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Changes in the Egg and Larval Densities of Striped Beakperch (Pisces; Oplegnathidae) during Development

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Synopsis

The densities of naturally spawned eggs and newly hatched larvae of cultured striped beakperch, *Oplegnathus fasciatus*, were measured to understand egg and larval transportation in the water. The density changed during embryonic development. The eggs in the early to middle developmental stages were less dense than the seawater in the tank in which they were spawned, but at a later developmental stage, they began to increase rapidly in density, becoming more dense than the seawater in the tank by the time of hatching. Larvae that did not move in the first 10 min after hatching became less dense than eggs in the early to middle developmental stages. The osmotic regulation of eggs and larvae may change during development. The results suggented that eggs and newly hatched larvae in the sea would not stay at a certain water level during development. Therefore, passive movement of such eggs and larvae may not always be uniform throughout development, because in situ horizontal flow sometimes varies with depth.

Introduction

Various marine fish spawn numerous floating eggs; most of which die of starvation or predation in the egg or larval stage[1]. Whether larvae survive depends on the quality and quantity of food and predators in the space in which they float. Thus, transportation in the water of eggs and larvae is important for recruitment of fishery resources.

Studies done to understand transportation of floating fish-eggs in the sea started in Europe in the late 19th century. The floating egg of many species change density during development[2]. When the eggs change in density, their vertical positioning in the sea will change accordingly, affecting their horizontal distribution[3]. There have been few quantitative measurements of egg density for fish species in Japanese waters[4-6]. Here, I measured the egg and larval density of the striped beakperch, *Oplegnathus fasciatus*, an important food and game fish in Japanese coastal waters.

Materials and methods

Naturally spawned eggs of *O. fasciatus* were collected on the night of 14 July 1989 from nine pairs of males and females kept together in a 3-t tank with overflowing seawater (23.9°C and 32.0 ‰; 1.0214 g/cm^3) at the Uragami Fisheries Laboratory of Kinki University.

Egg density was measured in the laboratory with use of density-gradient columns[7] (Fig. 1). The method relies on the preparation of stable columns of continuously graded solutions of

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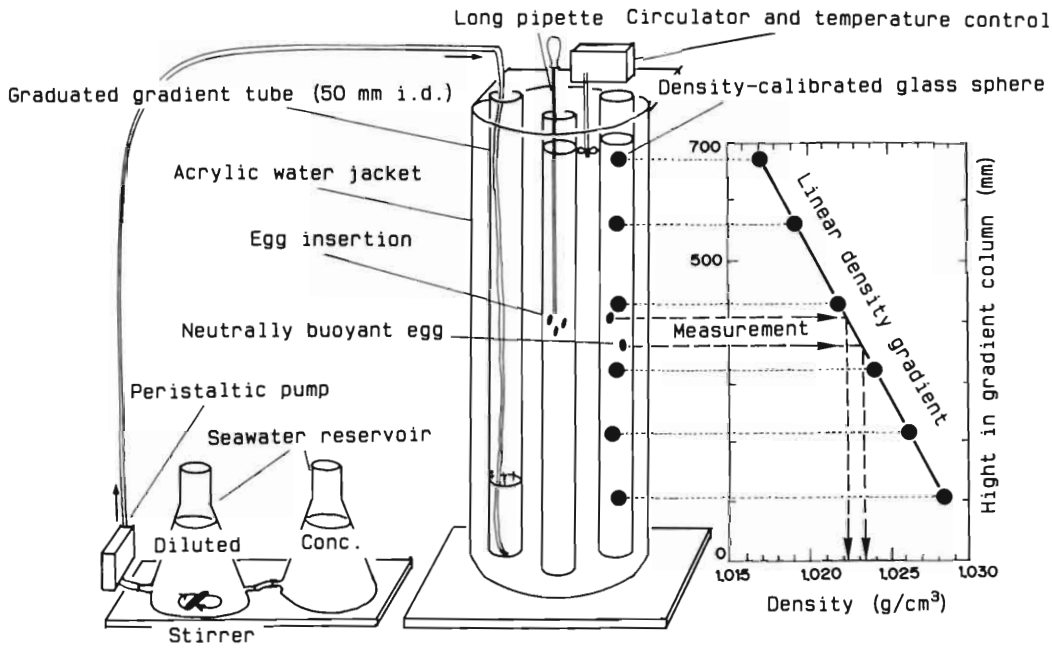

Fig. 1. Diagram of apparatus for measurement of egg and larval density with density-gradient columns[7]. For details of the procedure, see text.

seawater salts such that an egg introduced into the column moves to the level where it is in hydrostatic equilibrium. The absolute density at that level is found by reference to a calibration curve for each column made with marker floats (approx. 4 mm in diameter; Martin Instrument Co.) of known densities over a range of temperature. A temperature-controlled water jacket maintains the apparatus at a stable temperature and permits the resolution of densities to an accuracy of $\pm 2\times10^{-4}$ g/cm³ and a precision better than 4×10^{-5} g/cm³.

In operation, 11 or 12 eggs in the early developmental stage were introduced with a long, fine pipette into two density gradient columns (both maintained at 24°C) at a level with a density approximately equals to that of seawater in the tank in which the eggs were spawned. This introduction procedure was done to eliminate the osmotic effect of low-density water through which the eggs would pass; low-density water could cause underestimation of the egg density[8], and such underestimation might not be negligible when the eggs were placed on top of the density column.

The eggs were left to develop in the columns. The levels of the eggs in the columns were observed every 30 min from introduction until hatching; egg densities were computed later. Developmental stages of the eggs in stock samples kept in a 2-L beaker with 32‰ seawater at 24°C were checked under a microscope every 3 h; egg diameters were measured at this time with a micrometer. Newly hatched larvae were observed continuously for 90 min to find at which level they were suspended; the larvae were developing normally.

Here, a total of 23 eggs were examined; 11 eggs hatched normally, 3 eggs sank to the bottom of the columns and died in the middle developmental stage, and 9 eggs did not hatch, although they were developing well and were moving their tails. The first egg hatched out at 21:30 on 15 July and the last one hatched out at 06:30 on 16 July. The eggs were assumed to have been spawned between 16:00-20:00[9], so they took 24-34 h to hatch. All eggs were together in almost the same

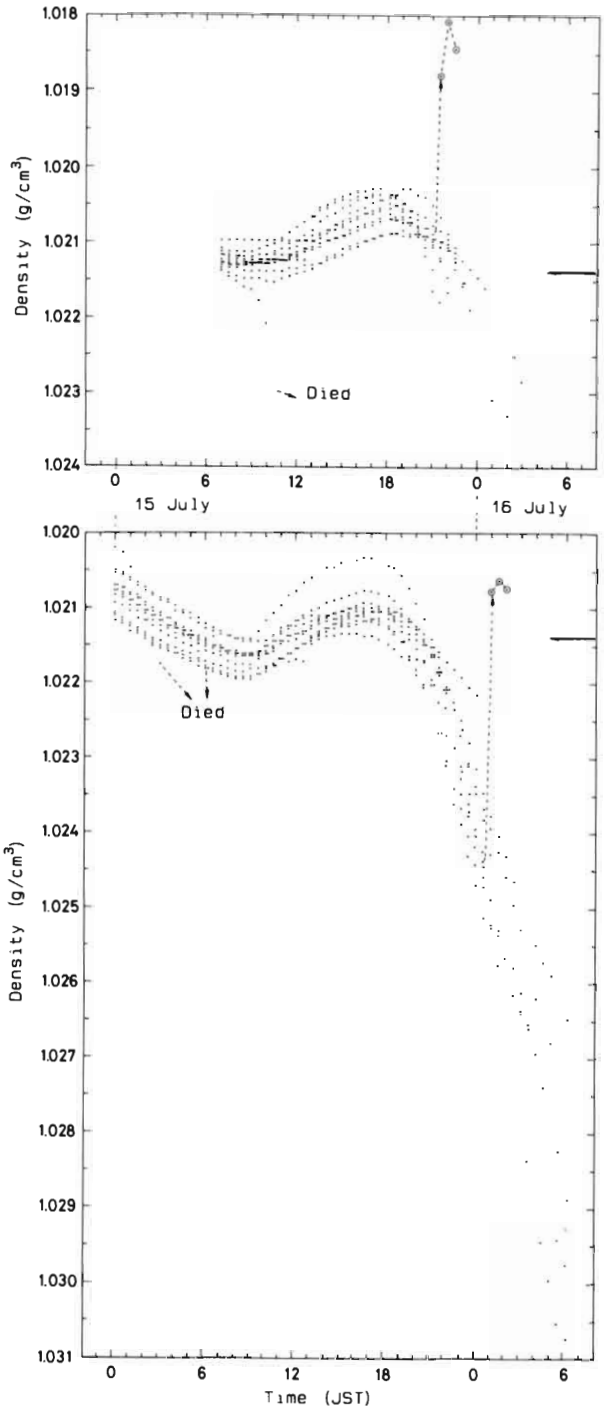

Fig. 2. Changes in the egg and larval densities of striped beakperch during development. Densities of 11 or 12 eggs (dots) in two density-gradient columns (upper and lower figures) were recorded every 30 min. Dots in circles show the densities of a larva within 90 min after hatching for each columns. Arrows show the density of the water in which the eggs were spawned.

developmental stage to each other at all times. Spawning therefore might have been accomplished in a short period on the evening of 14 July. The time of hatching out differed, perhaps because of differences in health or strength.

Results and discussion

1. Changes in the egg density and floating position during development

Figure 2 shows the changes in the egg density during development. The eggs in the early to middle developmental stages were 0–0.001 g/cm³ less dense than the water in which the parental fish spawned; however, the eggs became more dense in later stages. Their densities increased with time from spawning until the stage immediately before the appearance of the optic vesicle and Kupffer's vesicle (about 09 : 00 on 15 July), then decreased until a stage before the beginning of the heart beat and embryonal movement (about 18 : 00 on the same day), and then increased again rapidly until hatching. The increase was as rapid as that of dead eggs. Each egg maintained its position relative to the others in the course of ascending or descending in the columns.

It has been reported that eggs tend to become gradually heavier during development[2,7]. However, recent studies have shown that the egg density begins to increase in the later stages[6,8,10]. My results have also suggested that the egg density begins a rapid increase at a particular stage in later development.

What mechanisms cause the changes? The egg diameters ranged from 0.81 to 0.97 mm (mean; 0.90 mm) and did not change significantly with time. Thus, egg components must have changed. The eggs maintain their positive buoyancy by keeping low-density fluid against the downward force due to protein and other heavy components[11]. To keep eggs buoyant, osmotic work might thus have to be continued, because the chorion of floating eggs is not completely impermeable throughout development[12]. FRANZ[13] has suggested that the slight loss of egg buoyancy as hatching approaches is due to the gradual consumption of the low-density yolk with development. I suggest instead that the increase in egg density in the later stages of development might be triggered off by the end of osmotic regulation in the eggs; the observed increase seemed too large to be explained by yolk use. The trigger may be the hatching enzyme that softens the chorion in developmental stages near hatching[14]; I suppose it makes the chorion permeable enough to let the seawater enter the perivitelline space. Then the eggs can become more dense than the surrounding seawater.

That the eggs kept their positions relative to each other while ascending and descending may be usual when the sea is fairly calm[15]. The physiological cause and ecological meaning of this phenomenon are not known.

2. Density of newly hatched larvae

Larvae that did not move in the first 10 min after hatching became as buoyant as, or less dense than the eggs in the early to middle developmental stages (Fig. 2). Similar results have been reported for sprat and pilchard[8]. These results do not agree with the report that larvae newly hatched after the descent of late-stage eggs recover buoyancy to stop descending[10]. The degree of recovery in buoyancy was enough to make the larvae ascend.

As suggested by SHELBOURNE[16], and also through analogy with the causes of buoyancy in eggs[11], I assume that newly hatched larvae require low-density fluid in their subdermal space to ascend. The findings reported here suggest that the primordial fin-fold of a larva begins to regulate osmotic balance between the subdermal space and the surrounding seawater within 10 min after the larva hatches.

In conclusion, if eggs and newly hatched larvae change density with time, they would not stay

at a certain level in the sea. Such eggs and larvae may not always be uniformly drifted throughout embryonic development because in situ horizontal flow sometimes varies with depth. This suggestion was first made over 80 years ago[3], but it has not been emphasized enough when the transportation of eggs and larvae in the sea is being considered. Transportation even in the egg stage of development may not be uniform with time. The mechanisms of change in the egg and larval density should be studied. It is not known how the changes affect the in situ transportation of eggs and larvae.

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イシダイ卵・仔魚の発生にともなう比重変化

田中祐志

摘　要

魚卵・仔魚の輸送に関する基礎的知見を得るために，飼育イシダイが自然産卵した卵とそれから孵化した仔魚の密度を，Density-Gradient Column 法により測定した．卵の密度は，発生初期から中期には，産卵が行われた水槽内の海水密度よりも小さかったが，発生後期に増加を始め，孵化するまで増加し続け孵化時には飼育海水よりも大きくなっていた．仔魚の密度は，孵化後10分以内に，発生初期～中期の卵と比べて小さくなった．このような密度変化は，卵・仔魚の浸透圧調節の機能と能力が発生とともに変わるためであると推論した．これらの結果はまた，イシダイの卵および孵化仔魚が発生にともない分布深度を変えることを示している．海洋においては水平流の向きあるいは速さが深さにより異なる場合があることから，それら卵・仔魚は発生を続ける間，常に一様に輸送されるとは限らないと考えた．