

## Relationships Between Survival Period and Temperature of Newly Hatched Pacific saury *Cololabis saira* under Starvation Conditions

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**Abstract:** To clarify the relationships between the survival period of newly hatched Pacific saury *Cololabis saira* which use only endogenous nutrition and water temperature, we observed the survival periods under starvation conditions at four temperatures (10, 15, 20 and 25°C). The starvation tolerance period was shortened with increasing temperature. This study suggests that newly hatched Pacific saury can survive for approximately 5–10 days (50% mortality period) without feeding in 10–25°C under non-predator conditions, but such an extended period of starvation is considered to affect subsequent growth and survival.

**Key words:** Pacific saury; Survival period; Starvation tolerance; Temperature

Natural mortality rates of fish are highest in early life (Houde 1997). For coastal areas of Japan, growth and survival rates of Pacific saury *Cololabis saira* in the early life stage have been studied (Watanabe et al. 1988; Watanabe et al. 1997; Watanabe et al. 2003), however starvation tolerance of newly hatched larvae of Pacific saury has not yet been determined. Distribution of Pacific saury is spread widely in the North Pacific Ocean and the spawning is observed somewhere throughout all the seasons. The sea surface temperature (SST) of their larval distribution area has been found to vary markedly (SST in the distribution area range 10–25°C and in particular 15–18°C SST in nearshore Japan (Odate 1956); main distribution area is 18–23°C SST (Hattori 1964); main distribution area is 15–22°C SST (Oozeki et al. 2007)). This study investigated the relationships between survival and temperature of newly hatched

Pacific saury under starvation conditions. We estimated the potential period that newly hatched larvae were able to survive without encountering appropriate environmental conditions (good relationships between food availability and ambient water temperature).

Fertilized eggs of the Pacific saury, attached to drifting brown algae, were collected in Kumano-nada Mie Prefecture (18–19°C SST), Pacific Ocean, Japan on 10 May 2005. The eggs were kept in plastic bags containing 10 liters of ambient seawater (18°C, 32–34ppt) with oxygen and then transported to National Fisheries Research Institute, Fisheries Research Agency, Akkeshi by plane and truck. The eggs were stocked and then incubated in a 500 liters circular shaped tank at a temperature range of 17–18°C (water exchange rate was 120%/day). Replicates of 30 newly hatched larvae were collected and were stocked in plastic bags (Trade name: Unagi Bukuro and used for transport of fish fry) with 10 liters of filtered seawater (17°C, 32–33ppt). These plastic bags were floated two pieces each in four kinds of temperature tanks (controlled at 10, 15, 20 and 25°C using a 500W heater). Twice a day (08:00–09:00 and 15:00–16:00), we counted the number of living individuals, collected dead individuals, and measured the water temperature (true temperature: 10.90 ± 0.59°C (mean ± SD), 15.90 ± 0.49°C, 20.50 ± 0.27°C and 24.90 ± 1.40°C). To avoid confusing natural death with the death related to injury during the transport, dead individuals during 12 hours after the start of the experiment were not included in the data set.

We observed the survival period of newly hatched Pacific saury under starvation conditions at four temperatures (10, 15, 20 and 25°C) to determine the relationship between survival and temperature (Fig. 1). As a result, the first mortality were observed 2.0–3.5, 1.5–3.0, 1.5–2.0 and 1.5 days after hatching (DAH) under the four ambient water temperatures (10, 15, 20 and 25°C), respectively. Yusa (1960) reports that newly hatched larvae of Pacific saury consumed the yolk mostly by 2–3 DAH, and completely by 3–4 DAH under 14–21°C rearing conditions. In the case of Japanese eel *Anguilla japonica*, the survival rate rapidly decreased after consumption of the oil droplet (Okamura et al. 2007). Probably, the first mortality of Pacific saury is related to the consumption of the yolk. The survival rates of Pacific saury at 10°C in particular

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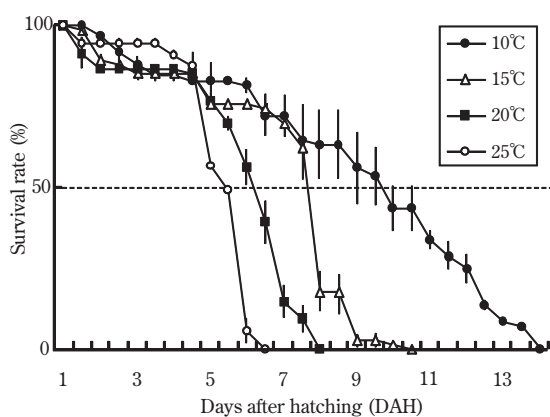
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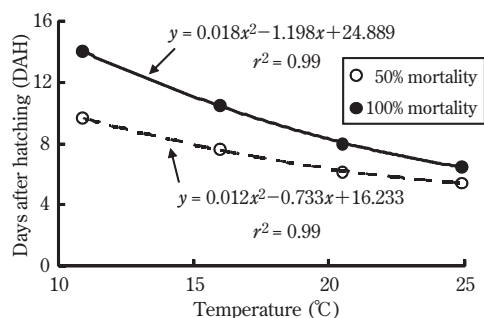
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slowly decreased. Although Pacific saury larvae have been observed to be distributed at SST ranging 10–25°C (Odate 1956; Hattori 1964; Oozeki et al. 2007), lower SST (such as 10°C) would induce lower growth and higher mortality in other fish larvae, for example Japanese sardine *Sardinops melanostictus* (Matsuoka 2001) and Japanese eel (Okamura et al. 2007). The relationship between survival periods of newly hatched Pacific saury and water temperature are shown in Fig. 2. The mean 50% mortality period at the four temperatures (10, 15, 20 and 25°C) was 9.7, 7.6, 6.2 and 5.4 days and the mean 100% mortality period was 14.0, 10.5, 8.0 and 6.5 days, respectively. The starvation tolerance period was shortened with increasing temperature. Exhaustion of endogenous reserves would be accelerated with increasing temperature. These results are supported by observations on relationships between exhaustion of endogenous reserves and temperature (Laurence 1973; Matsuoka 2001; Okamura et al. 2007). This study suggests that newly hatched Pacific saury can survive for approximately 5–10 and 7–14 days (50% and 100% mortality period, respectively) without feeding in 10–25°C under non-predator conditions, but such an extended period of starvation is considered to affect subsequent growth and survival, e.g. “Growth-mortality hypothesis”



**Fig. 1.** Relationships between days after hatching (DAH) and survival rate under the four different water temperature conditions. Vertical bars show standard deviation.



**Fig. 2.** Relationships between water temperature and 50% or 100% mortality period. Regression formula are given adjacent to the respective 50% and 100% regression lines for the mortality period models under different water conditions, respectively.

(Anderson 1988) and “Growth-selective mortality” (Takasuka et al. 2003). Further study is needed to research the effects of temperature and delayed initial feeding for the survival and growth of newly hatched Pacific saury.

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