.088		

TABLE 10. Mean initial and final weights (± standard deviation) of 6 groups of juvenile siganids fed at a rates of either 3, 6, or 12% of initial weight per day.

FEEDING RATE (%/DAY)	INITIAL COUNT	MEAN INITIAL WEIGHT (g)	FINAL COUNT	MEAN FINAL WEIGHT (g)
3	15	3.22 ± 0.52	15	5.03 ± 0.28
3	15	3.30 ± 0.53	13	5.32 ± 0.44
3	15	3.07 ± 0.59	14	5.29 ± 0.39
6	15	2.86 ± 0.49	14	5.17 ± 0.33
6	15	3.35 ± 0.52	15	5.47 ± 0.35
6	15	3.15 ± 0.40	15	5.63 ± 0.37
12	15	2.99 ± 0.57	15	5.81 ± 0.43
12	15	3.43 ± 0.62	15	5.87 ± 0.47
12	15	3.45 ± 0.54	15	6.08 ± 0.48

TABLE 11. ANOVA table comparing final weights of siganids fed at three rates with 3 tanks per diet and 10 fish per tank. A mixed-model, nested ANOVA was used. Codes are T = tank, R = feeding rate, F = fish.

SOURCE	ERROR TERM	SUM OF SQUARES	DF	MEAN SQUARE	F	PROB.
Mean	T(R)	3625.4699	1	3625.470	781.65	0.0000
Rate	T(R)	62.197	2	62.197	13.4	0.0061
T(R)	F(RT)	27.8293	6	4.638	3.15	0.0079
F(RT)		119.1321	81	1.471		

TABLE 12. Calculation of apparent food conversion ratio (FCR) for juvenile siganids in relation to feeding rate (values that are not corrected for moisture content are shown in parentheses).

FEEDING RATE (%/DAY)	INITIAL WEIGHT (g)	FINAL WEIGHT (g)	WEIGHT GAIN (g)	AMOUNT FED (g)	APPARENT FCR
3	48.3	74.4	26.1	40.5	1.6(1.5)
3	48.0	80.6	32.6	40.4	1.2(1.1)
3	46.0	75.5	29.5	38.6	1.3(1.2)
6	42.9	78.2	35.3	70.0	2.0(1.9)
6	50.2	94.1	43.9	84.3	1.9(1.8)
6	47.2	98.7	51.5	79.4	1.5(1.4)
12	44.8	116.0	71.2	150.4	2.1(2.0)
12	50.1	112.4	62.2	168.5	2.7(2.5)
12	51.8	129.7	77.9	174.1	2.2(2.1)

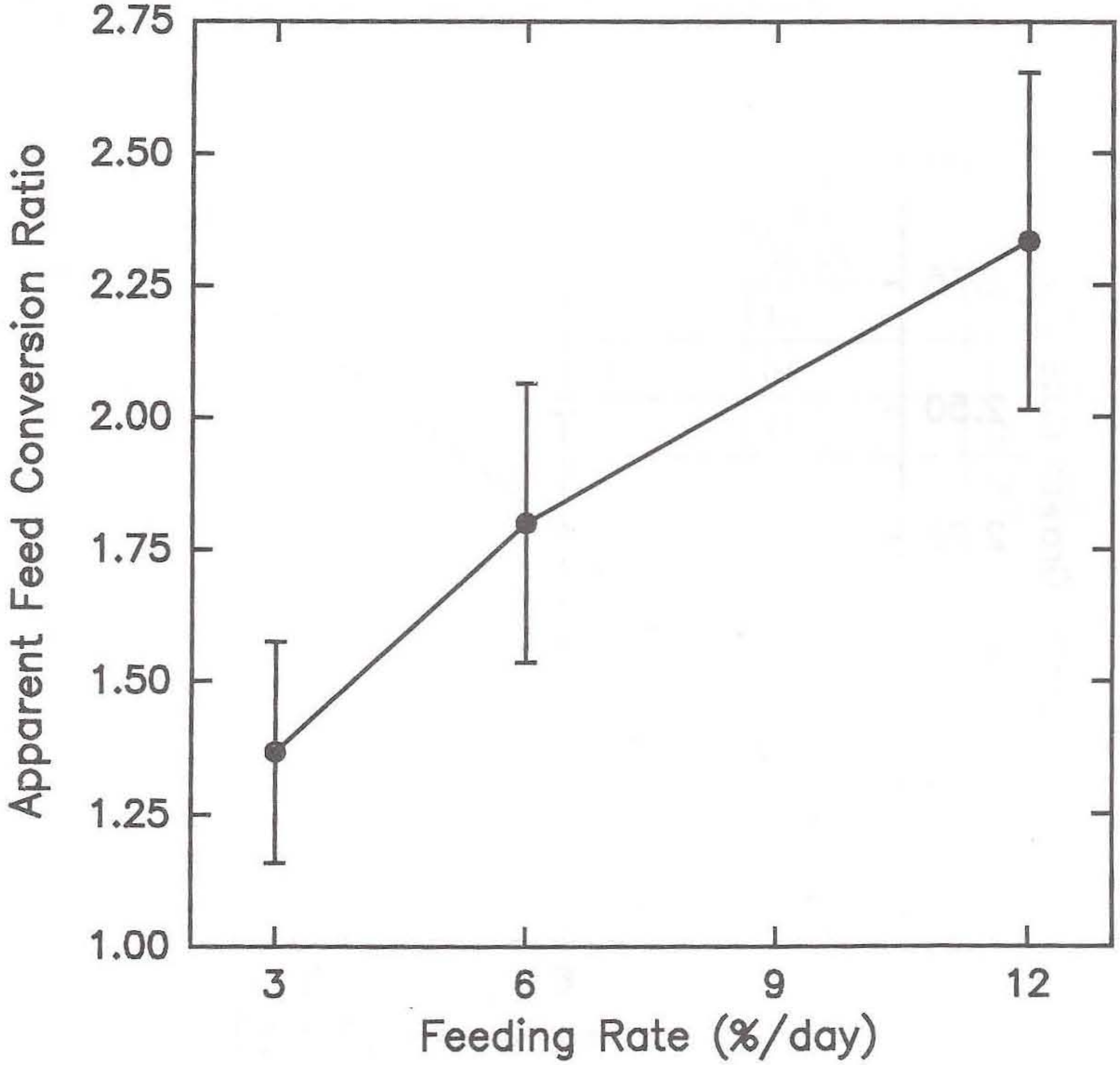

Figure 5. Apparent feed conversion ratio is dependent on feeding rate of juvenile *Siganus randalli*. The error bars denote the standard deviation.

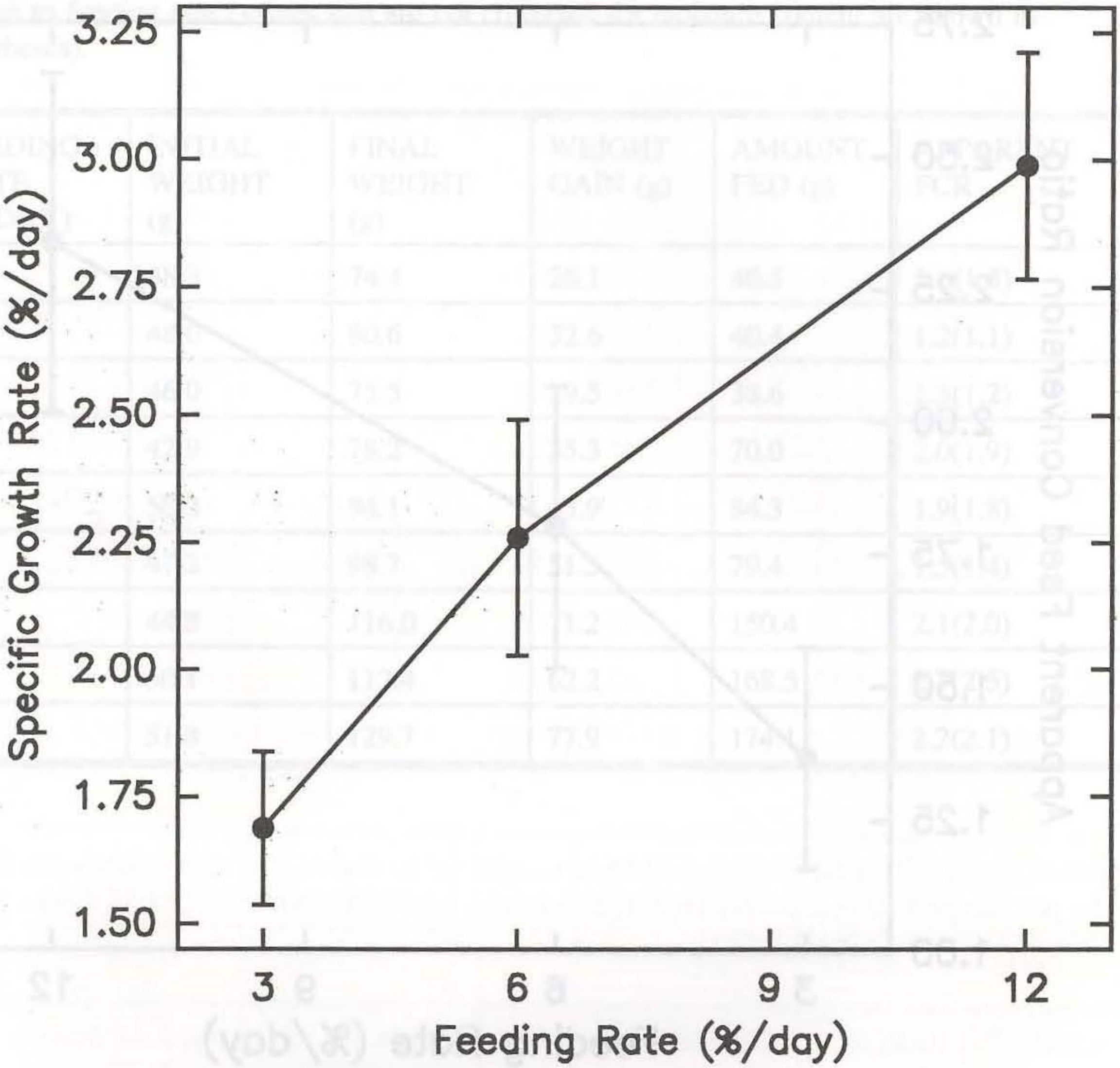

Figure 6. Specific growth rate is dependent on feeding rate of juvenile *Siganus randalli*. The error bars denote the standard deviation.

TABLE 13. Summary of trial comparing growth of juvenile siganids with respect to frequency of feeding. The table shows the mean sizes of the fish in each tank at the beginning and at the end of the trial and the number surviving.

DAILY FEEDING FREQ.	INITIAL MEAN WEIGHT (g)	STANDARD ERROR OF INITIAL MEAN	FINAL MEAN WEIGHT (g)	STANDARD ERROR OF FINAL MEAN	NUMBER AT END
1	3.2	0.2	5.7	1.4	15
1	3.2	0.6	5.1	0.8	15
1	3.9	0.8	8.6	1.6	15
2	3.4	0.5	6.0	0.8	14
2	3.8	0.9	7.0	2.2	15
2	3.9	0.7	7.7	0.8	15
3	3.3	0.8	5.8	1.4	14
3	3.5	0.7	5.8	1.3	15
3	3.9	0.9	7.2	1.4	15

TABLE 14. Nested one-way analysis of variance comparing the effects of feeding frequency on growth of juvenile siganids. Feeding rate was 12% of body weight per day. Codes are F = feeding frequency, T = tank, and I = individual fish.

SOURCE	ERROR TERM	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB.
Mean	T(F)	5379.94	1	5379.94	248.66	0.0000
Frequency	T(F)	11.32	2	5.66	0.26	0.7782
Tank(F)	T(F)	129.82	6	21.64	11.73	0.0000
Ind(T)	I(FT)	215.82	111	1.85		

DISCUSSION

Comparison of diets

Better growth of juvenile *Siganus randalli* was obtained with the salmon starter than with the catfish feed. This may be related to the higher protein content of the salmon starter. Parazo (1990) found increased growth of juvenile *S. guttatus* with increasing protein content of the diet. However, our tests were not designed to test the effects of specific components of the diet, and our results suggest that additional work in the evaluation and development of diets for siganid culture would be useful.

The rates of growth and feed conversion ratios that we found for *S. randalli* are similar to those reported for other siganids. Parazo (1990) examined the growth of juvenile *Siganus guttatus* fed 6 semi-purified diets. In that study, apparent feed conversion ratios ranged from 1.54 to 2.03, with specific growth rates ranging from 3.33 to 3.77%/day. Also, growth rate (3.85%/day) was higher with the commercial reference diet than with any of the experimental diets; apparent food conversion efficiency of fish fed with the commercial diet was 1.60. Less efficient conversion of pelletized feeds has been reported for siganids in cage culture. For example, Kungvankij et al. (1990) found that apparent food conversion ratios of *S. canaliculatus* fed ad libitum ranged from 3.4 to 10.7 in a 120-day grow-out period in cage culture in Indonesia. It is possible that feed conversion efficiencies in these cage-culture trials were low because of losses of feed through the mesh of the cages.

The apparent food conversion ratios of juvenile siganids fed at the lower ration level compared well with those reported for other fish under commercial cultivation in the tropics. For example, juvenile tilapia (*Oreochromis mossambicus*) raised in marine cages in the Bahamas were found to have feed conversion ratios of 1.2 to 1.3 (Watanabe et al., 1990). Also, food conversion ratios of juvenile Asian catfish (*Pangasius sutchi*) cultured in Thailand were reported to range from 1.3 to 2.3 (Chuapoehuk and Pothisoong, 1985). Commercial producers of milkfish (*Chanos chanos*) on Guam find feed conversion ratios of approximately 2.0; but in Taiwan, commercial milkfish producers achieve a feed conversion ratio of 1.3 (Liao and Chen, 1986).

Our results indicate that in the development of feeding regimes for juvenile siganids, there is a trade-off between growth and food conversion efficiency. We found that for 3- to 6-g fish, feeding rates greater than 12% will be required to maximize the growth of juvenile siganids. However, feeding rates below 12% will be needed to minimize food conversion ratios. These factors will be important in evaluating the economics of holding juvenile siganids in nursery ponds or tanks prior to their use in stocking grow-out facilities, as well as in pond culture.

Frequency of feeding

Frequency of feeding has been reported to influence growth and conversion efficiency for some species (Grayton and Beamish, 1977; Charles et al., 1984; Piper et al., 1982), but we found that the growth rates of juvenile *S. randalli* were not affected by the frequency of feeding . Carlos (1988) showed that feeding frequency, between 1 and 5 times per day, did not affect the growth of juvenile bighead carp (*Aristichthys nobilis*). The effect of feeding frequency, the number of feedings per day, on the apparent food conversion ratio is likely to be dependent on the rate of feeding, the amount fed per day. De Silva et al. (1986) found that feeding frequency did not significantly affect growth rate or feed conversion efficiency of juvenile tilapia (*Oreochromis niloticus*) that were fed a fixed ratio of 3% of their body weight per day; but for fish that were fed ad libitum, growth rate increased and feed conversion efficiency decreased as feeding frequency increased. Andrews and Page (1975) found that growth of catfish fed at satiation levels was lower if they were fed only once per day. However, they found that feed conversion efficiency was not affected by feeding frequency and attributed affects on growth to the effect of feeding frequency on the amount ingested per day. Feeding frequency would be more likely to influence growth if the fish were fed at or above satiation at each feeding and if food consumption increases at higher feeding frequencies. Additional work in developing feeding regimes for the production of juvenile siganids and for pond grow-out is needed to define more clearly the relations between feeding rate and feeding frequency.

FIELD GROWTH TRIALS

To allow farmers an opportunity to evaluate the growth of rabbitfish in ponds, juvenile *S. randalli* produced in the hatchery were provided to two commercial fish farms on Guam. Two of the ponds of Inarajan Aquaculture Enterprises (IAE) were stocked. These ponds were also being used for culturing milkfish. One pond belonging to Liu Island farm was also stocked. This pond was also being used for the experimental culture of grey mullet *Mugil cephalus*. Because of mass mortalities in the culture ponds, in one case (Liu Island farm) as a result of low oxygen content and in another (IAE) as a result of a typhoon, only one of the pond growth trials was successful. The trial and its results are described below.

MATERIALS AND METHODS

Inarajan Aquaculture Enterprise, a fish farming operation owned by Mr. George Tsai, was provided with 1400 juvenile siganids, ranging from 4.7 to 10.0 cm in standard length, on September 11, 1990. The fish were stocked in a pond that was being used for the culture of milkfish. The procedures used in the culture of milkfish on Guam have been described previously (Nelson, 1990). Fishes in the ponds were fed with the commercial feed formulated for catfish, the same feed as that used in the tank culture trials described above. A sample of 60 fish was taken the day before they were stocked in the pond. The standard length of each fish was measured to the nearest millimeter, and each fish was weighed on an electronic balance to the nearest 0.1 gram.

The fish were harvested for transfer to another pond on December 5, 1990, and at this time, a sample of 20 fish was collected, and the individual fish were measured and weighed.

A typhoon (Typhoon Russ) in December 1990 caused severe damage to the southern area of Guam, and all of the fish in the IAE ponds were lost. The losses included the siganids that had been previously stocked in one pond and those that had been recently sampled and transferred. Therefore, we were able to obtain data for only one relatively short grow-out period.

RESULTS

The samples of fish stocked and harvested are described by the statistical summary shown in Table 13. The fish averaged 6.09 cm in standard length and 9.46 g in weight at stocking and averaged 14.5 cm in standard length and 100.23 g in weight at harvest. The fish were smaller at harvest than most siganids found in the markets on Guam; but, even so, they were of marketable size, as evidenced by the fact that they were all sold from the IAE retail outlet less than 30 minutes after they were made available to consumers. The pond owner, Mr. Tsai, commented that, in his opinion, the growth of the siganids was acceptable for commercial production. He also noted that the siganids in the pond were smaller and less aggressive than the milkfish with which they were being cultured. He stated that he thought that the growth of the siganids would be better if they were grown in monoculture.

TABLE 13. Statistical summary of samples of rabbitfish (*Siganus randalli*) stocked in a commercial grow-out operation on Guam. Fish were raised in polyculture with milkfish. The pond was stocked on September 11, 1990 and harvested on December 5, 1990.

VARIABLE OR STATISTIC	SAMPLE OF STOCKED	SAMPLE OF HARVESTED
Standard length (cm)		
Number of Fish	60	20
Maximum Value	10.0	16.3
Minimum Value	3.7	11.3
Mean	6.09	14.15
Standard Deviation	1.58	1.48
Wet Weight (g)		
Number of Fish	60	20
Maximum Value	31.7	139.9
Minimum Value	1.8	50.5
Mean	9.46	100.23
Standard Deviation	7.42	28.4

DISCUSSION

The data indicate that *S. randalli* in pond culture on Guam can reach a marketable size in less than three months. Rapid growth has also been reported for other species of siganids fed daily with commercial feeds. Tawada (1991) reported that juvenile *S. canaliculatus* reared in a concrete tank in Okinawa grew from an average size of 0.3 g to 110 g in 170 days. Lichatowich et al. (1984) reported that, in growth trials in cages in the Red Sea, *S. rivulatus* juveniles grew from 3 g to 105 g in 150 days. Also, Lichatowich and Popper (1975) showed that *S. vermiculatus* raised in fertilized ponds in Fiji could reach a size of 190 g in 130 days, even without supplemental feeding.

Since, in our study, the juvenile rabbitfish had to compete with milkfish for feed around the feeders, it is likely that better growth could be achieved if *S. randalli* were produced in monoculture. Also, the commercial feed formulated for catfish was used in the pond growth trial, and results from the tank culture experiments suggest that production could be improved by using a feed with a higher protein content. While the pond trial indicates that growth of *S. randalli* is acceptable for commercial cultivation, attention to pond management, stocking densities, and feeds could result in improved performance.

POND CULTURE OF SIGANIDS IN TAIWAN

In the summer of 1991, one of us (SGN) visited an aquaculture farm at Penghu, off the western coast of Taiwan, and interviewed Mr. Hsien-Chung Hsu, a farmer that has had experience in the commercial production of rabbitfish. It is hoped that this information - so generously provided by the grower - might prove useful in estimating the potential for siganid aquaculture on Guam.

Although siganids are not common in the markets of Taiwan, they are raised commercially at Penghu and also at Keelung in northern Taiwan. The species being raised is *Siganus fuscescens*, a species which is known from Micronesia, although it has been previously referred to as *Siganus canaliculatus* in this region. In Penghu, siganids are currently raised in pond culture as a secondary species along with sea bream or grouper. In this capacity, the siganids function to control the growth of benthic algae in the ponds as well as contributing to overall production. Siganids have also been raised as the primary species in pond culture, and the information reported here refers to the production of siganids in monoculture at Penghu, Taiwan.

For stocking, fry are collected from the wild, because hatchery-produced siganid fry are not available in Taiwan. Fry are purchased from fishermen and are available from May through July. The pond is stocked with 3-cm juveniles at a density of 15 fish per square meter. The fish are harvested after a 6-month grow-out period, by which time the fish have reached an average size of approximately 100 grams. Survival in the pond is approximately 80%. Production is 1.5 kg per square meter in 180 days.

In Taiwan, siganids are most popular in the markets of coastal cities. In Penghu, siganids are sold in the fresh, whole state at fish markets and restaurants. Split and sun-dried siganids are also common in the markets of Penghu, especially at retail outlets that specialize in dried fish products. In general, larger individuals are marketed in the dried product form, more than in the fresh, whole form. Fresh fish weighing approximately 100 grams are desirable in the markets of Taiwan, and this size at harvest has proven to be the most profitable for commercial aquaculture production. In Penghu, a farmer gets NT$15 for each fish of this size or NT$150 per kilogram (approximately US$5.56/kg) for fresh, whole fish. Siganids sold live bring prices of up to NT$300 per kilogram (US$11.11/kg). The dried siganids sold for retail prices of approximately $NT400 per kilogram (US$14.81/kg).

Although many commercially available fish feeds are available in Taiwan, the farmer in Penghu prepares his own feed. This consists of a mixture of 30% soybean powder, 20% rice hulls, 20% corn meal, and 30% ground fish. With this feed, feed conversion ratios (kilograms of feed per kilogram of fish produced) of approximately 2.0 were obtained. This feed conversion ratio is similar to that obtained in commercial milkfish culture on Guam (Nelson, 1990).

The major problems encountered in the culture of siganids in Penghu were mostly associated with temperature. In the winter when the temperature drops below 13°C the fish die easily; this will not be a problem in culturing siganids on Guam. However, the farmer found that the fish are stressed at high temperatures and die easily when pond temperatures exceed 32°C. According to the farmer, larger fish, those weighing over 120 grams, are more likely to die at high temperatures than smaller fish. At Penghu, optimal temperatures for growth fall between 15°C and 30°C.

Although, there are few farms in Taiwan currently producing siganids as a primary crop, the farmers there have found through experience that rabbitfish grow well in ponds and that they have feed conversion ratios similar to those found for other commercially cultivated fishes. Presumably, similar rates of growth and feed conversion ratios would be obtained with *Siganus randalli* under similar conditions of cultivation.

SUMMARY

The results of the growth trials in tanks and ponds on Guam indicate that the growth rates of siganids and their feed conversion efficiency compare favorably with those of other commercially farmed fishes. This was also supported by the information obtained from a commercial fish farm at Penghu, where siganids are being cultured. It seems that the commercial production of siganids in pond culture on Guam would be feasible provided that juveniles for stocking the ponds could be made available on a reliable basis at a reasonable cost. Additional production trials on Guam with siganids, either in monoculture or stocked with juvenile milkfish, would be useful in evaluating the economic feasibility of siganid culture here; such trials would require that juveniles be provided in adequate numbers and at times appropriate for the farmer whose ponds are being used.

Hatchery production of juvenile *Siganus randalli* has been successful, but constraints to mass production remain. The major problem in the production of larval siganids is the high mortality that occurs at the time of transition from the yolk-sac stage to first feeding. If mortality during this critical period can be sufficiently reduced, the mass production of siganid larvae to support commercial production or further growth trials will be possible.

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