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ABSTRACT

The icefish (*Neosalanx taihuensis*) of Lake Chaohu, China, foraged almost exclusively on crustacean zooplankton in both spring and summer. The icefish showed diurnal feeding periodicity, with peak feeding in the morning. No food was observed in icefish guts collected at night. Our results indicate that that the icefish was a particulate feeder and light intensity greatly affected its foraging on zooplankton. Daily consumption of zooplankton by icefish varied significantly both diurnally and among seasons, which ranged from 0.22 to 2.23 g (wet weight) per 100 g wet fish weight at temperatures between 16.3 °C (spring) and 28.8 °C (summer).

INTRODUCTION

Icefishes (Salangidae) originated in the Chinese Yellow Sea and are distributed in coastal and inland waters of China, Korea, Japan, Vietnam and Russia (Nelson 1994, Xie and Xie 1997). In natural lakes and reservoirs, icefishes feed primarily on zooplankton, although they also consume phytoplankton (Liu and Zhang 1994, Yin et al. 1997, Gong et al. 1999, Liu 2001).

The quantity of food consumed by fishes in their natural habitat can be estimated with different models based on gut fullness in the field. The most commonly used models for estimating food consumption in the field are the Eggers (1977) and Elliott and Persson (1978) models. Comparative experiments showed that the Eggers model is applied correctly and gives an estimate as accurate as the Elliott-Persson model (Boisclair and Leggett 1988, Boisclair and Marchand 1993). Due to its simplicity, the Eggers model seems to be more lower variances for the daily ration estimates and the Elliott-Persson model is appropriate not only for daily ration estimates but also for estimates of diel changes in food consumption (Héroux and Mangan 1996, Speczíár 2002).

In Lake Chaohu the growth, diet compostion and spawning population of icefish, *Neosalanx taihuensis* Chen, have been studied (Wu 1979, Li and Chen 1982, Diao 1986) but there is no information on the quantity of food was consumed in this eutrophic lake. Thus, the aim of our study was to estimate the daily food consumption of this icefish in both spring and summer.

MATERIALS AND METHODS

Fish sampling

Fish were captured a 3-h intervals over a 24-h period both in the spring and summer of 2003 in Lake Chaohu, eastern China (117° 16' 54" - 117° 51' 46" E, 30° 25' 28" - 31°43'28"N). All fish were collected with paired trawls designed for catching icefish by local fishermen. At each sampling, 15-30 icefish were killed immediately with 10% formation and then measured for total length (TL) and weighed (wet weight). Guts

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were dissected and prey items were identified under magnification. Prey weights were estimate by length-weight regressions (Zhang and Huang 1991). Due to an extremely high air temperature, the 1500 h samples in summer were not collected.

Daily consumption

The Elliott-Persson model was used t0 estimate daily consumption, and we assumed that the initial gut fullness (at 1800 h) was equal to that at the end of the 24-h period (Eggers 1979, Boisclair and Marchnad 1993, Specziár 2002). In order to normalize percentage distributions, mean gut fullness for each 3-h interval was estimated from arcsine-transformed data (arc sin $\sqrt{0.01F_i}$) and used in further calculations in its backtransformed form.

The gut content of each fish was expressed as gut fullness, F_i (g wet weight per 100 g wet body weight), and was estimated as

$$F_i = G_i \cdot \frac{100}{W_i} \quad (1)$$

where G_i is the wet weight of the gut contents of fish $_i$, and W_i is the net wet weight of fish $_i$ (total fish weight minus gut contents weight).

Gut evacuation rate was estimated from the decrease in gut fullness observed during the successive sampling times. For convenience, we estimate gut evacuation rate (R) as the maximum rate at which food was evacuated for each 3-h time interval as

$$R = \frac{\ln F_{i+3} - \ln F_i}{3} \quad (2)$$

where ln F_i and ln F_{i+3} are the mean of the log-transformed weight of gut contents at the beginning and at the end of a 3-h interval, respectively.

Daily food consumption (C, g wet weight per 100 g fish wet weight per day) was calculated by the Elliott-Persson (1978) model as follows:

$$C = \sum_{t=1}^{p} C_{\Delta t} \quad (3)$$

where C is the quantity of food consumed by fish during an interval Δt between two successive sampling periods t and $t + 1$, and p is the number of intervals per day.

$C_{\Delta t}$ was estimated as

$$C_{\Delta t} = \frac{(F_{i+1} - F_i e^{-R\Delta t}) R\Delta t}{(1 - e^{-R\Delta t})} \quad (4)$$

where F_i and F_{i+1} are the geometric mean gut fullness at two successive sampling periods, R is the gut evacuation rate, and Δt is the time between two successive sampling periods in hours.

Data analyses

In order to compare gut fullness among 24-h period, data were analyzed primarily by analysis of variance (ANOVA) followed by Tukey's honestly significant difference multiple comparison (Statitstic Software packet, version 6.0).

RESULTS AND DISCUSSION

Gut fullness in *N. taihuensis* feeding on microcrustacean prey in Lake Chaohu peaked during the day and dropped to zero at night both in spring and summer, 2003 (Fig.1). Apparently icefish did not feed during darkness. This suggests that light intensity can be an important factor affecting feeding behavior in these zooplanktivorous fish. Visual detection of prey is typical in selective particulate feeders (i.e., fish attacking individual planktonic prey items). Our study demonstrated that the icefish is a particulate feeder.

Particulate feeding occurs when prey size is relatively large, whereas filter feeding occurs when prey organisms are small and abundant (Lammens 1985). The icefish in our study fed on large cladocerans of the *Daphnia* and *Leptodora* species and calanoid copepods in spring (Fig. 2). In summer, feeding was on medium-sized cyclopoid copepods and cladocerans of the *Moina* genus. This shift in prey types probably in part reflected a reduced availability of the daphnids and calanoid copepods. However, Deng (2004) reported that the zooplankton was dominated by *Bosmina* and *Ceriodaphnia* species throughout the time of our study, and *Leptodora* spp. was present also at very low densities. This is further evidence that the icefish is a selective particulate feeder and is in agreement with other recent reports. Liu and Zhu (1994) found that the majority of zooplankton in the diet of *N. taihuensis* comprised large-size cladocerans (e.g., *Daphnia* spp.) and large copepods (e.g., *Diaptomus* spp.) in Lake Dianchi, a hypereutrophic lake in southwestern China. Similarly, Yin et al. (1997) found that *Daphnia* spp. and calanoid copepods dominated the diet of icefish in Lake Wang, and Gong et al. (1999) observed a similar situation in icefish of the Fushui Reservoir.

The daily consumption of zooplankton by icefish was significantly higher in spring than in summer (Table 1). On a daily basis, icefish consumed 2.23 g of zooplankton per 100 g of body weight in the spring, whereas daily consumption was only 0.22 g per 100 g of body weight in the summer. Variation of the zooplankton community due to algal blooms may importantly affect the behavior of visual-feeding fishes in eutrophic Lake Chaohu. In summer, *Microcystis* spp. and *Anabaena* spp. dominated the phytoplankton and reached maximum colony biomasses of 24.8 mg. L^{-1} and 70.5 mg. L^{-1}, respectively (Deng, 2004). Dense blooms occurred frequently and decreased water

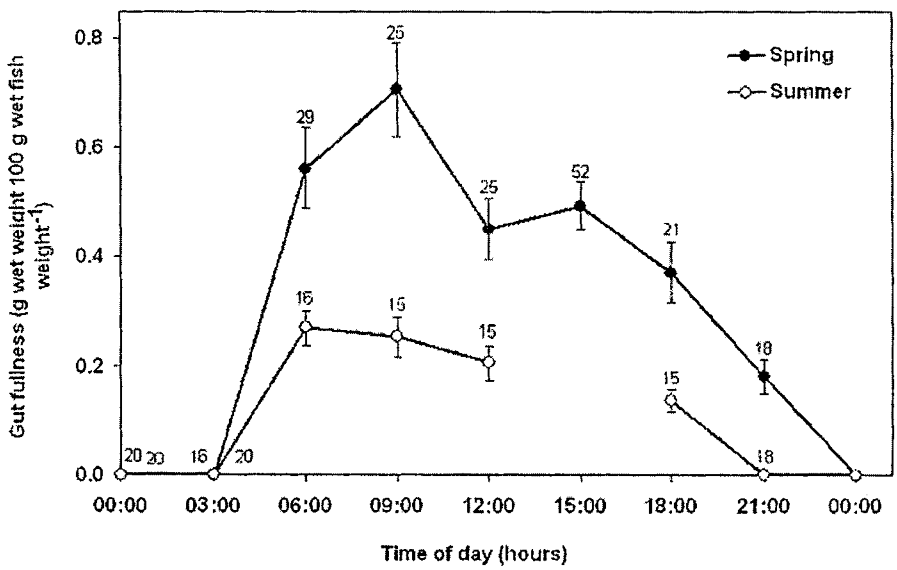

Figure 1. Diel variation in the mean gut fullness of icefish in the spring and summer of 2003. Vertical bars represent ± SE, and numbers of analyzed fish are shown close to symbols or error bars, excluded the empty guts.

transparency greatly and increased turbidity. These factors can affect prey selection of both zooplankton and fish (Vogel and Beauchamp 1999, Deng 2004). This may explain why daily consumption of zooplankton by icefish was lower in summer than in spring. Also, spawning behavior, which requires increased energy expenditure, results in an increased feeding rate, at least before ovulation (Wootton 1998). In Lake Chaohu, two spawning populations of icefish were found – one in spring and one in early autumn (Wu 1979, Li and Chen 1982). This may also have acted to affect the higher daily consumption by icefish by icefish during the spring sampling.

The quantity of food consumped by fish in the field varies over consecutive days for many reasons (Trudel and Boisclair 1993, Grant and Kott 1999). Since we sampled only a single 24-h period in both spring and summer, we can not describe the day-to-day variation in our estimates of food consumption. Thus, speculation regarding mechanisms behind the temporal variation in quantity of food consumed by icefish remains tentative.

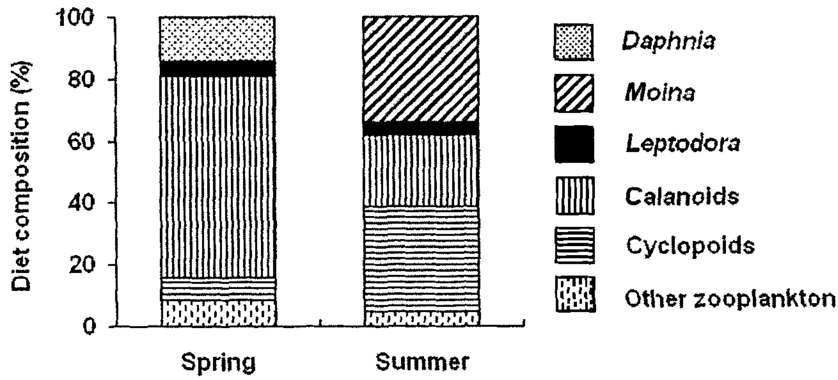

Figure 2. Diet composition expressed as crustacean zooplankton prey percentages by wet weight (weighted mean over the feeding diel cycle) for icefish sampled in the spring and summer of 2003.

Table 1. Overview of daily consumption estimates for icefish in Lake Chaohu in 2003. *TL* = mean total length of sampled fish ± SE; *Temp.* = mean water temperature; *R* = gastric evacuation rate; *F* = mean gut fullness ± SE during the 24-h period in g wet weight per 100 g wet fish weight; *C* = daily consumption, as per the Elliott-Persson model, in g wet weight per 100 g wet fish weight.

Season	*TL* (mm)	*Temp.* (°C)	*R*	*F*	*C*
Spring	52.8 ± 13.0	16.3	0.29	0.43 ± 0.07	2.23
Summer	49.9 ± 9.3	28.8	0.08	0.20 ± 0.03	0.22

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