Bull. Inst. Zool., Academia Sinica **29**(4): 233-241 (1990)

FEEDING CIRCADIAN IN THE EARLY STAGE OF SILVER BREAM, *SPARUS SARBA* FORSSKÅL

BAO-QUEY HUANG and CHI-SYANG HU

Institute of Fisheries, National Taiwan Ocean University, Keelung, Taiwan 20224, Republic of China

(Accepted April 13, 1990)

Bao-Quey Huang and Chi-Syang Hu (1990) Feeding circadian in the early stage of silver bream, *Sparus sarba* Forsskål. *Bull. Inst. Zool., Academia Sinica* **29**(4): 233-241. In order to find the appropriate time for food presentation and to investigate the potential role of light in controlling circadian, the feeding chronology of the silver bream in the early stages was studied under three photoperiods (natural, reversed and all light). A longer photoperiod did enhance the larval growth. Both juvenile and young increased their feeding after light-on, and decreased after light-off, and continued their intensive feeding during the light period and sparse feeding during the dark period, under either natural or reversed photoperiods. No significant differences among six tested feeding intervals were noted when either juvenile or young were fed under all light. Feeding circadian of silver bream in the early stages may be regulated by some endogenous mechanism and therefore demonstrates a diurnal feeding. Light, an exogenous factor, probably functions as a key factor in triggering feeding activity.

Key words: Feeding circadian, Silver bream, Juvenile, Young.

Most pelagic marine teleosts in the larval stage have first develop vision followed by the other sensations. Time of food presentation required to produce maximum growth has been proven to be closely linked with sensory development but varies with species and with many environmental factors (Schwassmann, 1980; Houde and Schekter, 1980; Sudo *et al.*, 1987). It is likely that the diel feeding chronology in teleosts is affected by the interactions of both the endogenous and exogenous rhythms (Priede, 1978; Mashiko, 1979; Baba and Sano, 1987; Brodeur and Pearcy, 1987; Huang, 1989a).

Silver bream, *Sparus sarba*, inhabits rocky coastal waters. It is an usual component of the surf ichthyofauna and is widely distributed along the waters from Japan to Taiwan. The evidence of having square cone mosaic with a wide range of sensitive spectrum indicates that adult breams might have a day-life mode and are visual feeders (Huang, 1989b). Silver breams are closely related to the black porgy, *Acanthopagrus schlegeli,* in taxonomy, and both of them show a similar living habitat, but porgies demonstrate their nocturnal activities from evaluated heart-rate rhythms and feeding circadian (Huang, 1988, 1989b). Since the interval of the feeding periodicity is a species-specific characteristic, it is a crucial factor in deciding the time when the food should be offered (Baba and Sano, 1987; Brodeur and Pearcy, 1987; Houde and Schekter, 1980; Townsend and Winfield, 1985).

The scotopic vision of marine teleosts

(e. g., silver bream) develop during their metamorphosis from larvae to juveniles (Hu, 1989). As the larvae have been considered as diurnal feeders, the present research sets out solely to look for the effects of photoperiod on the growth of larvae.

Mashiko (1981) proved that the daily activities of catfish, *Silurus asotus*, were regarded as a result of the synchronous cooperation of the endogenous rhythmical system and the daily light/dark stimuli. It was also proven that the intensity of light was a key factor controlling nocturnal action in another species of catfish, *Pseudobagrus aurantiacus* (Mashiko, 1979). The effects of light intensity on the prey-capture for 2-month-old silver bream were not significant (Huang and Hu, 1989). It is likely that the performance capacity of prey-capture (perception and recognition of prey, swimming and searching patterns corresponding to prey) increasingly developed during its growth (Blaxter, 1980; Lasker, 1981). The feeding ability of the later stage may be related to the development of sensory systems other than vision which is believed to predominate only in the very early larval stages (Blaxter, 1975; Iwai, 1980; Werner and Blaxter, 1981). The objective of the present study is to obtain the feeding circadian of juveniles and young and to know the potential roles of light in regulating feeding activities by reversed photoperiods or continuous light.

MATERIALS AND METHODS

Larvae

Fertilized eggs of silver bream, *Sparus sarba*, were obtained from the Pescadore Branch of the Taiwan Fisheries Research Institute during the spawning season, 1988. The filtered seawater (34‰) holding the eggs in room temperature, was changed every two days. Two hundred newly hatched larvae were reared in each 20-liter circular aquarium. A light intensity of about 1300 lux was used and the photoperiods were adjusted to light/dark=16/8 and 8/16 hours for the long and the short photoperiods, respectively. Feedings were started at the end of the yolk-sac stage at a prey (Rotifera) density above 10 individuals/ml. Ten larvae were sampled from each aquarium for measuring their total lengths (T. L.) every five days. Three replicated experiments were carried out under each photoperiod. A *t*-test was applied to compare the effects of the two photoperiods.

Juveniles and Youngs

Juveniles (T. L.=12-15 mm) and young (T. L.=30-40 mm) were fed with *Artemia nauplii* (density more than 1.6/ml) and fresh prawn flesh, respectively. The light intensity was about 600 lux. Photoperiods were manipulated automatically into three regimes: (1) natural, (2) all light, and (3) reversed photoperiods. The reversed one referred to being illuminated during night hours of natural photoperiods. Thirty juveniles or 5 young were kept in each aquarium. Every four hours, the prey density was examined or the prawn meat (after removal of excess water) was weighed on an analytical balance (Mettler PC 400). Water temperature was recorded at the same time. The experiment for each group continued for three days. For both stages three replicated experiments were carried out. One-way ANOVA (Analysis of variance) and Duncan's multiple-range tests were used to assess the difference among 6 measured data of daily records.

RESULTS

Larvae

The long (light: dark, L/D=16/8

hours) and the short (L/D=8/16) photoperiods showed different effects on the growth of the newly hatched larvae. The differences became significant after 10-day and 15-day rearings (t-test; $p>0.05$ and $p<0.01$, respectively, Fig. 1).

Juveniles

Juveniles reared under a natural photoperiod demonstrated a diurnal feeding periodicity with superior and inferior peaks at 16:00–20:00 and 8:00–12:00, respectively (Fig. 2A). Their feeding was significantly different among six intervals (Table 1, $F=6.60$, $p<0.01$) tested by Duncan's multiple-range test and a feeding peak was noted at 16:00–20:00. Similarly, significant differences were also found among the six intervals of feeding under a reversed photoperiod ($F=3.52$, $p<0.05$). Fig. 2B showed feeding circadian with peaks at 0:00–4:00 and 20:00–24:00 which were lighted periods. Under either of these photoperiods, feeding amounts were gradually increasing after light-on, and remained high during light-period, while the amounts were declining after light-off, and remained low during dark-periods (Figs. 2A, 2B). In contrast, feeding under continuous light showed no significant differences ($F=1.34$, $p>0.05$) among six tested intervals (Fig. 2C).

Youngs

The youngs fed with fresh prawn meat were noted to have the same feeding periodicity as the juveniles (Figs. 2, 3). Under either natural or reversed photoperiods, feeding was significantly different among six tested intervals (Table 1, $F=3.44$, $p<0.05$ and $F=3.79$, $p<0.05$, respectively). The patterns of diel feeding under either of these two photoperiods were nearly identical in increasing after light-on, remaining high during the light period, decreasing after light-off and remaining low during the dark period (Figs. 3A, 3B) On the contrary, there was no significant difference in the feeding amount (Table 1, $F=1.23$) under the all-light photoperiod. Their feeding activity was characterized by remaining

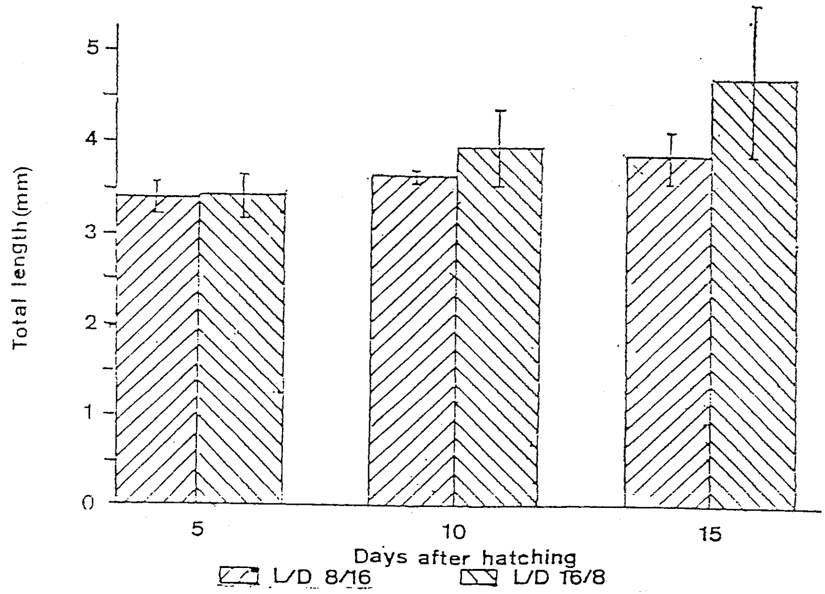

Fig. 1. Growth in length of larval *Sparus sarba* under two different photoperiods (LD=8/16 and 16/8). Standard deviations were indicated by the vertical bars. Note the different growths (in total length) were clearly shown after 15 days of rearing and no significant differences during the shorter rearing period.

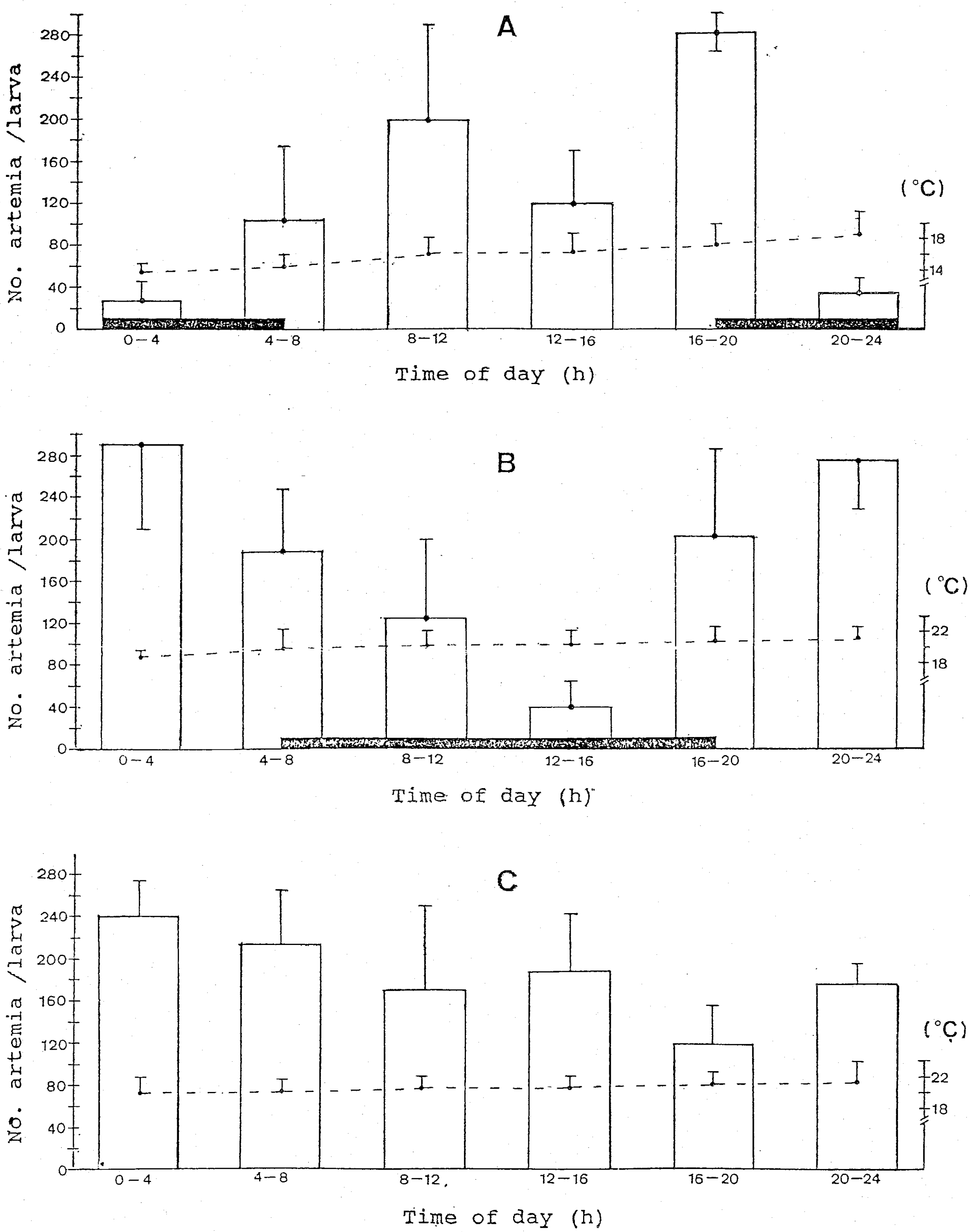

Fig. 2. Daily feeding of juvenile *Sparus sarba* (TL=12-15 mm) feeds with *Artemias nauplii* under natural (A), reversed (B) and continuous (C) illumination. The horizontal bar indicates the dark-period. The dashed curve shows the water temperature (°C). Standard deviations are indicated by the vertical bars.

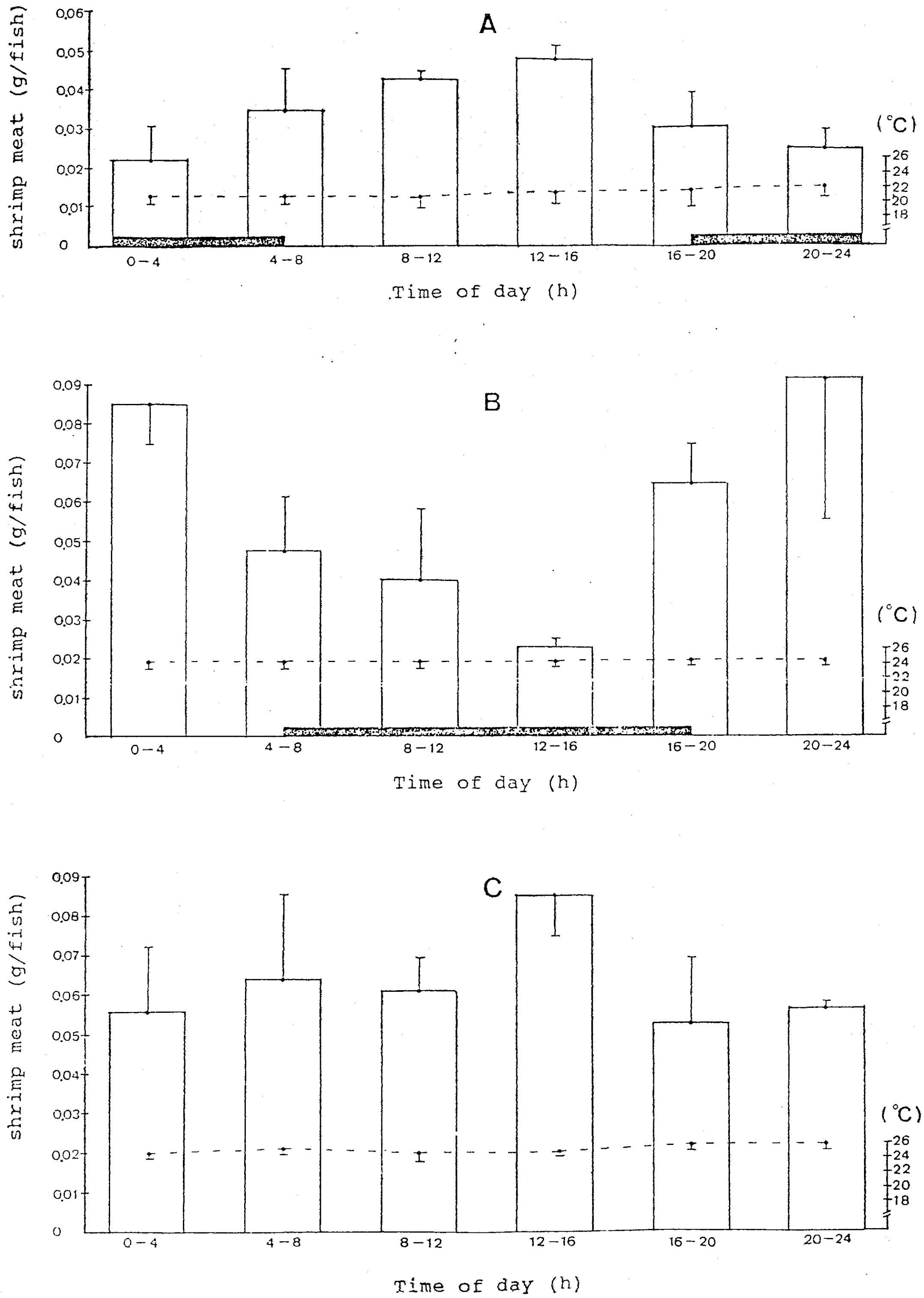

Fig. 3. Daily feeding of *Sparus sarba* (TL=30-40 mm) feeds wih shrimp meat under natural (A), reversed (B) and continuous (C) illumination. The horizontal bar indicates dark periods. The dashed curve shows the water temperature (°C). Standard deviations are indicated by the vertical bars.

Table 1
F values of ANOVA of the daily feeding in the early juvenile (TL=12-15 mm) and the late juvenile (TL=30-40 mm) of the silver bream (*Sparus sarba*)

	Early juvenile (TL=12-15 mm)	Late juvenile (TL=30-40 mm)
Natural photoperiod	A=6.60**	D=3.44*
Reversed photoperiod	B=3.52*	E=3.79*
Continuous light	C=1.34	F=1.23

* Significant at $p<0.5$
** Significant at $p<0.01$

similar throughout the whole period (Fig. 3C.)

Figs. 2 and 3 revealed a diel change of feeding activity along with the experimental water temperatures. Any sychronous changes of temperatures with the light on or off were not noted.

In summary, the results of the present experiments demonstrate that larvae, juveniles and young silver breams are likely to be visual feeders, since larvae grow better under a longer photoperiod, while juveniles and youngs have higher feeding activity during the light period.

DISCUSSION

Many studies on teleost larval feeding demonstrated that the effects of light on the feeding behaviour are crucial (Blaxter, 1980; Kiyono and Hirano, 1981; Tandler and Help, 1985) and that the larvae of most studied species are visual feeders (Gunzo and Shiro, 1980). In the present study, silver bream larvae reared under the longer photoperiod increased their growth rate. Two possible causes could account for the result: (1) longer photoperiods increased feeding hours, (2) longer photoperiods increased food consumption. The feeding of the early stage larvae limited within the daylight hours has been related to the lack of rods. Kiyono and Hirano (1981) worked on the effect of light on the feeding and growth of black porgy, concluded that longer photoperiod increased the food consumption and the growth of post-larvae, but did not increase those of juveniles. He also proved that the larvae fed almost continuously in the daytime and stopped at night but continued to feed even in the night if under artificial light. Tandler and Helps (1985) demonstrated the effects of photoperiods on the growth and survival of *Sparus aurata* from hatching to metamorphosis and proved that the longer photoperiod did enhance their prey-gaining, food-digesting and growing. Okautchi *et al.* (1980) found the number of rotifer, *Brachions plicatilis*, consummed daily by larvae and juveniles of black porgy, *Acanthopagrus schlegeli*, increased with lighting during the night hours.

Temperature and photoperiod often interact with each other or act independently on some physiological activities (Connors *et al.*, 1978; Priede, 1985). A long-term change in temperature may affect metabolism, while daily change in light intensity may influence the short-term feeding chronology (Brady, 1982; Priede, 1983; Ross and McKinney, 1988).

Kauffman *et al.* (1981) studied the vertical distribution and food selection of larval atherinids, and concluded that they were diurnal feeders. Bowman (1981) pointed out that the juveniles of the haddock had daily feeding period between 12:00 and 14:00 which possibly related to their diurnal vertical movement. Marliave (1981) found that the soft sculpin, *Gilbertidia siglutes*, larvae was visually feeding and might choose an optimal luminosity from a daytime to a crepuscular feeding, but the juveniles might develop from visual to "distant touch" feeding behaviour and shift their twilight feeding to nocturnal feeding. It is clearly noted that the entire development in most species demonstrated the adaptive functions to meet the maximization of feeding opportunities for themselves. The results of the present experiments showed that larvae have a higher growth rate under a longer photoperiod, and juveniles and youngs prefer the light-time feeding. These evidences demonstrated that the entire development of silver bream is based on visually feeding and they choose light time feeding to maximize their feeding success.

Brothers and McFarland (1981) correlated the otolith microstructure with life history transitions in French grunts, *Haemulon flavolineatum*. From the eco-behavioral results, it appeared that the fish developed from diurnal plankton feeding larvae to noctural benthic feeding juveniles. By reading the chronologically daily growth of the otolith microstructure, Brothers (1981) pointed out that temperature played a predominant role in determining the time relation and protein content of growth increments, with light being a subordinate factor. The present studies are not designed to compare the predominance or subordination between light and temperature. It is likely that the growth is influenced by the integrative function of light and temperature, but light is a direct and emergent key factor in controlling circadian rhythm and feeding periodicity (Mashiko, 1979; Brady, 1982; Brodeur and Pearcy, 1987).

Acknowledgements: The financial support from the Council of Agriculture, 78 AC-7.1-F- 31(7) is gratefully acknowledged. Thanks are also due to Dr. I. C. Liao, the Director of the Taiwan Fisheries Research Institute, for his encouragement and invaluable advice. The Director, Dr. C. H. Chen, and the staff of the Institute in the Pescadores are thankfully acknowledged for their kind help in fish-collection. The authors are also extremely grateful to Miss Y. R. Wang and Mr. W. L. Yiea for their lab assistance. Appreciation is extended to Dr. H. K. Mok, National Sun Yat-Sen University for reviewing the manuscript.

REFERENCES

Baba, O. and M. Sano (1987) Diel feeding patterns of the congiopodid fish *Hypodytes rubripinnis* in Aburatsubo Bay. *Japan. J. Ichthyol.* **34**: 209-214.

Blaxter, J. H. S. (1975) The eyes of larval fish. In *Vision in fishes* (M. A. Ali ed.) Plenum Press. *New York and London.* pp. 427-444.

Blaxter, J. H. S. (1980) Vision and the feeding of fishes. In *Fish behavior and its use in the capture of fishes.* (J. E. Bardach, J. J. Magnuson, R. C. May and J. M. Reinhart eds.) Published by ICLARM, MCC. *Manila, Philippines.* pp. 32-56.

Brady, J. (1982) Circadian rhythms in animal physiology. In *Biological Timekeeping* (J. Brady ed.). Cambridge University Press. pp. 121-142.

Brodeur, R. D. and W. G. Pearcy (1987) Diel feeding chronology, gastric evacuation and estimated daily ration of juvenile Coho Salmon *Oncorhynchus Kisutch* (Walbaum), in the coastal marine environment. *J. Fish Biol.* **31**: 465-477.

Brothers, E. B. (1981) What can otolith microstructure tell us about daily and subdaily events in the early life history of fish. Rapp. p.-V. R'eun. *Int. Explor. Mer.* **178**: 393-394.

Brother, E. B. and W. N. McFarland (1981) Correlations between otolith microstructure, growth, and life history transitions in newly recruited french Grunts (*Haemulon flavolineatum* (Desmarest), Haemulidae). Rapp. p.-V. R'eun. *Cons. Int. Explor. Mer.* **178**: 369-374.

Bowman, R. E. (1981) Food and feeding of 0-group Haddock in the northwest Atlantic. Rapp. P.-v. R'eun. *Cons. Int. Explor. Mer.* **178**: 312-313.

Connors, T.J., M.J. Schneider, R.G. Genoway and S.A. Barraclough (1978) Effect of acclimation temperature on plasma levels of glucose and lactate in Rainbow Trout, *Salmo gairdneri* (L). *J. Exp. Zool.* **206**: 443-449.

Gunzo, K. and H. Shiro (1980) On the visual feeding of Milkfish larvae and juveniles in captivity. *Bull. Japan. Soc. Sci. Fish.* **46**: 1297-1300.

Houde, E.D. and R.C. Schekter (1980) Feeding by marine fish larvae: developmental and functional responses. *Env. Biol. Fish.* **5**: 315-334.

Hu, C.S. (1989) Studies on the morphology, visual development and feeding behaviour in larval Silver Sea Bream, *Sparus sarba.* Master's thesis. Natl. Taiwan Ocean Univ. 84 pp.

Huang, B.Q. (1988) Heart rate as a measure of circadian rhythms in Black Porgy, *Acanthopagrus schlegeli. J. Fish. Soc. Taiwan* **15**: 1-7.

Huang, B.Q. (1989a) Feeding periodicity of Black Progy, *Acanthopagrus schlegeli. J. Fish. Soc. Taiwan* **16**: 1-9.

Huang, B.Q. (1989b) The chromatic organization of the cone mosaic in the Silver Sea Bream, *Sparus sarba. Bull. Inst. Zool., Academia Sinica* **28**: 295-301.

Huang, B.G. and C.S. Hu (1989) Effects of light intensity and prey density on the feeding of larval Silver Bream (*Sparus sarba*). *J. Fish. Soc. Taiwan* **16**: 165-173.

Iwai, T. (1980) Sensory anatomy and feeding of fish larvae. In *Fish behavior and its use in the capture and culture of fishes.* (J. E. Bardach, J.J. Magnuson, R.C. May and J.M. Reinhart eds). ICLARM, Makati, Manila, Philippines. pp. 124-145.

Kauffman, T.A., J. Lindsay and R. Leithiser (1981) Vertical distribution and food selection of larval atherinids. Rapp. P.-v. R'eun. *Cons. Int. Explor. Mer.* **178**: 342-343.

Kiyono, M. and R. Hirano (1981) Effects of light on the feeding and growth of Black Porgy, *Mylio macrocephalus* (Basilewsky), postlarvae and juveniles. Rapp. P.-v. R'eun. *Cons. Int. Explor. Mer.* **178**: 334-336.

Lasker, R. (1981) Marine Fish Larvae, Washington Sea Grant Program, University of Washington Press, Seattle and London. 40-42.

Marliave, J.B. (1981) Vertical migrations and larval settlement in *Gilbertidia sigalutes*, F. Cottidae. Rapp. P.-v. R'eun. *Cons. Int. Explor. Mer.* **178**: 349-351.

Mashiko, K. (1979) The light intensity as a key factor controlling nocturnal action in the Catfish, *Pseudobagrus aurantiacus. Japan. J. Ichthyol.* **25**: 251-258.

Mashiko, K. (1981) Periodic nocturnal activities in Catfish, *Silurus asotus* in captivity. *Japan. J. Ichthyol.* **28**: 148-156.

Okautchi, M., O. Takashi, K. Shoji and T. Akira (1980) Number of Rotifer, *Brachionus plicatilis*, consummed daily by a larvae and juvenile of Porgy, *Acanthopagrus schlegeli. Bull. Natl. Res. Inst. Aquaculture* **1**: 39-45.

Priede, I.G. (1978) Behavioural and physiological and physiological rhythms of fish in their natural environment as indicated by ultrasonic telemetry of heat rate. In *Rytmic activity in fishes* (S. Thorpe ed.) Academic Press, New York.

Pride, I.G. (1983) Heart rate telemetry from fish in the natural environment. *Comp. Biochem. Physiol.* **76**a: 515-524.

Priede, I.G. (1985) Metabolic scope in fishes. In *Fish energetics new perspectives* (P. Tytler and P. Calow eds.). The Johns Hopkins Univ. Press. Maryland. pp. 33-64.

Ross, L.G. and R.W. McKinney (1988) Respiratory cycles in *Orechromis niloticus* (L.), measured using a six-channel microcomputer-operated respirometer. *Comp. Biochem. Physiol.* **89A**: 637-643.

Schwassmann, H.O. (1980) Biological rhythms: their adaptive significance. In *Environmental physiology of Fishes* (M.A. Ali ed.), Plenum Press pp. 613-630.

Sudo, H., M. Azuma and M. Azeta (1987) Diel Changes in Predator-Prey Relationships between Red Sea Bream and Gammaridean Amphipods in Shijiki Bay. *Nippon Suisan Gakkaishi* **53**: 1567-1575.

Tandler, A. and S. Helps (1985) The effects of photoperiod and water exchange rate on growth and survial of Gilthead Sea Bream *Sparus aurata* from hatching to metamorphosis in mass rearing system. *Aquaculture* **48**: 71-82.

Townsend, C.R. and I.J. Winfield (1985) The application of optimal foraging theory to feeding behaviour in fish. In *Fish energetic new perspectives* (P. Tytler and P. Calow eds.) The Johns Hopkins Univ. Press. Maryland. pp. 67-98.

Werner, R.G. and J.H.S. Blaxter (1981) The effect of prey density on mortality, growth and food consumption in larval Herring (*Clupea harengus* L.). Rapp. P.-v. R'eun. *Cons. Int. Explor. Mer.* **178**: 405-408.

黃錫鯛仔稚魚攝食之日夜周期性

黃寶貴　　胡其湘

為尋求最適投餌時間以期獲得最大成長，本實驗擬以黃錫鯛(*Sparus sarba*)各階段仔稚魚，探討其攝食之日夜周期性 (feeding circadian)。結果顯示長光照能增加早期仔魚之成長，且稚魚及幼魚之攝食之日夜周期均在日間；如改以日夜倒置之光照周期（即夜間才予光照）則其攝食峰 (feeding peaks) 均轉移至夜間（即有光照之周期)；另以連續光照，則稚魚及幼魚均未呈現顯著差異之攝食峰。因此，黃錫鯛之早期生活史可能為日間索餌者 (diurnal feeder)。