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A PRELIMINARY STUDY ON THE EFFECTS OF SALINITY ON EGG DEVELOPMENT OF EUROPEAN SQUID (*LOLIGO VULGARIS* LAMARCK, 1798)

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Key words: development, egg, incubation, *Loligo vulgaris*, salinity, squid

Abstract

The effects of salinity on the development and incubation of European squid (*Loligo vulgaris*, Lamarck, 1798) eggs were investigated from December 2001 to March 2002. The egg capsules were incubated in 37‰, 34‰, 31‰, 28‰, and 0‰ salinity without any acclimation process. Mean temperature was $12\pm 2.0^{\circ}\text{C}$. Illumination was maintained at 1.5 lux at the water surface. Full embryonic development and hatching were observed after 64-76 and 66-76 days at 37‰ and 34‰ salinity, respectively. Hatching rates were estimated as 88.5% at 37‰ and 60% at 34‰. In salinity below 34‰, the eggs died at very early stages. Average dorsal mantle lengths of the new hatchlings were 2.53 ± 0.08 mm at 37‰ and 2.48 ± 0.11 mm at 34‰.

Introduction

Embryonic development and hatching of eggs in *Loligo vulgaris* are well known at different incubation temperatures. Naef (1928) reported that, at 22°C , hatching occurs on day 28 after spawning. Jecklin (1934) noted that embryonic development takes 4.5 weeks at slightly above 14°C and 3 weeks at 22.5°C . According to Mangold-Wirz (1963), hatching

occurs 40-45 days, 26-27 days and 30 days after spawning at temperatures of $12-14^{\circ}\text{C}$, 22°C , and 17°C , respectively. Boletzky (1974) found that embryonic development takes about 40 days at 15°C and Boletzky (1987) found it takes 70 days at 10°C and 25 days at 20°C .

Egg masses of *L. vulgaris* occur in 60-160

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mm capsules. Each string contains 50-130 eggs (mean 90; Mangold-Wirz, 1963). Marthy and Aroles (1987) and Martins (2001) reported that one squid egg capsule contains 50-80 and 95-128 eggs, respectively. Egg diameters are 2.0-2.7 mm for *L. opalescens* (Fields, 1965), 1.0-1.6 mm for *L. pealei* (Summers, 1983), 2.8 mm for *L. vulgaris reynaudii* (Blackburn et al., 1998) and 2.3-2.7 mm for *L. v. vulgaris* (Worms, 1983).

The speed with which loliginid eggs develop is inversely related to the size of the eggs (Segawa et al., 1988). The size of hatchlings depends largely on the size of the spawned egg (Mangold et al., 1971; Segawa et al., 1988).

In the North Sea, squid is found in shallow coastal waters only when the salinity exceeds 30‰ and has a salinity tolerance of 30-36‰ (Tinbergen and Verwey, 1945). In the Marmara Sea (Turkey), squid is distributed in coastal waters with a salinity above 25‰ (Katagan et al., 1993; Ünsal et al., 1999). We have found no study about the effects of salinity on embryonic development and hatching of eggs in the squid. Therefore, this study aimed to determine the optimum salinity range for development and hatching of *L. vulgaris* eggs under controlled conditions.

Materials and Methods

Egg capsules of *L. vulgaris*, laid on gill or trammel nets at depths of 20-25 m, were collected by local fishermen in Izmir Bay on December 16, 2001. Experiments were carried out at indoor facilities of the Fisheries Faculty in Ege University, Izmir, Turkey, from December 16, 2001, to March 1, 2002. After obtaining the egg masses, their morphometric characteristics were measured and they were separated according to embryonic development stage. During the experimental period, embryonic development stages of the eggs were observed under a binocular microscope at regular intervals. Criteria according to Naef (1928; Roman numerals) and Arnold (1965; Arabic numerals) were used to describe the embryonic development stages. At the beginning of the experiment, the embryonic development stage was 7 (or I), which has 16 cells.

The egg mops were separated into clusters of five capsules. Then, they were divided into five groups based on experimental salinity levels: 37‰, 34‰, 31‰, 28‰ and 0‰. All experiments began at the same water temperature (11.5°C) and were maintained at ambient temperature during the experimental period. Sea water was changed daily by replacing 75% of the tank volume with fresh sea water which was regulated to the experimental salinity and temperature and supplied with continuous aeration at 35 ml/min, directly to the egg capsules.

For each experimental salinity at which hatching occurred, the length of the incubation period, total hatch, and viable hatch of the paralarvae were estimated. Live new hatchlings were removed from the tanks and counted daily. The length of the egg capsules, egg dimensions, number of eggs per capsule, and dorsal mantle lengths of the paralarvae were measured. Differences between grouped data were analyzed by Student's *t* test and χ^2 test.

Results

The water temperature ranged 6.9-15.1°C during the experimental period. The mean temperatures were $12\pm 2^\circ\text{C}$ for the 37‰ and 34‰ treatments and $11.4\pm 2^\circ\text{C}$, $10.9\pm 0.7^\circ\text{C}$ and $10.8\pm 0.5^\circ\text{C}$ for the 31‰, 28‰ and 0‰ treatments, respectively (Fig. 1). Lengths of egg capsules, egg dimensions and dorsal mantle lengths are given in Table 1.

Full embryonic development of the eggs was observed only in the 37‰ and 34‰ treatments. In the 31‰ treatment, the embryonic development stage of the eggs was unclear and, by day 20 of the experiment, all embryos died in stages 14-16 (IV-VI/VII). In the 28‰ treatment, the eggs died in the initial stage on day 4. In the 0‰ treatment, the eggs reached stage 10 (I), but all died in the second day of the experiment.

The embryonic development of the eggs in 37‰ and 34‰ salinity stopped when the temperature dropped below 8°C, but the embryos survived and continued developing as soon as the temperature increased. The embryonic development of the eggs, accord-

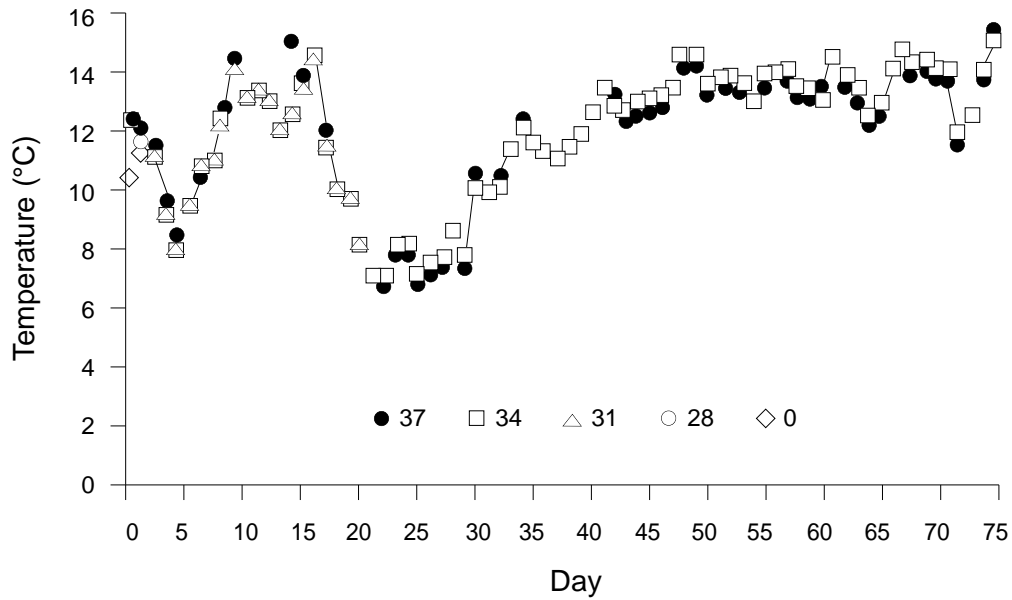


Fig. 1. Water temperatures.

Table 1. Lengths of egg capsules, eggs and new hatchlings.

Values	Capsule length (mm)	Egg length (mm)	Egg width (mm)	Eggs per capsule (no.)	Dorsal mantle length in 37‰ (mm)	Dorsal mantle length in 34‰ (mm)
n	25	30	30	1964	30	30
Minimum	115	2.36	1.64	53	2.28	2.24
Maximum	170	2.76	1.88	111	2.68	2.72
Mean	129.6	2.54	1.8	78.56	2.53	2.48
SD	12	0.12	0.07	13.3	0.08	0.11
V	9.3	4.7	3.9	17	2.8	4.4

SD = standard deviation; V = coefficient of variance

ing to the criteria of Arnold (1965), is summarized in Fig. 2.

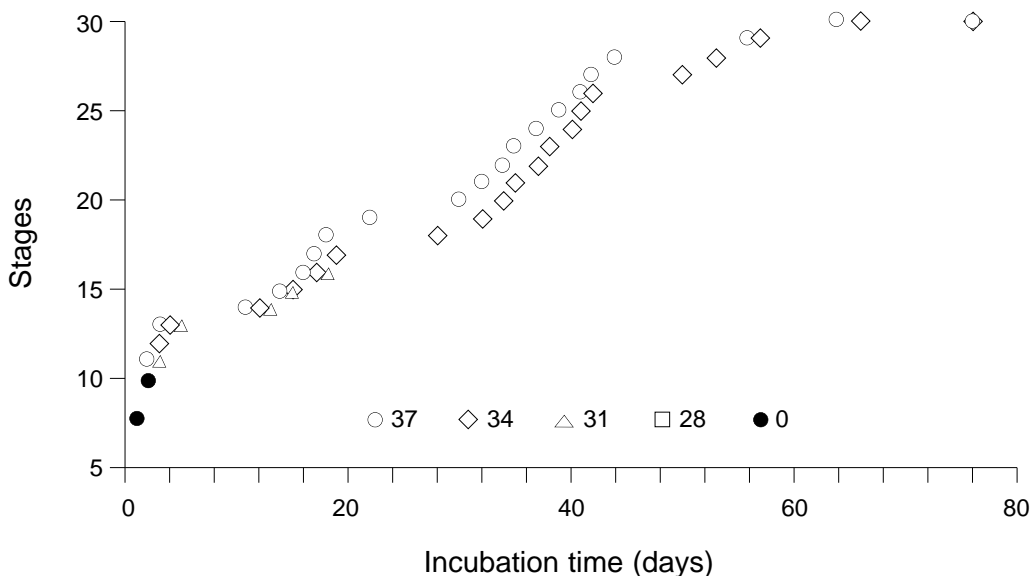
Hatching took place between 64 and 76 days in 37‰ salinity and 67 and 76 days in 34‰, so the length of incubation in both treatments is estimated as 76 days. Total hatching was 88.5% in 37‰ and 60% in 34‰ while viable hatching was estimated as 82% in 37‰ and 56% in 34‰. There were significant differences in viable hatching between 37‰ and 34‰ (χ^2 test; $p < 0.05$) but no significant difference in dorsal mantle length between these two treatments (Student's t test; $p > 0.05$). The hatching period in 37‰ and 34‰ salinity lasted 9-12 days. The percent of hatchling paralarvae is shown in Fig. 3.

Discussion

Salinity directly affected embryonic development, total hatching and viable hatching of *L. vulgaris* eggs. However, embryonic development time of the eggs was inversely related to the incubation temperature (Naef, 1928;

Jecklin, 1934; Mangold-Wirz, 1963; Mangold and Boletzky, 1973; Boletzky, 1974, 1979, 1987; O'Dor et al., 1982; Marthy, 1982; Worms, 1983; Segawa, 1987; Blackburn et al., 1998; Martins, 2001). Usually, lower temperature retards the rate of embryonic development of cephalopods and higher temperature accelerates it. Additionally, the rate of embryonic development of the squid investigated in this study is influenced by water temperature and low salinity.

Although, in this study the average length of the egg capsules corresponded to those of Mangold-Wirz (1963), the mean number of eggs per capsule was lower than those of Naef (1928), Jecklin (1934), Mangold-Wirz (1963) and Boletzky (1974, 1987). The speed at which eggs develop in loliginids is inversely related to the size of the eggs (Segawa et al., 1988). Yet, in *L. vulgaris*, which has small eggs, development was relatively slow; the present study indicated incubation periods in the 37‰ and 34‰ treatments as approximately one and a



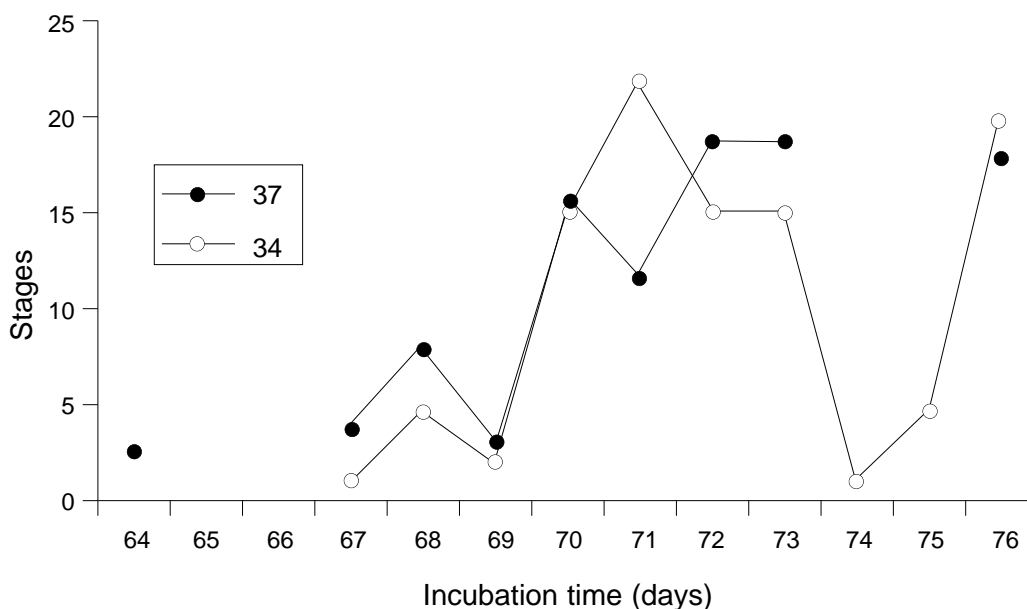


Fig. 3. Percent hatching in 37‰ and 34‰ salinity.

half times longer than those of Mangold-Wirz (1963) at the same temperature.

The size of hatchlings depends largely on the size of the spawned egg (Segawa et al., 1988; Mangold et al., 1971). The eggs of *L. forbesi*, which measure up to 3.1 mm in diameter (Segawa et al., 1988), are the largest known for any loliginid. Egg diameter in other species ranges 2.0-2.7 mm (*L. opalescens*; Fields, 1965), 1.0-1.6 mm (*L. pealei*; Summers, 1983), 2.8 mm (*L. vulgaris reynaudii*; Blackburn et al., 1998) and 2.3-2.7 mm (*L. v. vulgaris*; Worms, 1983). The average egg diameter in the present experiment was 2.54 mm.

In present paper, the dorsal mantle length of hatchlings (2.53 ± 0.08 mm in 37‰; 2.48 ± 0.11 mm in 34‰) was smaller than those of Turk et al. (1986; *L. vulgaris*, 3.4 mm) and Villanueva (1994; 3.06 mm), but the measurements were almost the same as for the larger *L. v. reynaudii* (2.4 mm; Blackburn et al., 1998). In other species of the genus, the dorsal mantle length of hatchlings differs

widely from rather small (1.8 mm in *L. pealei*; Summers, 1983) to medium (2.7 mm in *L. opalescens*; Hixon, 1983), large and very large (3.9-4.9 mm in *L. forbesi*; Hanlon et al., 1989).

Mangold-Wirz (1963) indicated that development of eggs stops when the temperature drops below 10°C, but embryos survive and continue development as soon as the temperature increases in *Octopus vulgaris*. In the present paper, the same phenomenon is recorded for the first time in squid embryos.

In conclusion, the hatching rate, survival rate and incubation time of *L. vulgaris* eggs were affected by the level of salinity. Squid eggs were easily incubated at 34-37‰ salinity while salinity levels below 34‰ were lethal. However, more detailed studies about the effects of salinity on development of *L. vulgaris* eggs are needed.

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