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Article

A Preliminary Study on the Growth and Feeding of Rockfish, *Sebastes schlegeli*, in Illuminated Sea Cages

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Abstract : The natural high productivity of temperate coastal waters in Korea can be used in advantage to reduce the feed costs for the cage-cultured marine carnivorous fish species. By using the night-lights methods an alternative of supplementary feeding strategy can be offered to the cage farmers and maintain sound environmental conditions that could enhance maximum sustainable yields. The aim of this study was to investigate the effects of night-lights which shown positive results on feeding and growth in sea cage cultured rockfish, *Sebastes schlegeli*. The study showed that for the water around overhead illuminated sea cage, higher zooplankton density was observed at night than during the daytime. Increased amounts of forage, evidenced by stomach content analyses were observed in the early evening, but decreased amounts were observed in the morning and afternoon. That is, feeding activities of the fish were most intensive from midnight to dawn. In a three month feeding experiment, the results showed that night-lighted groups were superior to groups with the highest feeding efficient. This study suggested that the evidence that night-lights superimposed on only day-lights enhance growth of rockfish in sea cages during summer and winter, with timing of exposure affecting growth of juvenile fish. The capability to control the feeding behavior of marine life via manipulation and external stimuli could considerably benefit the advancement of sea cage aquaculture in coastal areas.

Key words : night illuminate, feeding ability, rockfish, *Sebastes schlegeli*, growth.

1. Introduction

In Korea, destruction of habitat through poor land management practices and environmentally harmful fishing methods, over-harvesting and increased uses of already limited resources for subsistence, all have drastically reduced catch rates of inshore fisheries species. Establishment and restoration of spawning stocks, habitats and sustainable harvesting practices are needed to revitalize the fishery resources in Korean coastal waters. The releases of cultured juveniles are one way to expedite the re-establishment of spawning stocks (Blankenship and Leber 1995; Bartley 1996). This process is widely known as "stock enhancement" or "marine ranching".

Recently, fish seed production technology has improved in both quality and quantity. Many healthy fry have been released, however, many of the fish become too scattered in a comparatively short period after release and possibly dead before they grew into maturity. To avoid such inefficient results, it is necessary for the released juveniles to stay within the released area where it is possible for farmers to maintain some degrees of control. There is no evidence that disease or starvationcontributegreatly and directly to natural mortality of juvenile rockfish (Love *et al.* 1991).

A progressive application of night lighting to *Sebastes schlegeli* farming is to attract zooplankton and to use them as food and energy sources to increase the growth rates, survival andproduction of the planktivorous juveniles. In natural conditions, zooplankton vertically moves to the surface through water column at night (Raymont 1983). In addition to the vertical migration, most zooplankton species are also attracted and more toward artificial light sources at night, because they use the lights as the cue to

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regulate their vertical movements (Richards *et al.* 1996).

Additional night lights have been used in sea-cage farming of Atlantic salmon (*Salmo salar*) in recent years, as fish night light exposure during winter and spring had enhanced growth (Hansen *et al.* 1992; Taranger *et al.* 1995; Oppedal *et al.* 1997; Porter *et al.* 1999). One benefit of enhanced growth is shorter time to reach market size during winter and spring, allowing these fish to be harvested before sexual maturation which reduces meat quality and growth and increases mortality in Atlantic salmon (Taranger 1993; Endal *et al.* 2000).

Focusing on the intermediate rearing step between the initial seedling production and its eventual release in the natural conditions, a relatively healthy and survival,this study sought to develop means of controlling the night-lightening method for feeding ability of rockfish. This study supports the suggestion that artificial seed increase the fish survival after release in natural conditions by improving the feeding ability.

This paper describes a study undertaken on the development of marine ranching technologies in Tongyeong area, in cooperation with the Ministry of Maritime Affairs and Fisheries of Korea.

2. Materials and methods

Experimental fish

Juveniles rockfish, *Sebastes schlegeli,* used in the experiment were reared in the artificial seed production stations at the Korea Ocean Research and Development Institute (KORDI). In a night-light feeding experiment, 1,000 fish (6.3 g mean weight) were stocked in a 4×2×2 m (16 tons of water volume) cage with 6 mm net mesh size. For the growth experiment with night-lights, fish were stocked in three cages at same density (65.3 g mean wt.). All experimental cages were housed in ten (each; 10×10 m) floating rafts anchored near Jang-du Island at a KORDI Sea Ranching Station.

Light-feeding response

Night-light feeding and growth experiments were conducted with juvenile rockfish reared in inland culture tanks for 5 months.

An incandescent electric lamp (200 W) was used above the 4×2 m floating cage. This lamp was positioned approximatelly 0.5 m above the water surface, and operated every night from 18:00 to 06:00 during the experimental period (Fig. 1).

During the first 4 days of the night-light feeding

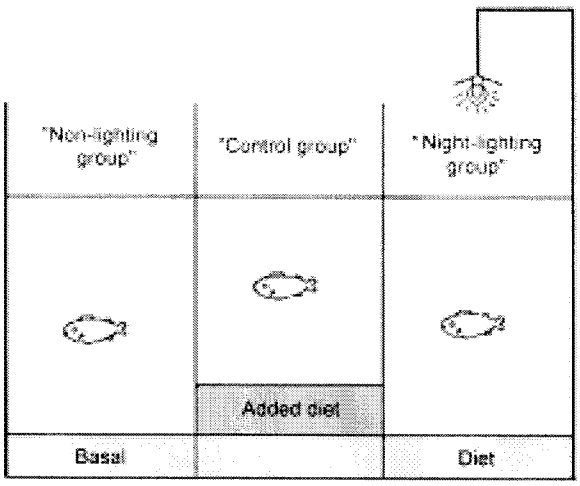

Fig. 1. A schematic drawing of night-light feeding experiment in floating fish cages.

experiment, no feed was given to the fish. The only food available to the hatchery-reared juvenile rockfish were in the surrounding waters, including any organisms that were attracted into the experimental cages by the electric light at night.

In the growth experiment, rockfish which had no experience of feeding natural food types were weighed under anaesthesic condition in the beginning of the experiment and every month for three months. Three experimental groups (night-lightening, non-lightening, and control) were fed with artificial formulated diet. All fish from each cage were sacrificed and individually weighed, measured, and subjected to stomach content analyses.

The relationship between weight (g) and stomach fullness (g) was evaluated by means of feeding rate (F) as follows.

$$\text{Feeding rate (F)} = \frac{\text{Food weight (g)}}{\text{Stomach wet weight per fish (g)}}$$

Growth response

Young rockfish were grown at a comparable rate during a 3-month period of feeding with formulated diet and natural food. Fish were equally divided into three groups; control, non-light, and night-light growth conditions of same total weight (about 30 kg) and similar numbers of fish per cage.

On feeding days, fish were fed with the formulated diet twice per day for experimental periods. Each group was fed until fish did not respond to feeding. Three experimental

groups were fed with formulated diet with different feeding methods. The control group was fed 1.5 % of total body weight per day and night-lightening and non-lighting groups were fed 1.0 % of total body weight per day.

3. Results and discussion

Light response

Zooplankton was actively attracted to the night-light emission from the incandescent electric lamps. As a consequence of this positive phototaxis, small fish larvae and planktonic life stage animals were easily seen in the water at night entering the floating cages. As expected, a lot of extraneous zooplankton were rapidly consumed by the cage fish.

In the present study, hatchery-reared juvenile rockfish have an ability to learnfeeding behaviour under non-feeding condition with naturally pelagic food organisms.

There were no significant differences of variation patterns in the quality of stomach contents and feeding rates (Table 1).

Feeding rates were increased in the evening and decreased in late morning and noon. That is, feeding activities of the fish were most intense during the night-light periods (Fig. 2). At times between 0 to 6 o'clock, Most of individuals were feeding between 24:00-06:00.

Food availability studies of substrate-associated juvenile rockfish showed that crustaceans are an extremely important

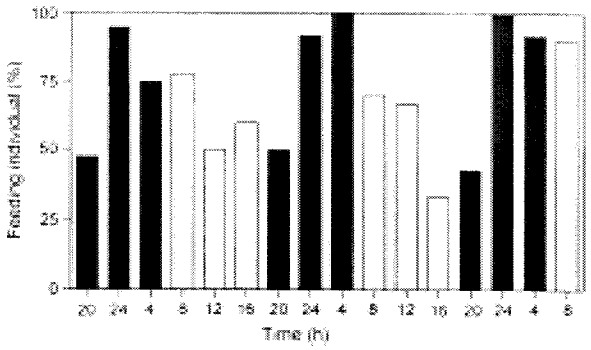

Fig. 2. Percentage of feeding individuals in different time of day (■ ; night, □; day).

component of their diet. In addition, for species that continue to forage from water column and as they grow, choice of dites changed to large crustaceans and fish as they shifted from diurnal to nocturnal foraging (Love *et al.* 1991). Juvenile *Sebastes schlegeli* under the night-lighting condition showed a distinctive nocturnal feeding behavior in relation to the nightly vertical movement of zooplankton and their predominant food items were crustacean species such as Cumaceans, Ostracods, and Decapods. This indicated that the cultivated juveniles in sea cages with night-lighting exhibited the same carnivorous feeding behavior as the wild stock and the attracted zooplankton by night-lighting would be a good additional food item for the growth and production of the juveniles.

In contrast, rocktrout (*Agrammus agrammus*) is another

Tables 1. Various feeding rate values under the night-lighting conditions for less than one-year old rockfish.

	1st day		2nd day						3rd day						4th day	
	20:00	24:00	4:00	8:00	12:00	16:00	20:00	24:00	4:00	8:00	12:00	16:00	20:00	24:00	4:00	8:00
Feeding rate*1	D*2	C	A	BC	BC	CD	D	C	A	BC	BC	CD	D	C	A	BC
(Mean)	0.30	1.47	2.65	2.60	0.60	1.08	0.27	1.65	5.21	1.39	1.62	0.47	0.07	4.46	2.92	0.60

*1Feeding rate (F) = Food weight (g)/Stomach weight per fish (g).

*2Results were calculated by Duncan's multiple range test grouping. Means with the same letter were not significantly different and without letters were significantly different from each other (α=0.05).

Table 2. Results of feeding trials with night-lighting for less than one year old rockfish.

Experimental group	No. of fish	Initial average body weight(g)	Final average body weight(g)	Growth rate(*1)	Feed coefficiency (*2)
Control	2,000	16.0 ± 3.91	53.5 ± 15.3	2.34	1.01
Non-light	2,000	16.0 ± 3.91	43.6 ± 10.9	1.72	1.66
Night-light	2,000	16.0 ± 3.91	80.4 ± 19.2	4.02	0.75

*1 [{Final body wt.(g) – Initial body wt.(g)} / Initial body wt.(g)].

*2 Amount of diet(g) / {Final body wt.(g) – Initial body wt.(g)}.

Table 3. Results of feeding trials with night-lighting for one year old rockfish.

Experimental group	No. of fish	Initial average body weight(g)	Final average body weight(g)	Growth rate*1	Feed coefficiency (*2)
Control	460	64.8 ± 10.4	110.3 ± 31.7	0.70	1.98
Non-light	440	68.0 ± 14.7	105.9 ± 29.7	0.53	1.66
Night-light	480	61.7 ± 12.5	102.2 ± 27.4	0.63	1.50

*1 [{Final body wt.(g) – Initial body wt.(g)} / Initial body wt.(g)].
*2 Amount of diet(g) / {Final body wt.(g) – Initial body wt.(g)}.

strongly substrate- associated species in natural condition, fullness of the stomach increased in the early morning and the late afternoon, and decreased in the late morning, at noon, and during the night. That is, feeding activity of the fish was more intense during sunrise and sunset (Kim and Kang 1991).

Growth response

Results of a six-months night-light feeding experiment are shown in Table 2. From this experiments, it was recognized that juveniles (four months old) with night-lightening condition have a higher growth rate than those without night-lights.

In addition, juveniles with night lighting distinctively showed a nocturnal feeding behavior in relation to the vertical migration of zooplankton. These results revealed that night-lighting highly affect the production of *Sebastes schlegeli* juveniles in sea cages by allowing them to use the attracted zooplankton as an additional food item.

The results revealed that night-lighting have more significant effect on the increment of growth and production than the different artificial diets. In general, artificial diets have various limitations in the stable supply of essential nutrient elements (Lee *et al.* 1994), but black rockfish culturists widely use them for easyfeeding and storage in sea-cage culture. Therefore, the supply of additional natural food of zooplankton by night lighting is certainly a progressive cultivation method for the increase production of this species.

Results of a three-month night-light feeding experiment with 15 months old rockfish are shown in Table 3. Survival rates did not differ among the experimental groups, and total amount of mortality were below than 20 individulas for each group during rearing period.

Among the three experimental groups, the control group showed the highest growth ratebut the night-lightening group recorded the highest feed coefficiency. This result indicated that the night-illuminated condition was effective to attract zooplankton in amounts that composed favorable percentage of food contents than the control group, which was fed with a low amount of formulated diet to determine the smallest possible requirement of food. Night illumination under short supply of artificial diets showed a significantly high feed coefficiency and subsequent higher production than groups with basic supply of artificial diet under natural light.

From these experiments, it was recognized that juveniles (four months old) havemuch higher growth rates than 15 months old rock fish with night-lightening training. Night-lighting for juveniles with high relative-growth rates would be more effective in promoting the growth response of the species.

In contrast, like other rockfish juveniles, *Sebastes schlegeli* predominantly fed on planktonic crustaceans. As they grow, diets shifted to larger crustaceans and fishes, with the simultaneous changes from diurnal to nocturnal foraging in the water column (Carlson and Haight 1976; Hobson and Chess 1976).

Night-lights have also been successfully used to attract zooplankton for cage cultures of fish fry in Japan (Kuronuma and Fukusho 1984) and Poland (Uryn 1979). Moreover, the night-lighting trained groups showed increased feeding when they were released into the wild. Differences in timing of onset of additional light exposure has ranged from 4 to 9 months. In salmonid species, like rainbow trout (*Oncorhynchus mykiss*) and masu salmon (*O. masou*), exposure to long photoperiods of 4 to 6 weeks can adjust the timing of sexual maturation (Bromage *et al.* 1984; Takashima and Yamata 1984; Duston and Bromage 1988), suggesting the shorter periods of additional light could be used in Atlantic salmon farming to obtain the desired effects on growth and sexual maturation.

On the other hand, additional night-illuminating training is a control method for the feeding behavior of released fish. No results, however, can be expected in areas not satisfying the conditions as a habitat for the released fish.

The effects expected by this method are as follows:

- The survival rate is improved by reducing the initial impact on the releasedfish.
- The training method helps the released fishto become accustomed to the sanctuary or nursery areas.
- From experiments conducted, it was recognized that released juveniles (under one year old) with night-lighting training have a much higher survival rate at the released point than those without such training. The system is thus extremely effective in preventing released fry from scattering into a wider area.
- Automatic feeding control is available by simple setting and operation.
- Adequate management of nursing, releasing, and fishing areas enables improvement of theresource-managerial awareness of persons engaging in fisheries.

Further experiments are being performed to study the feeding habits of released fish in wild conditions, including the releasing and monitoring of fish produced in artificial hatcheries.

The relative importance of predation in determining spatial and temporal patterns of rockfish recruitment and juvenile abundance has not been addressed. The local effects of predation will probably be determined by the abundance and species composition of predators, and the vulnerability of juvenile to different predator and in different habitats. The vulnerability of juvenile rockfish based on differences in size at recruitment, growth rate, morphology (e.g., color) and predator avoidance behavior. The role of any of these factors in vulnerability of juveniles rockfishes has not been studied.

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