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Diel Feeding Activity in Summer of Juvenile Pacific Herring, *Clupea pallasii* in the Southeastern Coast of Korea

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ABSTRACT Diel changes in feeding activity of juvenile Pacific herring, *Clupea pallasii* were investigated throughout the analysis of stomach contents of 301 fishes collected from the southeastern coast of Korea. Fish samples were collected every 3 hour over a 24 h period in summer using small bottom trawl. The ratio of empty stomach, stomach fullness, stomach contents index (SCI) and stomach fullness index (IF) of juvenile *C. pallasii* were varied markedly with day/night changes. The ratio of empty stomach tended be higher during nighttime, while the other values were higher at daytime, with showing peak before sunset. During daytime, the stomach contents mainly were made up of copepods and euphausiids, while the diets at midnight were composed of nearly digested and unidentifiable items.

Key words: circadian change, feeding activity, juvenile Pacific herring, East Sea

INTRODUCTION

The Pacific herring, *Clupea pallasii* is a pelagic fish that widely distributes in the coastal waters of North Pacific between 77°N and 33°N, and between 34°E and 119°W (FAO-FIGIS, 2001). This fish is an economically important fishery resource in the north-western Pacific including Korea and Japan (Yamada *et al*., 1986; Kim *et al*., 2004), where they are caught primarily by coastal purse seine in Korean waters (KOSIS, 1990∼2016). Juvenile *Clupea pallasii* is abundant throughout the southeastern coast of Korea, where it is one of the most abundant teleost during summer (Choo, 2007; Park, 2010). They consume mainly pelagic crustaceans such as copepods, euphausiids and caridean shrimps (Choo, 2007). Due to its high abundance and important role in marine food web as secondary consumer, *C. pallasii* may exert significant impacts on the pelagic and/or bentho-pelagic food webs of this ecosystem.

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Studies on feeding activity are useful to determine trophic interactions between organisms within ecosystems and to develop bioenergetic and ecosystem models (Darbyson *et al*., 2003), and also are basic tools to understand the autoecology of fish species (Carvalho and Soares, 2006). The diel rhythms in fish behavior may be associated with various factors such as light, temperature, salinity, and availability of prey or with interplay of these factors. In aquatic systems, planktivorous fishes can visually detect and capture prey items, especially small planktonic crustaceans (e.g., Hairston *et al*., 1982), but the ability to use visual cues is limited under conditions of darkness, high turbidity or dense macrophytes (e.g., Abrahams and Kattenfeld 1997; Lehtiniemi *et al*., 2005). Diel changes in available foods and tidal condition also can influence stomach fullness of fishes (Elliott, 1970; Hibino *et al*., 2006).

Data on the diet of juvenile *C. pallasii* are necessary for determining early life history of this species and for understanding specific features of coastal marine ecosystem functioning. In this study, we aimed to determine the food resource and diel feeding activity of juvenile *C. pallasii* during summer.

MATERIALS AND METHODS

Fish specimens, consisting of 301 juvenile *C. pallasii* ranging from 7.4 to 17.4 cm (mean ± SD = 10.2 ± 1.73 cm) in total length (TL), were collected in August of 2006 from the southeastern waters of Korea (35°17′N, 129°18′E; see also Park, 2010). Fishes were collected every 3 h over a 24-h period during neap tide at depths between 30 and 60 m using a small bottom trawl (length 20 m, width 4 m, mesh wing and body 3 cm, mesh liner 1 cm). The trawl towed during 30 min at each of eight different start times (i.e. at 02:00, 05:00, 08:00, 11:00, 14:00, 17:00, 20:00 and 23:00). The tidal range between high and low tide was 0.5 m.

All specimens collected were fixed in 5% formalin solution immediately after collection. For each specimen, prey items from the stomach were identified under a dissecting microscope, and the numbers and wet weights of each prey item were counted and weighed, respectively. Stomach fullness was visually estimated by assigning a score between 0 (empty) and 5 (fully distended with food) as a measure of diel feeding intensity. To access relative weight of stomach contents in given body weight, stomach content index (SCI) was calculated: $SCI = 100 \times SCW \times BW^{-1}$, where SCW is stomach contents weight and BW is body weight. A stomach fullness index (IF) was also calculated for each stomach to adjust for variation in fish size: $IF = 10000 \times SCW \times TL^{-3}$, where SCW is stomach contents weight and TL is total length (Darbyson *et al*., 2003).

One-way analysis of variance (ANOVA), followed by Tukey's post-hoc comparisons were used to test diel changes in stomach fullness, SCI and IF, and to test for differences in those variable among samples collected over diel cycle. ANOVA was conducted using SYSTAT software (Systat version 18, SPSS Inc., Chicago), and statistical differences were determined at the 0.05 significance level.

RESULTS

Of the 301 stomachs examined, 160 (53.2%) were empty. The empty ratio showed remarkably high diel variation (Fig. 1). The value was higher during night times (> 66%, between 20:00 and 05:00), and then gradually declined after sunrise, with being the lowest at 17:00. On the other hand, the stomach fullness, SCI and IF values showed similar trends with diurnal cycles (Fig. 2). Lower mean stomach fullness, SCI and IF were recorded during night times until in the morning, and then increased gradually from 11:00, with showing peaks at 17:00, followed by sharp declines after sunset. One-way ANOVA results demonstrated that all three variables differed significantly among eight time intervals ($P < 0.05$). Tukey's post-hoc tests for diurnal comparisons indicated that all three variables were significantly higher at 14:00 and 17:00 than other times, and those were higher at 17:00 than at 14:00.

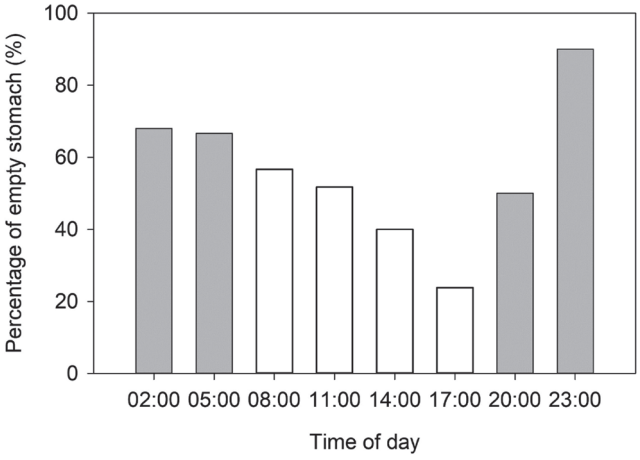

Fig. 1. Diel change in the ratio of empty stomach for juvenile *Clupea pallasii* in the southeastern coast of Korea. Gray and white columns indicate night and day samples, respectively.

The compositions of stomach contents also varied with diurnal cycles (Fig. 3). In the stomach contents of juvenile *C. pallasii*, two identifiable prey taxa (i.e. copepods and euphausiids) and unidentifiable materials were observed. At both 02:00 and 23:00, the stomachs were composed of only unidentifiable materials. Euphausiids was found from early morning (i.e. at 05:00), and constituted more than 68% to the diets of juvenile *C. pallasii* during daytime, as well as at 20:00. Copepods made up small amount throughout all the time intervals with exception at 02:00, 05:00, 11:00 and 23:00.

DISCUSSION

Our study indicates that juvenile *C. pallasii* fed primarily on small pelagic crustaceans such as copepods and euphausiids. Wailes (1936) reported that copepods and barnacle larvae were the most important food items for postlarvae of *C. pallasii*, and confirmed copepods and euphausiids comprising the bulk of the foods for adult *C. pallasii* from southern British Columbia waters. Choo (2007) also observed that pelagic crustaceans including

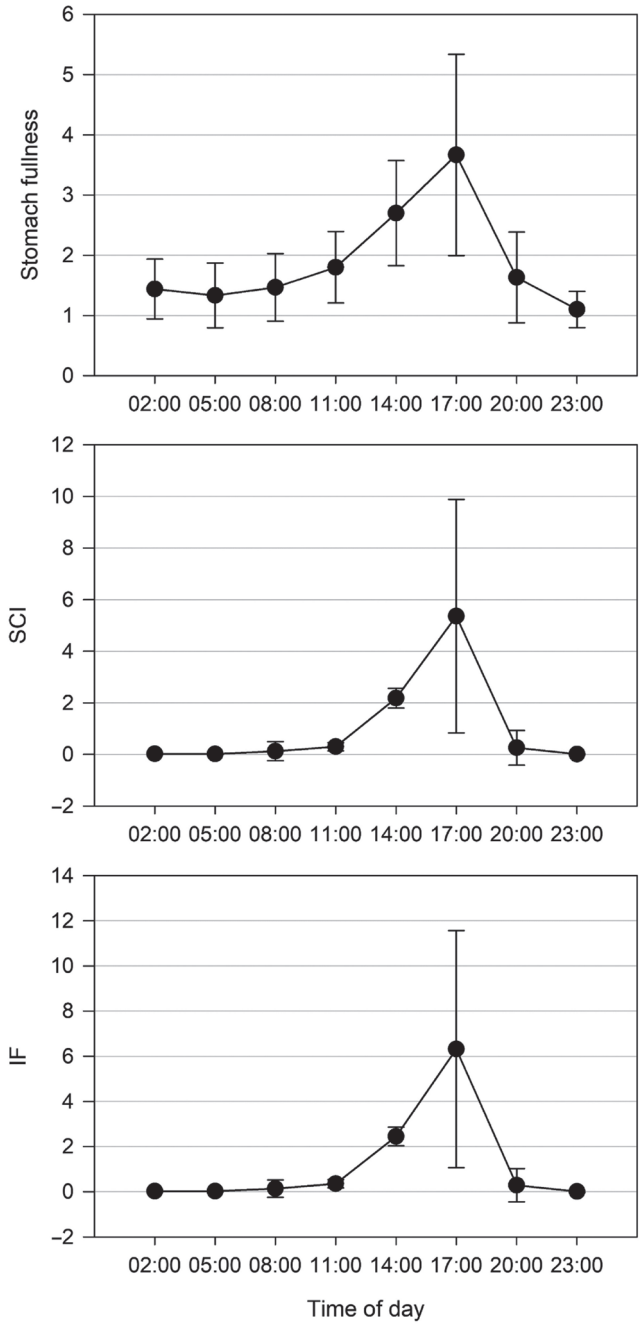

Fig. 2. Diel variations in stomach fullness, SCI and IF in summer of juvenile *Clupea pallasii* in the southeastern coast of Korea. Error bars represent standard deviation (SD).

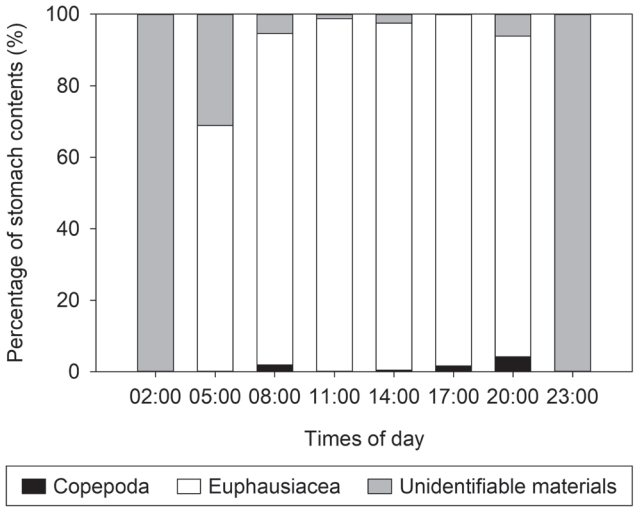

Fig. 3. Diel variation in composition of stomach contents in summer of juvenile *Clupea pallasii* in the southeastern coast of Korea.

caridean shrimps and euphausiids constituted overwhelmingly in the diets of juvenile and adult *C. pallasii* in the southeastern Korean waters. Thus, although there were some ontogenetic changes in food items, *C. pallasii* consumed pelagic crustaceans throughout the whole life history.

This study confirmed low empty stomach and high feeding intensity in the diets of juvenile *C. pallasii* during daytime. Generally, diurnal and nocturnal changes in feeding activity of fishes can be related to the difference in the light intensity, which brings alternation in the period of the light and dark phases of the day (Boujard & Leatherland, 1992). Darbyson *et al.* (2003) observed that two peaks in stomach fullness of herring occurred during diurnal cycle, one was after dawn and the other was before dusk. Köster & Schnack (1994) found that stomach contents of cod in the Baltic Sea increased steadily from dawn to dusk, suggesting there was feeding throughout the day. Tudela and Palomera (1995) also indicated that anchovies in the western Mediterranean Sea showed maximum values of stomach fullness before sunset. From above the results, those pelagic fishes are likely to feed on food during daytime for specific needs for food, shelter and refuge from predation. While, low feeding rates by herring during the night are probably due to decreased light intensity, because herring will feed selectively on larger prey items when sufficient light is present for them to feed visually (Batty *et al.*, 1990). In addition, Hunter (1968) suggested that if adequate light is provided, such as when there is a full moon, some fish are able to feed at the surface during night.

In conclusion, this study gives important insights into diel variations in feeding intensity and food composition of juvenile *C. pallasii* during summer. Our results indicated that *C. pallasii* was a daylight feeder feeding heavily before sunset. Such results are essential for understanding trophodynamics of the species, and are an important baseline for studies on management and conservation ef-

forts of commercial fish species in southern Korean waters.

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여름철 동해 남부에 출현하는 청어(*Clupea pallasii*) 유어의 일섭식 변동

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요 약 : 본 연구는 여름철 동해 남부 연안에 출현하는 청어 유어 301개체의 일섭식율 변동을 조사하였다. 어류 시료는 여름철에 3시간 간격으로 24시간 동안 소형 저인망을 이용하여 채집하였다. 청어 유어의 공위율(ratio of empty stomach), 만복도(stomach fullness), 위내용물중량지수(stomach contents index, SCI), 만복도지수(stomach fullness index, IF)는 낮과 밤의 변화에 따라 뚜렷하게 변동하였다. 공위율은 밤에 높았지만, 다른 지수들은 낮에 높아지는 경향을 보였고, 일몰 직전에 가장 높은 값을 보였다. 낮 동안 청어 유어의 위내용물은 요각류(Copepoda)와 난바다곤쟁이류(Euphausiacea)로 구성되어 있었고, 자정 근처에는 거의 소화되어 확인이 어려운 먹이생물로 구성되어 있었다.

찾아보기 낱말 : 일주기변동, 섭식강도, 청어 유어, 동해