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EFFECTS OF FLOW VELOCITY ON GROWTH OF JUVENILE COBIA *(RACHYCENTRON CANADUM)*

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Key words: cage aquaculture, cobia, flow velocity, growth, *Rachycentron canadum*

Abstract

The objective of this study was to investigate the growth rate and feed conversion ratio (FCR) of juvenile cobia, *Rachycentron canadum*, in different flow velocities. In experiment A, fifteen groups of fish with an initial mean weight of 14.35 g were reared for 28 days in one of five flow velocities: 0, 5, 10, 15, and 20 cm/s. In experiment B, fifteen groups of fish with an initial mean weight of 30 g were reared for 21 days in the same velocities as in experiment A. In experiment C, fish weighing an average 77 g were raised for 21 days in 0, 10, 20, 30, and 40 cm/s. The optimal velocities in terms of growth rate were 10 cm/s for fish of 10-30 g (experiment A), 20 cm/s for fish of 30-60 g (experiment B), and 23 cm/s for fish of 60-200 g (experiment C); the optimal velocity increased as the fish weight increased. FCR and specific growth rate (SGR) also significantly (p<0.05) corresponded to the flow velocity for the different sized juveniles with the optimal FCR and weight gains occurring at 10-23 cm/s. FCR rapidly increased when the velocity exceeded 35 cm/s, regarded as the maximum flow velocity for fish growth.

Introduction

Cobia, *Rachycentron canadum*, is widely distributed in subtropical and warm temperate seas (Franks et al., 1999). A recreational species, it is also caught in commercial fisheries along the entire coast of Taiwan. Stomach contents of cobia include crab, shrimp, fish, and seashell species. This may relate to their habitual behavior of remaining in shallow water during the day (Smith, 1995; Franks et al., 1996). Artificial propagation and larvae production of cobia has recently been successful in Taiwan and cobia has become one of the popular cage culturing species in Asia, including Taiwan, Japan, mainland

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China, Indonesia, Vietnam, the Philippines, and Thailand. Taiwan has the highest production of cage-cultured cobia in Asia, with a harvest of 3500 tons in 2001 (Chou et al., 2001) and later production of 4500.

The rapid growth of cobia is very important to its economical value and gives it a strong advantage over other cage culture species (Liao, 2000). Spawning of cobia in captivity can be induced with photoperiod and temperature cycles (Arnold et al., 2002). Franks et al. (2001) reported that spawning of cobia can be induced with human chorionic gonadotrophin (HCG). Growth of many fish species such as halibut (*Hippoglossus hippoglossus*) related to diet, stocking density, sexual maturation, nutrition, water temperature, dissolved oxygen, and water flow has been widely studied (Brett, 1979; Haug et al., 1989, Berge and Storebakken, 1991; Bjornsson, 1994, 1995 ; Tuene and Nortvedt ,1995; Bjornsson and Tryggvadottir, 1996; Franks et al., 1999; Su et al., 2000; Chou et al., 2001; Ueng et al., 2002). However no literature about the relationship between water flow and growth of cobia is available.

Dissolved oxygen concentrations are depleted by fish respiration, feces, and waste feed. In optimizing environments to control fish production, a number of factors are related to dissolved oxygen including water flow. Increasing the water flow increases dissolved oxygen in the water, thereby improving water quality (Brett, 1979). Also, water flow can flush out metabolic wastes, dilute the concentration of pathogens, and reduce infections to fish (Su et al., 2000). The optimal flow velocity can be determined for fish of a specific weight by adjusting the flow velocity in the rearing unit until the growth rate reaches its maximum.

According to information from cage culture workers in Taiwan, cobia grow 4-6 kg per year. However, in Indonesia, Vietnam, the Philippines, and Thailand, cobia grow 7-8 kg per year (Chou et al., 2001). From Taiwanese cage culture experience, rearing juvenile cobia to 200 g onshore before transferring them to cages can raise the survival rate to 60%. This is double the current 30% survival rate of juvenile cobia cultivated directly in cages. Young juveniles have a lower survival rate because they are not strong enough to withstand the water flow (Liao, 2000).

It is important to provide optimal environments for breeding juvenile cobia. It takes 3.5 months for cobia to grow from 4 to 200 g and 9 months from 200 g to 6-8 kg. If the breeding period to 1 kg could be shortened, the overall breeding cycle would be shorter. Therefore, the objective of this study was to investigate the optimal flow velocity for growth of juvenile cobia in order to increase the survival rate, increase the growth rate, shorten the breeding cycle, and lessen the costs and risks of cage aquaculture.

Materials and Methods

Tanks and equipment. Fifteen circular fiberglass reinforced plastic tanks (Fig. 1) were separated into five groups of three tanks each, one group for each velocity. Water temperature was 26±1°C. Motors of 2000, 3000, and 4500 rpm were used to adjust the flow velocity. Flow velocity was measured at eight randomly selected points in each tank.

Experiment A. Three hundred and fifteen juvenile cobia of 10-30 g were chosen from 600 fish, divided amongst the fifteen tanks (63 per treatment, 3 replicates), and cultured in one of five flow velocities (0, 5±0.5, 10±1.0, 15±1.5, or 20±2.5 cm/s). The mean weight was 14.35±0.43 g and feed was given at 3.5% of the mean weight at each of two daily feedings (09:00 and 16:30). After 28 days, nine fish from each tank were individually measured, weighed, and recorded.

Experiment B. Experiment A was continued, the same fish (weight = 30-60 g) were used in experiment B. As we discovered that the growth curve of the cobia exceeded the flow velocity range (Fig. 2), the experiment was stopped after 21 days, nine fish of each tank were weighed, and the related data were analyzed.

Experiment C. Experiment B was continued with fish weighing 60-200 g in velocities of 0, 10±1, 20±2.5, 30±3, and 40±3.5 cm/s. The mean weight was 77.24±3.3 g and the feed ration was 3.5% of the mean weight at each

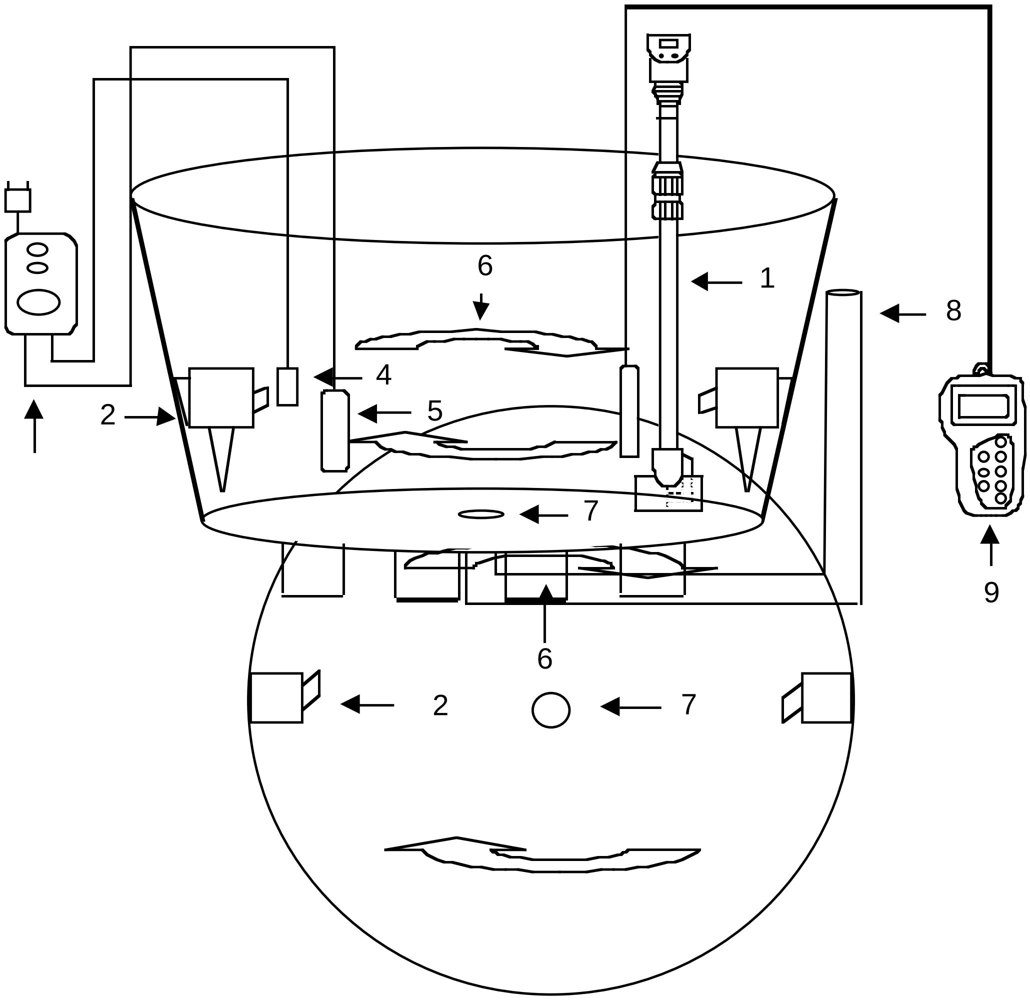

Fig. 1. The water tank and equipment used in the experiment. 1 = current meter, 2 = underwater motor, 3 = temperature control, 4 = heater, 5 = temperature sensor, 6 = flow director, 7&8 = water outlet, 9 = dissolved oxygen meter.

feeding (09:00 and 16:30). The amounts fed were recorded. After 21 days, nine fish from each tank were measured, weighed, and recorded.

Calculations. The weight variations in the experiments were used to calculate specific growth rate (SGR) according to the formula $SGR = 100(\ln W_2 - \ln W_1)/(t_2 - t_1)$, where W_1 = initial weight, W_2 = final weight, t_1 = time when W_1 was measured, t_2 = time when W_2 was measured, and (t_2-t_1) = the interval between W_1 to W_2. The feed conversion ratio (FCR) was calculated as FCR = weight of feed fed (g)/live weight gain (g). Coefficients of variation (CV) of weights for sampled fish from each flow treatment were calculated as CV = SD x 100/wt, where SD = standard deviation and wt = mean weight.

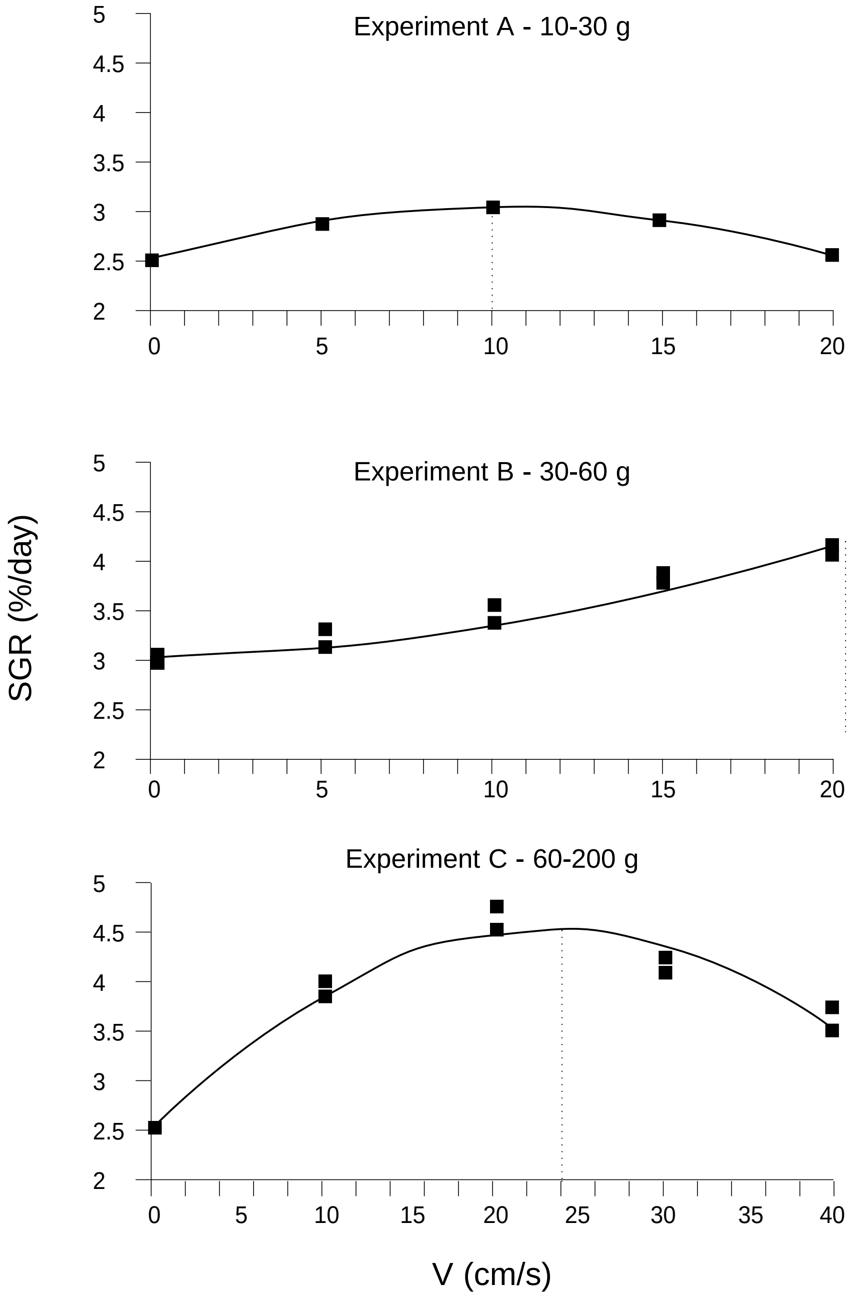

Fig. 2. Specific growth rate (SGR) versus flow velocity (V) for cobia of different weights. The data were fitted to the equation: $SGR = a + bV + cV^2$. In experiment A, a = 2.545242, b = 0.097911, c = -0.004813, $r^2 = 0.9630$; in B, a = 3.035993, b = 0.012132, c = 0.002342, $r^2 = 0.9507$; and in C, a = 2.561096, b = 0.171097, c = -0.003689, $r^2 = 0.9618$.

Results

The juvenile cobia grew at different rates in different velocities (Table 1). The variation of weight for different velocities had the same trend in all three experiments: the CV was greatest in the lowest and highest velocities. A possible explanation for this difference is that the fish chose the optimal location within the habitat, the area with the most suitable water flow, resulting in different size distributions. Therefore, the flow velocity influenced not

Table 1. Initial and final number of fish, mean weight (g), standard deviation (SD) and coefficient of variation (CV = SD x 100/wt) for different flow velocities.

					Velocity (cm/s)		
Experiment A - 10-30 g			*0*	*5*	*10*	*15*	*20*
Jan 17	no.		63	63	63	63	63
	wt	Mean	13.92	14.69	14.48	14.03	14.65
		SD	1.25	1.81	1.65	1.40	1.30
		CV	8.98	12.32	11.40	9.98	8.85
Feb 14	no.		52	61	58	60	56
	wt	Mean	28.39	33.07	34.37	31.50	30.28
		SD	5.42	4.34	5.21	5.10	6.32
		CV	19.09	13.10	15.16	16.20	20.27
Experiment B - 30-60 g			*0*	*5*	*10*	*15*	*20*
Feb 14	no.		52	61	58	60	56
	wt	Mean	28.39	33.07	34.37	31.50	30.28
		SD	5.42	4.34	5.21	5.10	5.32
		CV	19.09	13.10	15.16	16.20	20.27
Mar 7	no.		46	57	55	58	52
	wt	Mean	50.71	62.42	64.80	71.66	66.71
		SD	11.73	11.25	11.91	10.46	13.17
		CV	23.13	18.02	18.38	15.17	19.72
Experiment C - 60-200 g			*0*	*10*	*20*	*30*	*40*
Mar 14	no.		46	57	55	58	52
	wt	Mean	75.96	75.48	78.92	80.57	75.25
		SD	14.36	15.29	14.40	15.78	13.38
		CV	18.90	20.26	18.25	19.59	17.78
Apr 11	no.		33	48	53	56	49
	wt	Mean	128.94	162.45	196.59	187.97	153.03
		SD	31.80	35.23	40.49	40.12	36.17
		CV	24.66	21.68	20.60	21.34	23.66

only the growth rate but also the size variation.

The resulting growth curves demonstrate that the optimal flow velocities for juvenile cobia in different stages are 10 cm/s for cobia of 10-30 g, 20 cm/s for 30-60 g, and 23 cm/s for 60-200 g (Fig. 2). The optimal flow velocity increased as the weight of the cobia increased and the peak of the growth curve gradually moved to the right.

The FCR in experiments A and B ranged 1.3-1.5 and in experiment C 1.4-2.2 (Fig. 3), while the lowest FCR in each experiment occurred at different velocities. For each experiment, the best FCR occurred in the same velocity as the highest SGR. A flow rate of 10-23 cm/s was optimal for both SGR and FCR and the FCR rapidly increased when the flow velocity exceeded 35 cm/s, regarded as the maximum flow velocity for fish growth. For cobia in all experiments, the flow velocity significantly (p<0.05) affected both the SGR and the FCR.

Discussion

This study showed that flow velocity is an important factor for juvenile cobia growth. Although the effect of velocity on fish growth of cultured species is not novel, our study showed the optimal flow velocity range for juvenile cobia in different stages. The growth curve of experiment B does not agree with those of experiments A and C. It could be that the velocities used in experiment B were not challengingly high enough for cobia of that size.

In a cobia hatchery, changes in environmental factors (e.g., flow velocity, temperature, oxygen, and pH) primarily affect carrying capacity and influence growth (Su et al., 2000). Denson et al. (2003) reported that cobia are more active in water temperatures higher than 27°C, similar to our field observations. Increased activity generally results in higher FCRs, thereby affecting fish growth. The oxygen content and exchange rate of water significantly affect the growth of fish (Brett, 1979; Fivelstad et al., 1999). The higher the flow velocity, the higher the oxygen contained in the water. Also, a strong current can flush out excess nutrients, disperse solid wastes, and allow for higher stocking densities (Su et al., 2000). Not having a swim bladder, cobia must constantly swim to maintain their position in a high velocity flow. To constantly swim, they require an increased amount of oxygen. If the flow velocity is too high, cobia waste energy to maintain their position in the water. If the flow velocity is too low, a depleted oxygen supply and resultant mortality can occur. The incessant swimming activity of cobia may be associated with the search and collection of food, similar to the swimming behavior of salmonid fish in Norway (Sutterlin et al. 1979). Fish in intensive culture conditions are continuously affected by environmental fluctuations such as handling, crowding, hauling, and associated transfers, all of which can impose stress on the fish. In this experiment, cobia were observed to stay on the tank bottom, suggesting possible stress symptoms. Alternatively, the possibility that the presence of human observers influenced the cobia behavior must not be excluded. In general, the unusual behavior of juvenile cobia under culture conditions may provide an early warning for recognizing fish disturbances, and it is important for management of fish farms.

Adequate amounts of dissolved oxygen are a major concern of fish culturists because oxygen is critical for cobia growth and survival (Su et al., 2000). The success of a fish culture operation must take water quality into consideration. Oxygen demand in intensive culture conditions should be monitored in cobia culture. Even though flow velocity may be adequate to provide enough oxygen under field conditions, overcrowding may cause other problems such as behavioral stress and physical damage to the fish in cage culture (Su et al., 2000). The importance of stocking density, SGR, and FCR of European sea bass (*Dicentrarchus labrax*) has been reported by Papoutsoglou et al. (1998). Further research is needed to obtain information and estimate the relationship between optimal flow velocity and maximum density for cobia growth.

From the results of the present study, it would appear that the development of an arti-

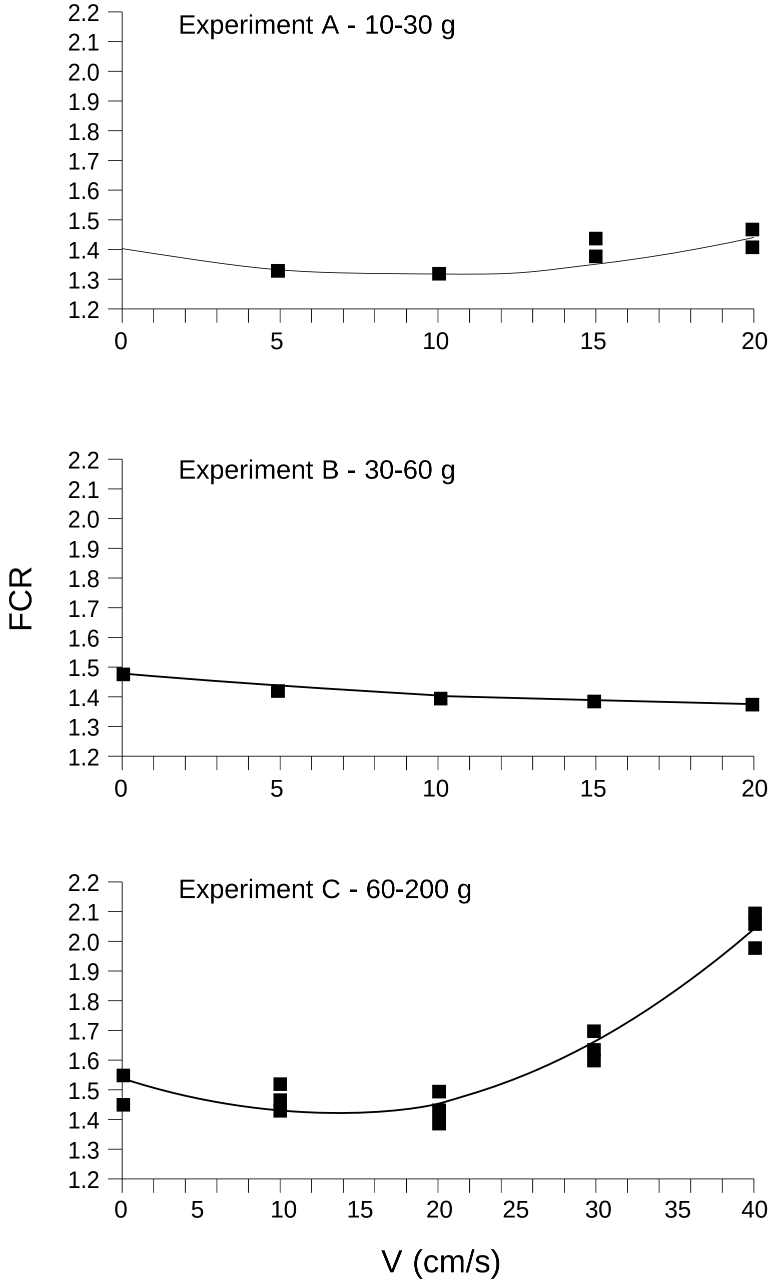

Fig. 3. Feed conversion ratio (FCR) versus flow velocity (V) for cobia of different weights. The data were fitted to the equation: $FCR = a + bV + cV^2$. In experiment A, a = 1.398952, b = -0.018314, c = 0.001019, r^2 = 0.7224; in B a = 1.493410, b = -0.011804, c = 0.000303, r^2 = 0.9210; in C a = 1.533143, b = -0.020162, c = 0.000819, r^2 = 0.9521.

ficial flow system for use in the intensive culture of juvenile cobia is possible. The velocity and direction of the water flow can easily be changed to generate the optimal flow speed, reduce the drift of feed not yet consumed, and reduce the higher electricity costs required to generate higher flow speeds. Offshore cobia farms may have advantages over onshore farms, such as better growth and lower mortality (Myrseth 1993), but these improvements must be significant to compensate for the increased costs of maintaining flow velocity. Therefore, growers still need an onshore base for breeding juvenile cobia before transferring them to offshore cages.

Our study showed the necessary flow velocity for obtaining the highest growth rate of juvenile cobia at different stages. Practical applications should be incorporated into farm designs so that they are easy to carry out in onshore bases and offshore cages. The information gained from this study may bring the grower a step closer to the complete cage culturing system.

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