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Embryonic Development of Muddy Paper Nautilus, *Argonauta hians* Lightfoot, 1786, from Andaman Sea, Thailand

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ABSTRACT

Thirty-three specimens of muddy paper nautilus (*Argonauta hians* Lightfoot, 1786) were collected from fish market and bycatch of purse seine in Phuket Province, Andaman Sea, Thailand. All specimens were mature females with shells or egg cases with developing eggs inside. Egg capsules were collected for observation from each female. Embryonic developmental stages were observed under the binocular microscope and recorded by digital camera. The average number of eggs from individual was 12,048.3±4,432.2. The size of egg capsule (egg) was 1.06±0.11 millimeters in average length. Embryonic development was observed for 15 stages. Hatchlings were planktonic with approximately 0.6 millimeters mantle length.

Key words: argonaut, muddy paper nautilus, *Argonauta hians*, embryonic development

INTRODUCTION

Paper nautilus is the member of family Argonautidae and closely related to octopods but they are epipelagic living, predominantly in the upper 100 meters and at all epipelagic depths. *Argonauta hians* is cosmopolitan in tropical and subtropical oceans (Beesley *et al*., 1998). In Thai waters, *A. hians* is recorded from the Gulf of Thailand, Pacific Ocean and Andaman Sea, Indian Ocean (Nateewathana, 1997; Nabhitabhata, 1999). Argonauts feed on heteropods, pteropods and small fish (Nixon and Young, 2003). Okutani (1960) reported that female *A. boettgeri* preyed on the pteropod(*Cavoilnia tridentata)*. Argonauts exhibited extreme sexual dimorphism in size. The male is dwarf and much smaller than female (Roper *et al*., 1984; Nesis, 1987).

Paper nautilus has a slender body, narrow head, and unequal length arms. Mantle length of female *A. hians* can reach up to 50 millimeters while mantle length of male is only 20 millimeters (Norman, 2000). Paper nautilus has eight arms, each arm with two rows of sucker, the number of suckers on the arm are different among species. Dorsal arms in female are with laterally enlarged membrane. Male third left arm is hectocotylized, which is huge by comparison and detachable. The hectocotylus of paper nautilus consists of three parts; a basal spermatophore reservoir, a central section bearing suckers and distally, a long lash-like 'penis' (Beesley *et al*., 1998). At copulation, the hectocotylus detached, formed an active, autonomous spermatophore carrier remaining in the mantle cavity of the female (Hanlon and Messenger, 1996).

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The unique characteristic of *Argonauta* is that the female secretes a shell with the enlarged web of dorsal arms, functioning as an elaborate egg case. The calcareous structured shell is thin and laterally compressed. Egg case is a single chamber with a flat keel fringed by two rows of tubercles (Beesley *et al*., 1998). The lateral sides of shell are with radial ribs. The shell center is pressed in or bent outwards into a prominent horn (Nateewathana, 1997). The shell provides protection and flotation for the female and is a site of attachment for her eggs.

As of all over the world, knowledge of life history of paper nautilus in Thailand is still lacking. In order to be able to manage the use of paper nautilus either for biodiversity preservation or for economic purposes, there is a need to understand the life cycle of this organism. As the study of paper nautilus is limited in Thailand, this study aims to observe the embryonic development process of paper nautilus as a preliminary study for further research.

MATERIALS AND METHOD

Thirty-three specimens of paper nautilus were collected between March and April 2006 from fish market and bycatch landing of purse seiner, fishing in the Andaman Sea at the depth of more than 80 meters and maintained onboard in PVC tanks with aeration supplied. The specimens (Figure 1) were later transported to the hatchery of Phuket Marine Biological Center. The specimens were observed in the laboratorial tank. They survived for 30 days. All specimens were mature females with average shell length of 25.22±2.94 millimeters (20.70-34.35 millimeters). Fertilized eggs were inside their shells, and hectocotylized arms of mating males were found in the mantle cavity. Egg capsules were collected from each female for observation. Embryonic developmental stages were observed under the binocular microscope and recorded by digital camera. Stages reported in this study were observed stages or stages for recognition, since the first stage after fertilization was unavailable.

RESULTS AND DISCUSSION

Egg capsules

The egg capsules were single and connected to each other by stalks without festoons (Figure 2). The average length of egg capsules of *A. hians* was 1.06±0.11 millimeters (0.77-1.46 millimeters), the same size as *A. boettgeri* which was about 0.85-1.1 millimeter (Nesis, 1977). Normally, female argonaut began to reproduce at the young stage, where *A. boettgeri* was 14-15

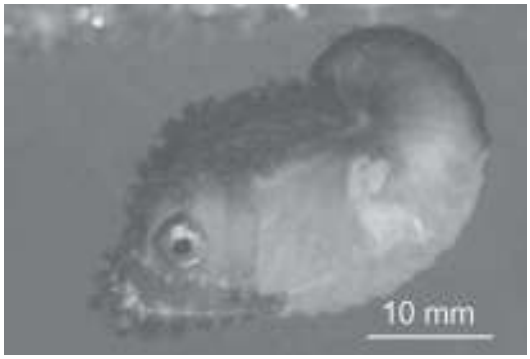

Figure 1 Live specimen of female muddy paper nautilus (*Argonauta hians*) from Andaman Sea.

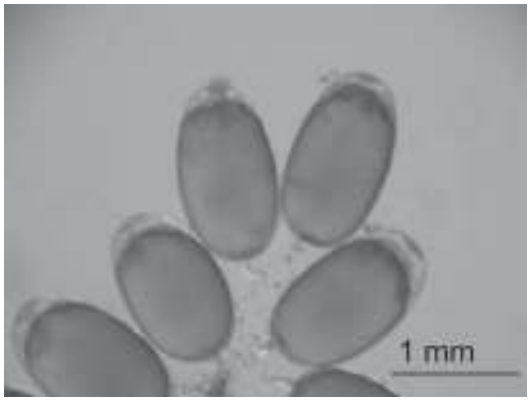

Figure 2 Egg capsules of *Argonauta hians*.

millimeters mantle length and *A. hians* 18-20 millimeters (Beesley *et al*., 1998). The sizes of *A. hians* collected in this study were around 24-42 millimeters which might be assumed that the collected specimens partially spawned.

The average number of eggs inside the egg case (shell) was 12,048±4,432 (6,276-17,936) which was lower than the number stated by Laptikchovsky and Salman (2003) who reported that the estimated potential fecundity of *A. hians* was around 18,000 eggs in the egg cluster. Average weight of the egg cluster inside the egg case was 3.09±1.26 grams. The oval shaped eggs were telolecithal. The egg capsules inside the egg case had various embryonic stages, which could be visually separated by colors. The eggs in early stages of development were yellow or white in color, and situated in the outer part of shell or egg case and closest to the shell aperture. The eggs in the following stages with red eyes or orange spots, demonstrating the beginning of chromatophore formation, situated in the middle part of shell chamber. The eggs with the black eyes were the almost hatching stages, situated in the inner part of the shell chamber. From observation, most of the eggs hatched at night. The mantle lengths of hatchlings were approximately 0.60 millimeters with total length of 1.0 millimeters and relatively short arms of nearly equal in length. The first pair of female arms was not laterally enlarged. The hatchlings were planktonic, suspending in the water column by means of water jetting from funnels. Female hatchlings had no shell at the beginning of their lives. They were able to survive for about 4-7 days without feeding. The female *A. hians* died after egg hatching. They sank to the bottom and crawled out of their shell, and then died. This finding was contrast to Beesleys *et al*. (1998) reported that after reproduction, the females continued to grow and reproduce again for a number of times. The cause of the difference between survival periods of this study's specimen and the literature is unknown. Further study is required to be confidentially explained this differences.

Embryonic development

Embryonic development of muddy paper nautilus, *A. hians*, (after being collected) could be observed for 15 stages of recognition (Figure 3-17). Early embryonic stages after fertilization could not be observed.

Observed stage 1: the earliest stage obtained, oval in shape, chorion cover yolk (Figure 3).

Observed stage 2: blastoderm covering about 15% of the egg (Figure 4).

Observed stage 3: blastoderm covering about 30% of the egg (Figure 5).

Observed stage 4: blastoderm covering about 50% of the egg (Figure 6).

Observed stage 5: blastoderm covering about 75% of the egg (Figure 7).

Observed stage 6: blastoderm covering about 90% of the egg (Figure 8).

Observed stage 7: another organ primordial observed, the vegetal pole developing into yolk sac and the animal pole developing into mantle and appendages, head forming, pale orange spots developing into eyes, primordial of arms observed (Figure 9).

Observed stage 8: orange eyes and gills observed, arms were observed with suckers, mantle round on the animal pole, internal yolk sac observed (Figure10).

Observed stage 9: mantle fully developed, funnel protruding, head enlarging into 2 lobes, optic lobes developing into eyes with lens color changed from orange to black, internal yolk

sac forming 2 lobes, arms developed (Figure 11a - dorsum, and 11b -lateral side).

Observed stage 10: about 10 orange and black chromatophores observed on dorsum (Figure 12).

Observed stage 11: arm length increasing from previous stages, size of external yolk sac decreased to about 40% of head (Figure 13).

Observed stage 12: yolk transferring from external into internal yolk sac and decreasing in size to be about 25% of head, 3-4 chromatophores on ventral mantle and head patterning in straight line (Figure 14).

Observed stage 13: external yolk decreasing to about 15% of head, size of internal yolk sac observed about 50% of mantle width, chromatophores scattered (Figure 15).

Observed stage 14: external yolk sac about 10% of head (Figure 16).

Observed stage 15: internal yolk sac about 50% of mantle width, hatching started, hatchling (Figure 17).

Abbreviations for Figures 3-17

a	=	arm
ani-p	=	animal pole
bde	=	blastoderm
bh	=	branchial heart
bm	=	buccal mass
cho	=	chorion
chr	=	chromatophore
e	=	eye
eys	=	external yolk sac
f	=	funnel
g	=	gill
h	=	head
l	=	lens
is	=	ink sac
iys	=	internal yolk sac
m	=	mantle
ol	=	opic lobe
pe	=	perivitelline space
r	=	retina
s	=	sucker
st	=	stalk
vet-p	=	vegetal pole
yo	=	yolk
ys	=	yolk sac

So far, the knowledge of life history of paper nautilus is still lacking. The finding in this study was unique and might not be able to compare to any other study. While paper nautilus is closely

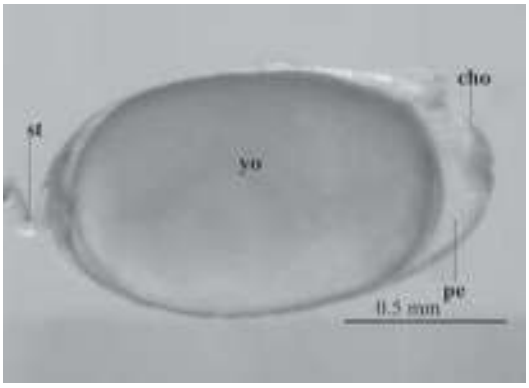

Figure 3 Observed stage 1.

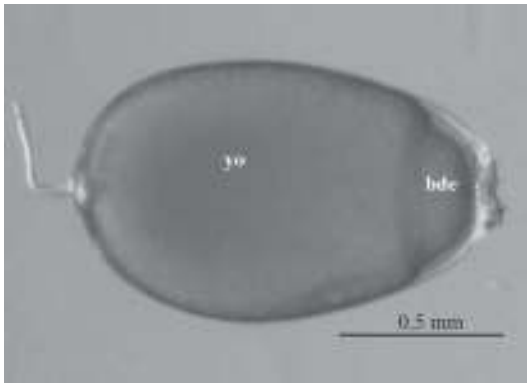

Figure 4 Observed stage 2.

related to octopods (Norman, 2000), the embryonic development of nautilus might be related with octopods. However, embryonic development of octopods was different among species and environment, and could be separated into different numbers of stages, such as octopus *Eledone cirrosa* with 20 stages (Mangold *et al.,* 1971), sharp-tail pygmy squid *Ideosepius pygmaeus* 30 stages (Yamamoto, 1988). The embryonic development of muddy paper nautilus, *A. hians*, in this study was able to be observed for only 15 stages. The early stages could not be observed

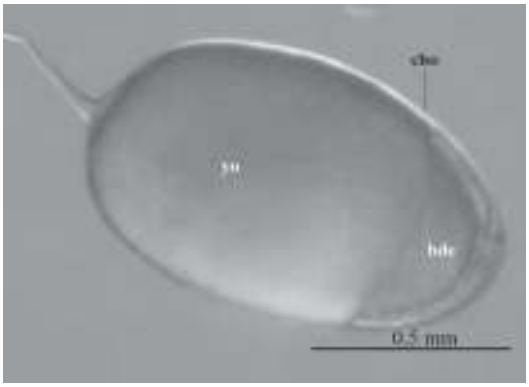

Figure 5 Observed stage 3.

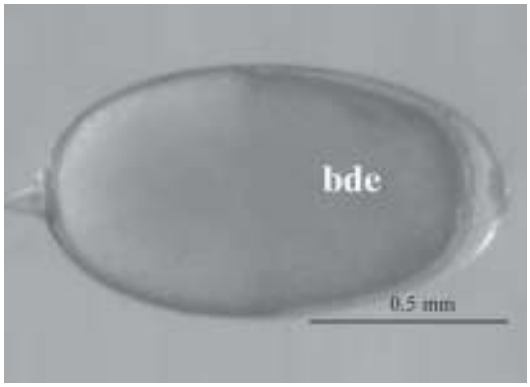

Figure 6 Observed stage 4.

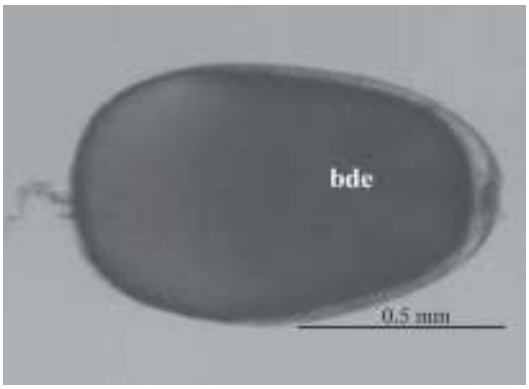

Figure 7 Observed stage 5.

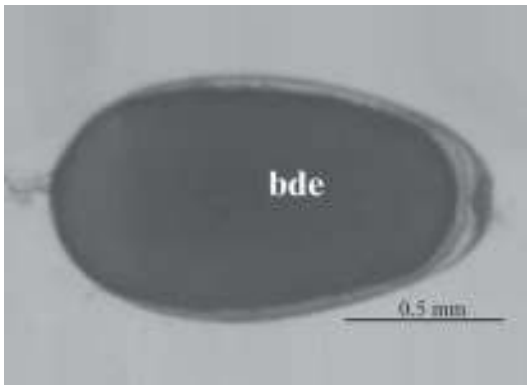

Figure 8 Observed stage 6.

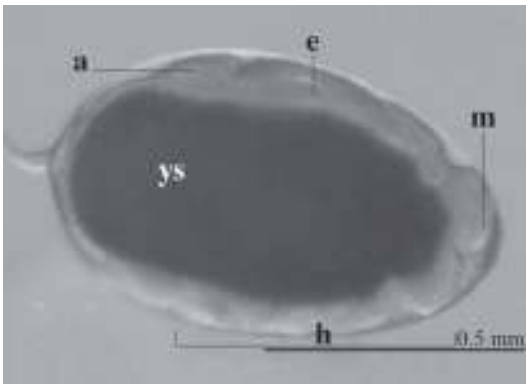

Figure 9 Observed stage 7.

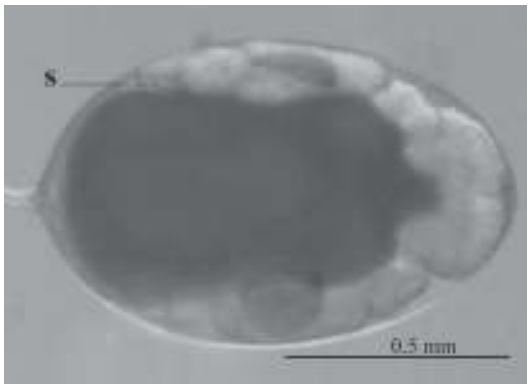

Figure 10 Observed stage 8.

because the live specimens collected after the time of mating and fertilization of eggs. The further study on the relationship of embryonic development stages between paper nautilus and the octopods are recommended.

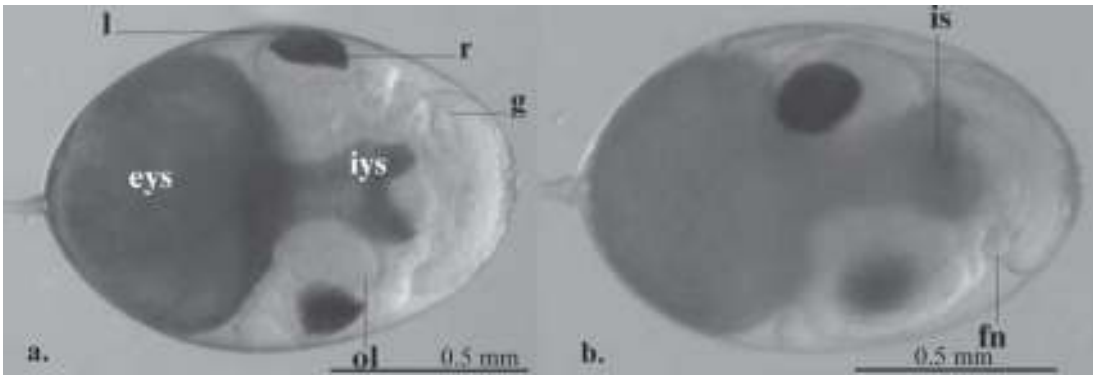

Figure 11 Observed stage 9a -dorsum and 9b -laterum.

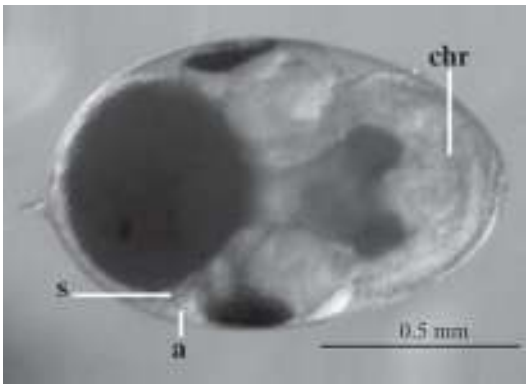

Figure 12 Observed stage 10.

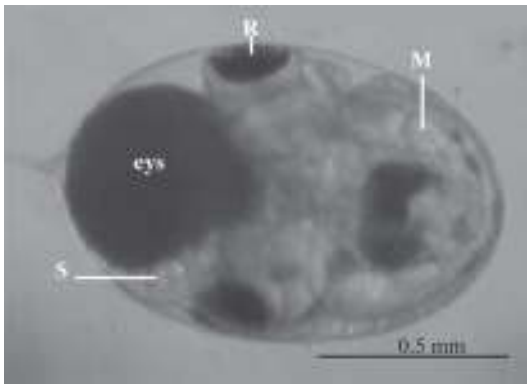

Figure 13 Observed stage 11.

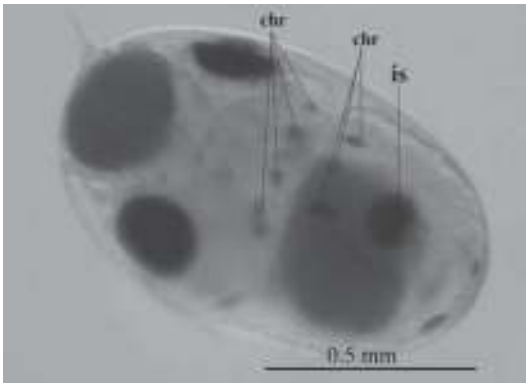

Figure 14 Observed stage 12.

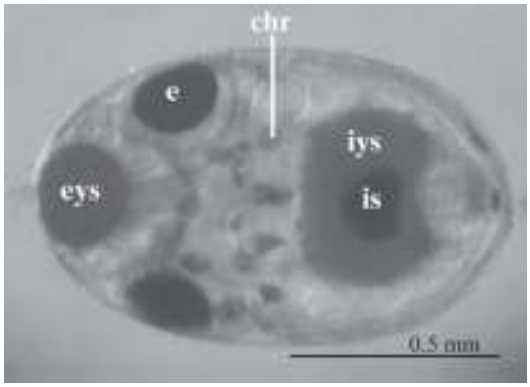

Figure 15 Observed stage 13.

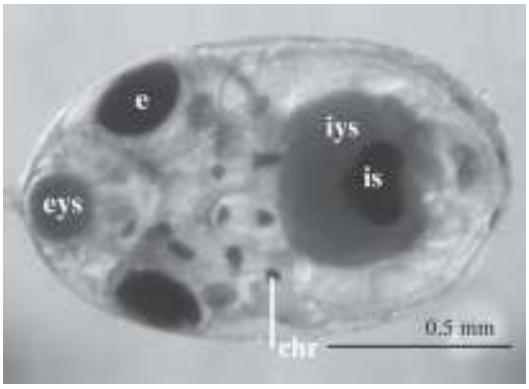

Figure 16 Observed stage 14.

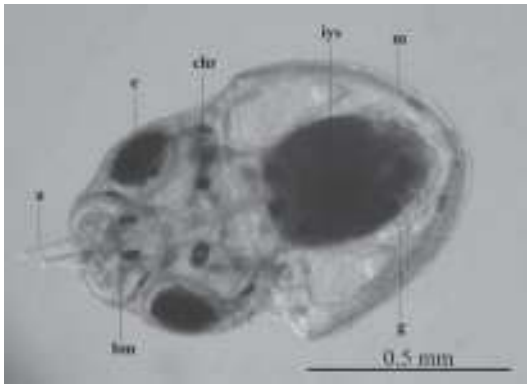

Figure 17 Observed stage 15.

CONCLUSION

This study found the average egg size of *A. hians* to be around 1.06 millimeters. The average number of eggs was 12,048.3 ± 4,432.2. Embryonic development was observed for15 stages. The most of the eggs hatched at night and they were planktonic, arms are short and nearly equal in length, female hatchlings had no shell at the beginning of their lives. Further study on the fecundity of *A. hians* is recommended in order to understand the life history of paper nautilus. The paralarvae hatched in the laboratorial tank died after four days so the development stage of the specimens cannot be completed. Recommended study should be specified on the optimum condition of the specimen being able to survive in the laboratorial tank.

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