Impact of Artificial Illumination on Zooplankton Dynamics

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Abstract - **Impact of artificial illumination on zooplankton dynamics has been studied in Tongyong marine ranch during the period from August 1998 to August 1999. Monthly sampling has been carried out to collect zooplankters from both natural waters and artificially illuminated waters at night. A total of 48 taxa of zooplankton occurred during the study. Copepods showed the prosperity in species number with 21 species. Every sample from illuminated waters consisted of more than 15 species except February while less than 15 species in samples from natural waters during the winter. Benthic amphipods occurred abundantly in illuminated waters. Zooplankton abundance was revealed to be increased in illuminated waters mainly due to the gathering of amphipods (4,500 indiv. m^{-3}) in September and October. Twenty times of zooplankton abundance was recorded in illuminated waters when compared with that in natural ones in September due to the gathering of amphipods and ten times by the explosion of *N. scintillans* in August 1999. However, no distinct difference in the abundance was observed between two waters in the winter. Zooplankton gathering with artificial illumination seemed to be effective in amphipods, while copepods were hardly affected by the artificial illumination at night.**

Key words : Artificial illumination, zooplankton dynamics, Tongyong marine ranch

INTRODUCTION

Artificial illumination has been used in sea cage farming of Atlantic salmon (*Salmo salar*) over recent years, as night light exposure during winter and spring enhance 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 during winter and spring to reach market size, allowing the fish to be harvested before sexual maturation which reduce flesh quality and growth, and increase mortality in Atlantic salmon (Endal *et al.* 2000). The other is to supply natural food, *i.e.*, gathering zooplankters with artificial illumination at night (Uryn 1979). Focusing on the intermediate rearing step between the initial seedling production, this study sought to develop means of controlling the night lightening of feeding ability in feeding time and food items with ranching fishes. In natural conditions, zooplankton vertically moves to the surface through water column at night (Mashall and Orr 1955; Raymont 1983). In addition to the vertical migration, most zooplankton species are also attracted to artificial light sources at night, because they use the lights as the cue to regulate their vertical movements (Richards *et al.* 1996). The objectives of the study is to know the impact of artificial illumination on the food item variability as a part of the development of marine ranching technologies, which were established under these programs, as of 1998 exist in model site in Tongyong area of KORDI, in

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cooperation with Ministry of Maritime Affairs and Fisheries in Korea.

MATERIALS AND METHODS

Quantitative zooplankton samples were collected from both natural waters and artificially illuminated ones in Tongyong marine ranch (34° 46′050″N, 128° 23′130″E) at night monthly during the period from August 1998 to August 1999. An incandescent electric lamp (200 W) was used above the 4 × 2 m floating cage (cage depth: 6 m). This lamp was positioned approximately 0.5 m above the water surface, and operated every night from 18:00 to 06:00 during the experimental period. Kitahata plankton net (mouth diameter: 25 cm, mesh aperture: 0.1 mm) equipped with flow meter (Hydrobios 438 110) in the front of net mouth was hauled vertically from the bottom fo the cage to the surface. Samples were fixed with 4% neutralized formalin on board and moved to the laboratory. Each sample was identified to species under a dissecting microscope (Zeiss SV11) and a compound microscope (Zeiss Auxiolab), and number of individuals of zooplankters was converted into number per cubic meter using data of filtered water measured by a flow meter.

Table 1. List of zooplankton taxa observed in Tongyong marine ranch in 1998–1999

Phylum Protozoa	*O. similis*
Noctiluca scintillans	*Oncaea media*
Phylum Coelenterata	*Paracalanus indicus*
unidentified sp.	*Pseudocalanus minutus*
Phylum Chaetognatha	*Temora discaudata*
Sagitta crassa	*Tortanus forcipatus*
S. enflata	Unidentified Harpacticoida sp.
Phylum Arthropoda	Copepodite
Class Crustacea	Copepoda nauplius
Order Cladocera	**Order Amphipoda**
Evadne nordmanni	unidentified sp.
E. tergestina	**Order Decapoda**
Podon leuckarti	unidentified sp.
P. polyphemoides	**Order Mysidacea**
Order Ostracoda	unidentified sp.
unidentified sp.	**Order Euphausiacea**
Order Copepoda	unidentified sp.
Acartia erythraea	**Phylum Protochordata**
A. pacifica	**Class Urochordata**
Calanopia thompsoni	**Order Appendicularia**
Calanus sinicus	*Oikopluera dioika*
Candacia catula	**Order Thaliacea**
Canthocalanus pauper	*Salpa* sp.
Centropages abdominalis	**Larvae**
C. dorsispinatus	Cirripedia cyprid
Corycaeus affinis	Cirripedia nauplius
Euterpina acutifrons	Mollusca larvae
Hemicyclops japonicus	Decapoda zoea
Labidocera acuta	Decapoda megalopa
L. rotunda	Decapoda larvae
Microsetella norvegica	Polychaeta larvae
Oithona setigera	Fish eggs
	Fish larvae

RESULTS AND DISCUSSION

A total of 48 kinds of zooplankter was distributed in Tongyong marine ranch during the study (Table 1). Copepods showed the prosperity in species number and 21 species were identified to species, and four species of cladocerans distributed seasonally. Every sample collected in illuminated waters consisted of more than 15 species except February and March while less than 15 species during the period from November to March in samples from natural waters (Fig. 1). No distinct difference was observed in the number of species occurred in August, September 1998, February, March, April and May 1999. In August 1999, however, illuminated waters showed twice number of zooplankton taxa occurred when compared with that in natural ones mainly due to the occurrence of various larval organisms, *i.e.*, cirripedia nauplius, decapod zoea and fish eggs, in former waters.

Zooplankton abundance was revealed to increase in illuminated waters mainly due to the gathering of amphipods in September and October, and due to *Noctiluca scintillans* in August (Fig. 2). Twenty times of zooplankton abundance was recorded in illuminated waters when compared with that in natural ones in September due to the gathering of amphipods (4,500 indiv. m^{-3} in illuminate waters and ten indiv. m^{-3} in natural ones) in September and five times also by amphipods (1,786 indiv. m^{-3} in illuminated waters and 19 indiv. m^{-3} in natural ones) in October. The abundance of *N. scintillans* (1,843 indiv. m^{-3} in illuminate waters and 192 indiv. m^{-3} in natural ones) was the main reason to increase zooplankton abundance in August. The abundance of *N. scintillans* was observed to be twice higher in natural

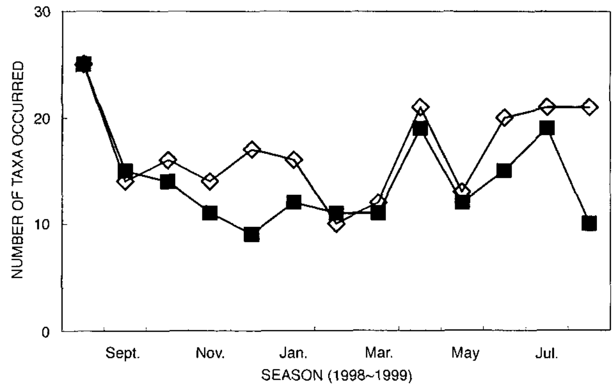

Fig. 1. Number of zooplankton taxa occurred at night during the period from August 1998 to August 1999 in natural waters (solid symbol) and artificially illuminated ones (open symbol) in Tongyong marine ranch.

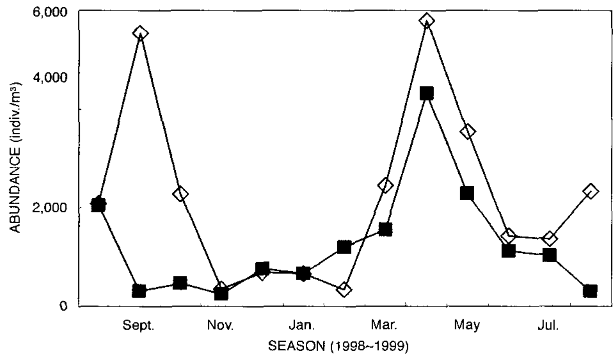

Fig. 2. Zooplankton abundance (indiv. m^{-3}) at night during the period from August 1998 to August 1999 in natural waters (solid symbol) and artificially illuminated ones (open symbol) in Tongyong marine ranch.

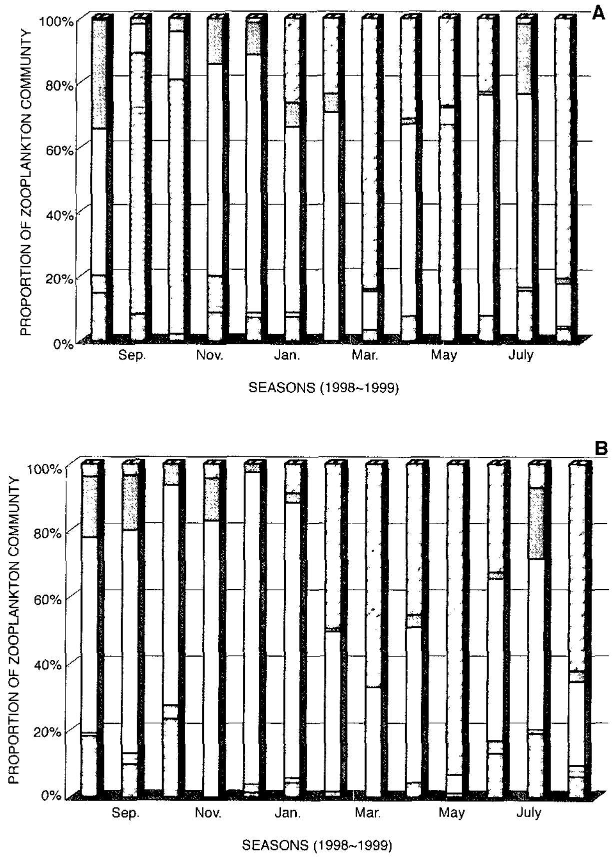

Fig. 3. Proportion of zooplankton community among total zooplankton abundance during the period from August 1998 to August 1999 in Tongyong marine ranch. A: artificially illuminated waters. B: natural waters. Hatched column: *Noctiluca scintillans*, solid: metazoans except copepods and amphipods, open: copepods, copepodite and copepod nauplius, stripe: amphipods, lattice: larval animals.

water (2,100 indiv. m^{-3}) when compared with that in illuminated waters (960 indiv. m^{-3}) in May. However, gathering of fish eggs in illuminated waters (2,227 egg. m^{-3}) compensated, then zooplankton abundance in illuminated waters exceeded that in natural ones. This result agrees well with the documentation by Tacon *et al.* (1991). Although they did not measure the precise impact of artificial illumination on zooplankton gathering, fast growth of cultured fish supported the attack of pelagic food organisms into night lighting sea cage.

During this period of September and October, strong phototaxis was observed in amphipods (Fig. 3). The proportion of amphipods exceeded 80% of total zooplankton abundance in artificially illuminated waters while 3.4% in natural waters in September. Similar pattern was observed by amphipods in October, too. Despite the clear evidence on the attack of amphipods into sea cage, we are doubtful whether these animals are useful for the growth of cultured fishes and prawns or not. Because that most of studies on food selectivity or stomach contents examination reported that amphipods was a minor food items for both captured and cultured fishes and prawns (Angsupanich *et al.* 1999 for *Penaeus indicus* and *P. merguiensis*; Cha and Park 2001 for *Argyrosomus argentatus*) In the case of *Noctiluca scintillans*, its proportion was higher in natural waters than that in illuminated waters except March and August. Copepods showed similar pattern of occurrence between two waters with higher proportion in natural water. In May, the proportion of fish eggs exceeded 60% of total zooplankton abundance in illuminated waters.

With these results, more taxa of zooplankton seemed to attack into lluminated waters in winter season when the abundances in two waters were not so different. Prosperity in taxa number occurred in illuminated waters was revealed to be due to the gathering of larval animals. Namely, larval animals such as mollusc larvae, decapod larvae, polychaet larvae, and fish egg and larvae occurred only in illuminated waters in the winter. Nevertheless the prosperity in zooplankton taxa number occurred in illuminated waters, the abundance of copepodite was higher in natural waters throughout the winter (copepodite abundance in illuminated waters : natural waters = 38 indiv. m^{-3} : 77 indiv. m^{-3} in November, 326 : 403 in December and 173 : 211 in January). Phototaxis seems not to be the case for copepodites.

We conclude the strong phototaxis in amphipods. Artificial illumination also plays a role to gather larval animals in the winter. No such phenomenon is the case for copepods.

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