Effect of Feeding Regimen on the Food Consumption, Growth, and Body Composition in Hybrid Striped Bass Morone saxatilis \( \times \) M. chrysops

Fu-Guang Liu*1,2,† and I Chiu Liao*2

*1Institute of Zoology, National Taiwan University, Taipei 107, Taiwan, R.O.C.
*2Taiwan Fisheries Research Institute, Keelung 202, Taiwan, R.O.C.

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Juveniles (averaging 12.5 g) hybrid striped bass Morone saxatilis \( \times \) M. chrysops were reared for 56 days to compare the performance among the six feeding regimens: one meal daily (M1), two meals daily (M2/D; both during daylight), two meals daily (M2/N; one at daylight and the other at night), three meals daily with three-hour meal interval (M3/3), three meals daily with six-hour meal interval (M3/6), and four meals daily (M4). The maximum specific growth rate occurred with the group fed three meals daily. The elevation in the feeding frequency resulted in increased food intake but decreased feed conversion efficiency. The total food consumption was higher but the quantity of food eaten per feeding was observed to be lower in the fish fed frequently. A slightly lower size variation was indicated in fish fed higher feeding frequencies. In addition, body moisture and lipid contents were affected by the feeding regimen, whereas protein and ash contents were not. However, the effect of the feeding regimen on morphological measurements, muscle ratio, hepatosomatic index, viscerosomatic index, and condition factor was not found to be significant. Based on the results of this study, the total amount of food eaten was significantly greater during the day than at night, and the best growth for hybrid striped bass was at three meals daily when food deprivation time was equal to six hours under the condition used in this study.

Key words: Morone saxatilis \( \times \) M. chrysops, feeding regimens, growth, body composition, size distribution

In captivity, the growth of fish is influenced by a number of factors including water temperature, stocking density, diet composition and quality, fish size, ration size, and feeding regimes, and etc. Any restricted feeding may result in a lower metabolism. Accordingly, a reduction of metabolic rate leads to the depression in the growth of fish. On the other hand, over-feeding causes a decrease in feed conversion efficiency, whereas the unconsumed feed deteriorates the water quality. In response to the changes in feeding frequency, mammals may show some physiological adaptations such as development of hyperphagia, improvement in growth and alterations in body composition. These adaptations might also occur in fish and it is of importance for husbandry techniques if the operational efficiency and quality control are concerned. In addition, increasing the feeding frequency has been reported to be associated with increase in feeding rate, and consequently, in growth rate. However, some researchers observed that feeding frequency did not affect growth. These discrepancies appear to be related to timing of food intake relative to the circadian feeding time. Moreover, feeding rate is affected by the stomach capacity; therefore, the food deprivation time seems to be an important factor in determining food intake.

Original hybrid striped bass Morone saxatilis \( \times \) M. chrysops is native to United States and has proved to be a commercially viable sport and food fish. Due to its favorable characteristics for aquaculture including euryhaline, eurythermal, faster growth rate, greater disease resistance, easy to culture, acceptance by local consumers, and high market value, this fish is becoming a more and more important candidate species for aquaculture in Taiwan. However, the relevant investigations on feeding schedule are sparse. The present study reports the effect of feeding regimen on the food intake, growth, muscle proximate composition, and size distribution. Further, the optimal feeding frequency and fasting time at which best growth was obtained were also determined.

Materials and Methods

Fish and Rearing Conditions

Hybrid striped bass juveniles were obtained from a local fish farm and were stocked into a concrete pond (8.0 \( \times \) 7.9 \( \times \) 0.8 m) for one month. Fish were fed a commercial sea bass floating pelleted diet (Fwuow Industry Co., Taiwan, 0.45 cm in diameter). This feed had a proximate composition on wet basis of 8.93% moisture, 51.05% protein, 8.03% lipid and 11.45% ash. A total of 840 fish averaging 10.6 cm in total length and 12.5 g in body weight were selected and transferred to 12 concrete tanks (2.35 \( \times \) 1.35 \( \times \) 0.70 m) and acclimated to the experimental condition for two weeks. During acclimation, aerated well

† Correspondence to: Fu-Guang Liu, Taiwan Fisheries Research Institute, 199 Hou-Ih Road, Keelung 202, Taiwan, R.O.C. TEL: 886-2-24622101, FAX: 886-2-24629388

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water was supplied to each tank at a rate of 8.0 l/min.

Prior to the experiment, 30 fish from each tank were recaptured and were individually weighed and measured for total length, then a total of 60 fish were restocked in each tank. Temperature was monitored twice daily (09:00 and 15:00 h), while dissolved oxygen (DO) and total ammonia nitrogen (TAN) were measured biweekly. DO levels were measured by oxygen temperature meter (YSI Model 56) and TAN concentrations were analyzed by phenated method. During the experiment, the water temperature varied from 23.5 to 26.5°C; the DO levels did not dip lower than 5.1 mg/l and TAN did not rise higher than 0.3 ppm.

**Feeding Regimens**

Six feeding regimens were performed: one meal daily (M1; at 11:00 h), two meals daily (M2/D; at 08:00 and 14:00 h), three meals daily (M2/N; at 14:00 and 20:00 h), three meals daily (M3/3; at 08:00, 11:00, and 14:00 h), three meals daily (M3/6; at 08:00, 14:00, and 20:00 h), and four meals daily (M4; at 08:00, 11:00, 14:00, and 17:00 h) (Table 1). Fish were fed to satiation at each meal. After 20 minutes, all uneaten feed was collected and its weight (after conversion to a dry-matter basis) was subtracted from the amount fed. Each feeding regime was tested in duplicate groups. During the experiment, the natural photoperiod was 12 L: 12 D, with the light period between 06:00 h and 18:00 h.

**Biological Measurements**

Total body length and wet body weight of 30 randomly selected fish from each tank were measured individually once every two weeks during the experiment which lasted for 56 days. Fish were not fed on the day of measuring. In addition to morphological measurements, muscle, liver, and visceral fat (VF) were weighed at the termination of the experiment. The data obtained were analyzed for the percent of weight gain (%WG) and associated fat tissue/wet body weight), percent of weight gain (%WG) = (wet weight of visceral fat/wet body weight) x 100

Vicerosomatic index (%) = (wet weight of visceral organs)/wet body weight) x 100

Hepatosomatic index (%) = (wet weight of liver/wet body weight) x 100

Visceral fat ratio (%) = (wet weight of visceral fat/wet body weight) x 100

Biochemical Measurements

At the beginning and the end of the experiment, five fish from each tank were frozen for determination of muscle proximate composition. Moisture, crude protein, and ash levels of the muscle were analyzed according to AOAC26 standard methods. Lipid extracted with the methanol-chloroform mixture of Floch et al. was subjected to quantitative analysis.

Statistical Analysis

All the data were analyzed by one-way analysis of variance (ANOVA) and Duncan’s multiple range tests were made to compare the means. Statistical significance was examined at p < 0.05.

**Results**

The growth performance of hybrid striped bass fed to satiation under different feeding regimens is presented in Table 2. The weight gain (WG) increased in the order of groups M2/N, M1, M2/D, M3/3, M4, and M3/6. In general, the WG increased with feeding frequency from one feeding per day to two feedings and finally up to three feedings, then slightly decreased for fish fed four feedings. The changes in percent of weight gain (%WG) followed a pattern similar to WG. Maximum specific growth rate (SGR) occurred with the group fed three meals daily and six hour food deprivation time (M3/6). The values in SGR were substantially reduced in groups fed one and two meals daily and were not enhanced by feeding four meals daily. In regard to feeding frequencies of groups M1, M2/D, M3/6, and M4, differences in SGR between fish fed once and three meals daily were significant, whereas those between one meal and two meals, as well as between three meals and four meals were not. Fish subjected to the lower feeding frequencies showed generally somewhat lower values in daily food intake (FI) but higher in feed conversion efficiency (FCE). In group M3/6, fish attained the highest FI, followed by those fish provided four, two, and one feeding daily. On the contrary, fish fed once a day, exhibited the best FCE, with reduced values in subsequent groups of two, four, and three meals daily.

Total food consumption in response to different feeding regimens is shown in Table 3. There appeared to be a trend that the increase in the feeding frequency was associated with an increase in consumption. Fish consumed more food per meal, but the total amount of food eaten was found much lower in the fish fed less frequently. The greatest quantity of food was consumed at the first meal of the day, which was the longest intereval from the previous feeding. The percentage of total food consumed declined at each successive feeding for all feeding regimens.

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**Table 1.** Daily feeding regimen for hybrid striped bass

<table>
<thead>
<tr>
<th>Feeding regimen</th>
<th>Feeding frequency (meals day⁻¹)</th>
<th>Feeding time</th>
<th>Food deprivation time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>1</td>
<td>11:00</td>
<td>—</td>
</tr>
<tr>
<td>M2/D</td>
<td>2</td>
<td>08:00 and 14:00</td>
<td>6</td>
</tr>
<tr>
<td>M2/N</td>
<td>2</td>
<td>14:00 and 20:00</td>
<td>6</td>
</tr>
<tr>
<td>M3/3</td>
<td>3</td>
<td>08:00, 11:00 and 14:00</td>
<td>3</td>
</tr>
<tr>
<td>M3/6</td>
<td>3</td>
<td>08:00, 14:00 and 20:00</td>
<td>6</td>
</tr>
<tr>
<td>M4</td>
<td>4</td>
<td>08:00, 11:00, 14:00 and 17:00</td>
<td>3</td>
</tr>
</tbody>
</table>
Effect of Feeding Regimen on Hybrid Striped Bass

Table 2. Growth performance of hybrid striped bass held under different feeding regimens

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Feeding regimen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M1</td>
</tr>
<tr>
<td>Initial weight (g)</td>
<td>13.7 ± 1.7</td>
</tr>
<tr>
<td>Final weight (g)</td>
<td>51.5 ± 8.9</td>
</tr>
<tr>
<td>Weight gain (g)</td>
<td>37.9 ± 0.18</td>
</tr>
<tr>
<td>Percent weight gain (%)</td>
<td>277.1 ± 1.6</td>
</tr>
<tr>
<td>Specific growth rate (%)</td>
<td>2.37 ± 0.01</td>
</tr>
<tr>
<td>Survival rate (%)</td>
<td>93.3</td>
</tr>
<tr>
<td>Daily food intake (%)</td>
<td>1.92 ± 0.09</td>
</tr>
<tr>
<td>Feed conversion efficiency (%)</td>
<td>98.8 ± 0.06</td>
</tr>
</tbody>
</table>

Data are mean ± s.d. (n=30). Values in the same row with different superscripts are significantly different (p<0.05).

In regard to food deprivation time, fish in the M3/6 group with longer intervals (6 h) consumed much more food than those in the M3/3 group with shorter intervals (3 h) (Table 3). In addition, in terms of SGR, FI, and FCE, significantly better growth performance was shown in the M3/6 than in the M3/3 feeding regimen (Fig. 1).

There were no significant differences in total food consumed between the feeding regimens of M2/D and M2/N (Table 3). However, the total amount of food eaten in group M2/N was significantly greater during the day (73%) than at night (27%). Similarly result was observed for group M3/6, where higher proportions of food was consumed during the day (71.6%) than at night (28.4%) (Table 3). Comparison of total food consumption between day and night in M2/N and M3/6 feeding regimens is shown in Fig. 2.

Figure 3 shows that fish at higher feeding frequencies had slightly lower variation in size compared to fish at lower feeding frequencies. Weight distribution for the higher feeding frequencies was in a range of 35-85 g, whereas it was broader for fish at lower feeding frequencies ranging from 20 to 85 g. Moreover, the percentage of larger fish (>60 g) was higher in fish fed more frequently, while that of smaller fish (<50 g) was higher with infrequently fed fish.

Feeding regimen had no effect on the morphological measurements (Table 4). The muscle ratio of the M1 group was significantly lower than in all the other groups, whereas the value of VSI in M1 group was significantly higher than in all the other groups. The HSI did not differ significantly among the experimental groups. The observed trend towards an increase in visceral fat ratio with increasing feeding frequencies was significant except M2/N and M4 groups. The significant differences in condition factor were only found between M2/D and M3/6 groups as well as between M2/N and M3/6 groups.

Proximate analyses showed a general decline in moisture whilst an increase in lipid content over the course of the experiment (Table 5). It appeared that the reduction in moisture content increased with feeding frequency (up to three feedings daily, then decreased slightly in four feedings daily). The pattern exhibited by lipid was the inverse of that for moisture. The increase in lipid was most pronounced in fish receiving three meals per day. The differences in protein content among all the feeding regimens were not found to be significant. The observed trend towards a decrease in ash content with increased feeding was found to be significant only for M1 and M4 as well as M3/3 and M4 groups.

Discussion

Previous studies have shown that an increase in feeding frequency results in the improvement of growth rate. Similarly, the SGR in the present study was substantially elevated by increasing feeding frequency from one to three times daily, but was not enhanced by four times per day. The value of FI increased with increasing feeding frequency, maximum FI occurred with three feedings per day; at higher feeding frequencies, a slight decrease in
value was observed. This result is also in accordance with the reports from other authors,\textsuperscript{6,11} Tsevis et al.\textsuperscript{30} indicated that feeding frequency affected directly the food intake, which in turn affected the total metabolic efficiency and growth of fish.

In this study, fish fed less frequently showed better FCE but poor SGR. A similar result was obtained for sea bass \textit{Dicentrarchus labrax}.\textsuperscript{30} The better FCE could be attributed to less physiological activity and lower endocrine function of fish.\textsuperscript{31} However, the poor FCE at high feeding frequency reflects that the undigested portion of the food consumed gradually increased. Incomplete digestion leads to poor utilization of food.\textsuperscript{27} The food consumed per fish per feeding was higher in fish fed less frequently. Similarly, more food was consumed at the first meal, which was the feeding preceded by the longest food deprivation time. According to Brett,\textsuperscript{15} food consumption is related to the capacity of the stomach and the rate of digestion. As the digestion rate is constant under constant conditions, food deprivation seems to be the determining factor. The food intake is related to the amount of food remaining in the stomach; therefore, maximum intake would then be expected when the stomach is empty.

Regarding the food deprivation time, the growth perfor-
mance of six-hour interval in the M3/6 group was better than that of three-hour interval in the M3/3 group (Fig. 1). If the meal interval is short, the food leaves the stomach and passes down the digestive tract more quickly, resulting in less efficient digestion.31) On the other hand, the responses of the most infrequently fed fish—decreased metabolic rate and increased feed efficiency—are likely to occur in fish only when rather long intervals are imposed.) It is impossible, however, for food intake of these fish to equal that of fish fed more frequently (Table 2). The food consumed per fish per feeding increased following a period of deprivation as observed by some researchers. However, if the feeding frequency were reduced beyond a certain limit, the intake compensation might not be possible as indicated by the fall in total food consumption (Table 3).

It was found that hybrid striped bass fed predominantly during the daylight hours (Fig. 2). This result is in accord with the findings from other studies.10,33) In fish, the differential entrainer of circadian biorhythms caused by specific feeding regimen could have profound effects on metabolism.14,15) Therefore, fish fed at night might have a disturbance in their biorhythm which affected the metabolism as reported by Tsevis et al.20) It can be concluded that frequent feeding may promote the possibility of feeding at a more metabolically efficient time of day.

The present study showed that much larger fish were yielded in fish fed frequently, whereas numerous smaller fish were found in fish fed periodically. This result demonstrates that the skews in the weight distribution for fish in the higher feeding frequencies are slightly positive, whilst a negative skew is obtained for infrequently fed fish. The same conclusion can be drawn for Epinephelus tauvina.27) Moreover, the coefficient of variation of body weight decreased with feeding frequency, reflecting that the high feeding frequency reduced size variation. Low size variation of the frequently fed fish was attributed to the food intake.20) In addition, Jobling5) suggested that the growth retardation of small fish caused by social hierarchy increased with a reduction in feeding frequency. A tendency for body moisture to decrease and lipid to increase with time for all experimental groups was found in this study, and their values at the end of the experiment were significantly affected by differences in feeding regimen. This is in agreement with the finding of Cui et al.24) As satiation feeding was performed, those fish fed more frequently tended to deposit more lipid than infrequent feeding fish since total feed intake was greater.4) Our data showed that the increased visceral fat was increased with feeding frequency as observed by Kayano et al.26,27) for Epinephelus acaara. This is probably due to the accelerated lipid accumulation in fish under frequent feeding. Usually, the feeding regimen influences partitioning of an energy source into growth or fat storage. Adequate feedings can improve digestibility, and consequently accelerates protein assimilation which results in high growth. However, fish fed frequently can alter body composition by enhancing lipogenic activity, in other words, the frequent feedings may cause metabolic changes and depress protein assimilation, consequently, the surplus energy converted from dietary protein will be accumulated as the lipid reserves.

The optimum feeding frequency may vary with species. Optimum feeding frequency was reported as once in two days for estuary grouper Epinephelus tauvina;27) once a day for white mouth croaker Micropteron furnieri;35) twice per day for rainbow trout Oncorhyncus mykiss;6) three times daily for common carp Cyprinus carpio,36) and four times daily for striped bass Morone saxatilis.7) These differences in optimum feeding frequency must be related...
to the differences in fish species and size, stomach capacity and digestion time, fish biorhythm, diet composition and quality, and culture environments.\textsuperscript{6,10,14}

In conclusion, the elevation in the feeding frequency is associated with an increase in food intake, but there is a decrease in the feed conversion efficiency. Fish consumed more food per meal but total food consumption is found to be lower in the fish fed infrequently. The results of the present study suggest that the best growth for hybrid striped bass is obtained when the feeding frequency is three meals daily and food deprivation time is six hours. It is also shown that less food is consumed out of daylight. Additionally, feeding regimen affects body moisture and lipid contents, but not protein or ash content.

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