

Development and Distribution of the Japanese Mantis Shrimp *Oratosquilla oratoria* Larvae in the Northwestern Water off Incheon

In-Ja YEON · Won-Gyu PARK[†]

(National Fisheries Research & Development Institute · [†] Pukyong National University)

인천 북서부 해역에서 출현하는 갯가재 유생의 발달과 분포

연인자 · 박원규[†]

(국립수산과학원 · 부경대학교[†])

Abstract

Development and distribution of Japanese mantis shrimp, *Oratosquilla oratoria* (De Haan) larvae were investigated in the northwestern water off Incheon. *O. oratoria* larvae were monthly collected at 15 stations from early June to early October in 2007. Bongo net with 330 and 505 um mesh was deployed in a double once with an oblique tow way. Larval densities were relatively higher in southerner stations in July and in northerner stations in August and September. No larvae were discovered in June. Zoea I and II were not captured during the entire sampling period. Zoea III occurred in July for the first time and were found until September. Thereafter, the proportion of later stages increased. The number of zoeal stages decreased during the summer months and no larvae were found in October. Of zoeal stages, zoea IV was the most abundant in number. Zoeal densities were highest in July and August, particularly at the stations near the coast. *O. oratoria* larvae may be retained and grow within our study sites without advection to growing areas. Non-occurrence of zoea I and II indicate that they were retained near spawning grounds or near parental burrows. Pattern of larval occurrence was coincided with previous researches conducted in conspecific distribution ranges.

Key words : Mantis shrimp, *Oratosquilla oratoria*, Distribution, Larval development

I . Introduction

The Japanese mantis shrimp *Oratosquilla oratoria* (DeHaan, 1844) distributes in burrows in mud bottoms in the shallow waters from Peter the Great Bay, Russia through Japan,

Taiwan and China (Komai, 1927; Manning, 1971) and are commercially harvested in Asian countries (Colloca et al., 2003; Garces et al., 2006; Lui et al., 2007). *O. oratoria* distributes with the depth range from 10 to 30 m on mud flats and inhabits in the U-type burrows

[†] Corresponding author : 051-629-5928, wpark@pknu.ac.kr

up to 30 cm (Hamano & Matsuura, 1986). *O. oratoria* predaes small crustaceans, polychaetes and small fish during night (Hamano & Matsuura, 1986), and is consumed by various kinds of demersal fish (Shuozeng, 1993).

Coastal areas including the shallow continental shelf and intertidal zone are preferred by *O. oratoria* because they use the areas for reproduction and growth (Dai & Yang, 1991). Coastal areas along the western and southern Korean peninsula display a similar pattern so that *O. oratoria* abundantly occur along the Korean coastal waters (Hong et al., 2006).

O. oratoria spawns from the middle of May to late August in the sea of Hiuchi-Nada and Tokyo Bay in Japan (Hamano & Matsuura, 1984; Senta et al., 1969). The eggs of *O. oratoria* hatch about two weeks later after spawning at 25°C (Hamano & Matsuura, 1987). After hatching, the first zoea and second zoea stay near the parental burrows before leaving for planktonic life (Hamano & Matsuura, 1987). *O. oratoria* settles as juveniles two or three months after planktonic life (Kawamura et al., 1997; Kodama et al., 2009). Juveniles grow up to 6 cm in total length in the first year in Japan (Hamano & Morrissy, 1992) and may live approximately for four years (Hong et al., 2006). The age when they are fished commercially reaches 2-3 years in Tokyo Bay, Japan, according to the age estimation using lipofuscin (Kodama et al., 2005).

Hypoxia generally occurs during summer when the density stratification in the water column is prominent and hypoxic waters affect marine animals in abundance, vertical distribution and behaviors (Miller et al., 2002).

Hypoxia affects stock decline of *O. oratoria* in Tokyo Bay, in Japan (Kodama et al. 2006a).

Planktonic larval stages are critical to the life histories of many benthic marine invertebrates (Thorson, 1950; Park et al., 2007). Variable recruitment events caused by differential larval survival have been implicated as possible factors explaining population fluctuations in marine invertebrates (Thorson, 1950; Jamieson, 1986). In *O. oratoria*, interannual variation of planktonic larval recruitment has been regarded as a major factor affecting the interannual variability of populations (Kodama et al., 2006b, 2009). However, although *O. oratoria* is an economically important species, little research of larval ecology of the species has been done in Korean waters.

We investigated the development and distribution of *O. oratoria* larvae in the northwestern water off Incheon. This will provide basic information for the effective management of *O. oratoria* populations in the research area.

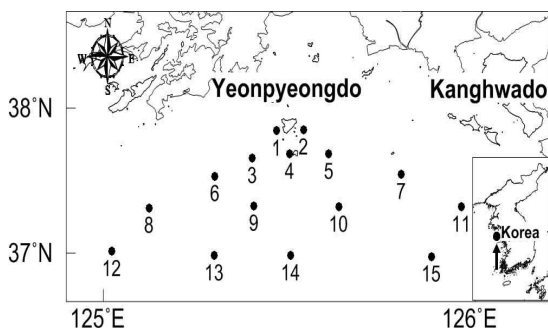
II. Materials and methods

This research was conducted based on the samples collected from the rehabilitation project for Korean swimming crab in the northwestern waters off Incheon. Zooplankton was collected at 15 sampling stations monthly from early June to early October in 2007 [Fig. 1]. At each station, a 80 cm diameter bongo net with 505 and 330 μm meshes was deployed at each station in a double oblique fashion once from near the bottom to the surface. We report here data on samples collected with the 330 μm

mesh net. General Oceanics model 2031 flow meters were placed inside the bongo nets for calculation of filtered water volumes using beginning and end readings. Plankton samples were preserved in 5% buffered formalin aboard the sampling ship and transported to the laboratory. We separated *O. oratoria* larvae from the zooplankton samples and identified to the larval stage following Hamano & Matsuura (1986).

Sea surface temperature (SST), sea surface salinity (SSS) and dissolved oxygen (DO) were simultaneously measured during zooplankton sampling periods. The physical environments were sampled vertically with a conductivity, temperature, and depth (CTD) profiler, Sea-Bird SBE 19 Seacat to near bottom at each sampling station.

Pearson product moment correlation coefficient was used to analyze the relationship between SST, SSS, DO and larval density.

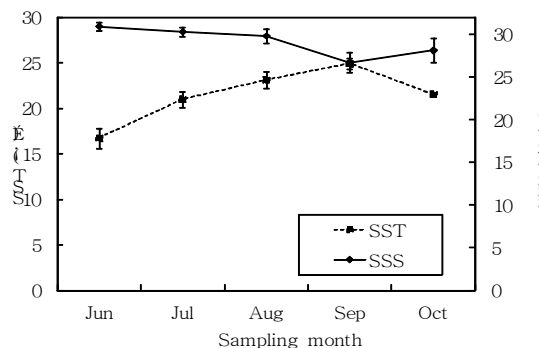


[Fig. 1] Sampling stations of zooplankton in the northwestern water off Incheon in 2007

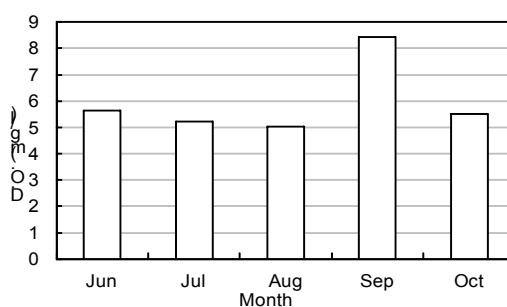
III. Results

1. Sea surface temperature (SST) and salinity (SSS), and dissolved oxygen (DO)

During the sampling periods, SST ranged from 16.7°C to 24.9°C. SST was lowest in June (16.7°C) and increased during the summer months. SST was highest in September (24.9°C) and decreased in October [Fig. 2]. SSS did not vary widely during the sampling periods at approximately average 29.5 psu. However, it was relatively lower in September with the value of 26.7 psu [Fig. 2]. Average DO concentration between sampling stations gradually decreased from June (5.64 mg/l) to August (5.03 mg/l), and it varied with months in September (8.4 mg/l) and in October (5.5 mg/l) [Fig. 3].



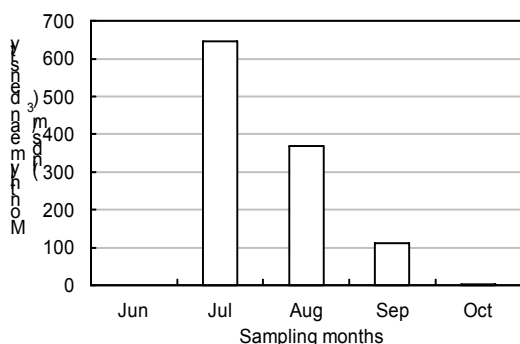
[Fig. 2] Monthly variation of mean sea surface temperature (°C) and salinity (psu) in the northwestern water off Incheon in 2007



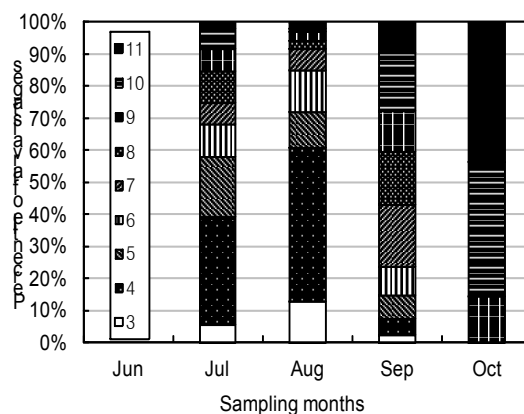
[Fig. 3] Monthly variation of mean dissolved oxygen (mg/l) in the northwestern water off Incheon in 2007

2. Larval development and distribution

O. oratoria larvae did not occur in June and were collected firstly in July [Fig. 4]. Earliest larval stage was zoea III (ZIII), which collected in July. Mean densities of *O. oratoria* larvae in July were 650 inds./m³ and decreased there after up to 0.04 inds./m³ at a few stations in October. All larval stages were collected from July to September [Fig. 5]. During the entire sampling period, density of zoea IV (ZIV) was highest, followed by zoea V (ZV) [Fig. 5]. In July, larval density was relatively higher at the stations near Yeonpyeongdo and offshore [Fig. 6]. In August, larval densities were higher than 1,000 inds./m³ at the northern stations except three stations lower than 1,000 inds./m³ [Fig. 6]. In September, larval densities were higher than 500 inds./m³ at the stations near Yeonpyeongdo while those of other stations were lower than 100 inds./m³ [Fig. 6]. In October, larvae occurred at only five stations with the densities lower than 10 inds./m³ [Fig. 6].



[Fig. 4] Monthly mean density (inds./m³) of Japanese mantis shrimp *Oratosquilla oratoria* larvae in the northwestern water off Incheon in 2007



[Fig. 5] Monthly composition of zoeal stages of Japanese mantis shrimp *Oratosquilla oratoria* in the northwestern water off Incheon in 2007. Numbers in the legend indicate zoeal stages

3. Relationship between larval density and environmental factors

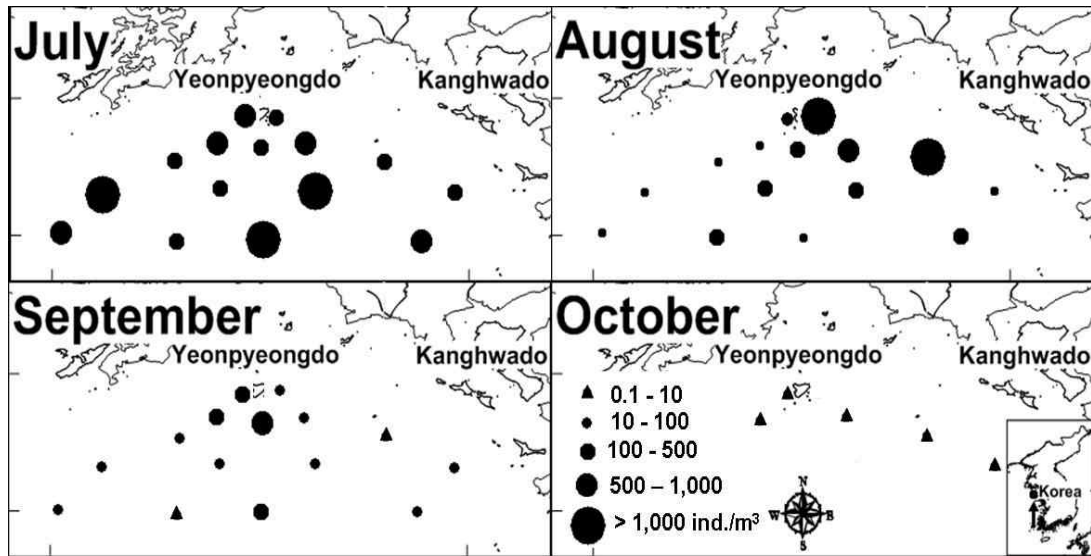
Larval densities were not significantly correlated with environmental factors: larval density and SST ($r=0.59$, $p=0.12$); larval density and SSS ($r=0.41$, $p=0.30$); larval density and DO ($r=0.62$, $p=0.14$) <Table 1>.

<Table 1> Pearson's product moment correlation coefficients between larval densities and environmental factors, sea surface temperature (SST), sea surface salinity (SSS) and dissolved oxygen concentration (DO)

	SST	SSS	DO
Larval densities	$r=0.59$, $p=0.13$	$r=0.41$, $p=0.30$	$r=0.62$, $p=0.14$

V. Discussion

O. oratoria spawns two times during the spawning period (Hamano & Matsuura, 1984).



[Fig. 6] Larval density (inds./m³) of Japanese mantis shrimp *Oratosquilla oratoria* in the northwestern water off Incheon during July–October 2007. *O. oratoria* larvae were not collected in June 2007

After egg hatching, zoea I and II swim or crawl near the parental burrows, or inhabit and stay mother's marsupiums in the burrows (Hamano & Matsuura, 1984; Ohtomi et al., 2006). Mother shrimps protect the egg and early larvae until they grow to the second zoeal stage. Actively moving and feeding ZIII are found in the pelagic waters at a relatively long distance from spawning grounds (Hamano & Matsuura, 1984; Ohtomi et al., 2006). While zoea I and II stay near spawning and hatching areas and ZIII start planktonic life. At the current research, we found larval stages later than ZIII in the pelagic waters because the first planktonic stage of *O. oratoria* is ZIII.

Low dissolved oxygen in the water column causes seriously high mortality of aquatic animals (Diaz & Rosenberg, 1995). In particular, low dissolved oxygen at deeper water is fatal to *O. oratoria* because juveniles of *O. oratoria*

live on the bottom. In Tokyo Bay, Japan, bottom hypoxia begins to appear in April and occupies more than half of the whole bay area in July and August (Kodama et al., 2006a). Bottom hypoxia fades out in November (Kodama et al., 2006a). The threshold level of bottom dissolved oxygen concentration for the existence of juveniles was 2.78 ml/l, implying that hypoxia restricted the spatial distribution of juveniles. In addition, high mortality of juveniles of *O. oratoria* may result in low fishery harvest for commercial sizes (Narita et al., 2007; Kodama et al., 2006a; Ohtomi et al., 2006). Low dissolved oxygen in the water column also affects the survival rates of zooplankton (Kodama et al., 2006a). However, dissolved oxygen concentration in the study was higher than threshold level at all stations.

Mortality rate of *O. oratoria* larvae lower than 10 psu drastically increases (Kodama et

al., 2003). During the entire research period, salinities were higher than 25 psu, implying that salinity at the sampling areas did not affect the distribution of *O. oratoria* larvae.

Marine crustacean populations are sustained by the recruitment of larvae that undergo ontogeny near hatching locations or by returning larvae that emigrate to the coastal region for ontogeny after hatching (Cronin & Forward, 1979; Christy & Morgan, 1998).

Zoea I of *Callinectes sapidus* in Chesapeake Bay (Provenzano et al., 1983) and Delaware Bay (Epifanio, 1995) and *Pachygrapsus crassipes* in San Diego Bay (DiBacco et al., 2001) are positioned at the surface water during ebb tides when they emigrate. After undergoing ontogeny on the shelf or offshore areas, crab megalopae return to nearshore and estuaries (Dittel & Epifanio, 1982; Little & Epifanio, 1991). Alternatively, larvae which are retained in estuaries display no migratory patterns or reverse migratory behavior to surface water to avoid offshore advection during ebb tides (Lambert & Epifanio, 1982; DiBacco et al., 2001). Zoea I of *Rhithropanopeus harrisi* in Delaware Bay is found near bottom during flood tides when they are transported upriver (Lambert & Epifanio, 1982). *Lophopanopeus* spp., which are retained in San Diego Bay, do not migrate vertically (DiBacco et al., 2001). Larval stages of migrating species are the first stage and the last stage at the egg hatching while all larval stages of non-migrating species are found at the egg hatching areas. In our study, all larval stages were found except zoea I and II, which stay near bottom. Accordingly, *O. oratoria* larvae did not migrate, but undergo development in the study area, being recruited

to local populations after completing larval development.

Primary blooms in temperate latitudes are controlled by sunlight and nutrients in the water column (Garrison, 2005). Primary bloom in spring supports the secondary production of various kinds of zooplankton. Phytoplankton consumes nutrients in the water column and after using all nutrients in the water column, phytoplankton production decreased drastically by the consumption of zooplankton and by the low production of phytoplankton due to lack of nutrients (Garrison, 2005). First occurrence of *O. oratoria* larvae in the study area in July indicates that zoea I and II of *O. oratoria* were born in June or earlier than that to feed benthic diatom or settled phytoplankton because the larvae of the stages dwell on the bottom.

Also, bloom of secondary production of zooplankton support larval populations of marine crustaceans in the water column to enhance larval survival. Continuous occurrence of zoea III may be resulted from continuous spawning, which means they are not synchronized spawners. However, larval occurrence pattern in the study did not coincide with Tokyo Bay, spawning two times during the spawning periods, early season (May-June) and late season (July-September) per year (Kodama et al., 2006b). Ohtomi et al. (2005) separated temporal distributions of *O. oratoria* larvae in Tokyo Bay into two distinct periods in relation to commercial catch data. Commercial catch of the Japanese mantis shrimp, *O. oratoria* in Tokyo Bay was higher during 1980s and lower during the 1990s. The peak of larval densities of *O. oratoria* was in June and July during the

higher catch period, while it was in August and September during the poor catch period. However, we could not match whether larval density peaked in July indicated it was higher catch period, or we might have missed the second peak because of monthly sampling interval. In addition, we do not have comparable commercial data for *O. oratoria* with larval data because larvae were collected for only single year and long time catch data in the research area did not exist. Accordingly, to verify the pattern of larval occurrence pattern of *O. oratoria* in the study area, long period monitoring in adult and larval catch is strongly required.

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