Hatching mechanism, early and delayed hatching of the eggs of broadcast and brood-sac spawning euphausiids under laboratory conditions

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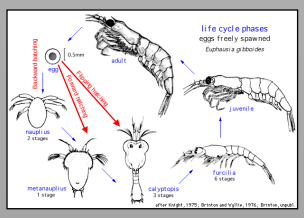
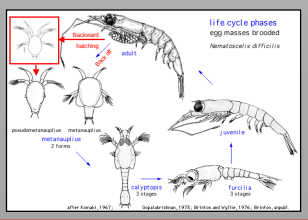
Broadcast spawning species



Life cycle and reproductive strategies

There are 86 species of euphausiids in the oceans. Euphausiids of the genera ***Bentheuphausia, Euphausia, Thysanoessa, Meganyctiphanes***, and ***Thysanopoda*** spawn freely and hatch as nauplius 1 (N1), while the genera ***Nematoscelis, Nyctiphanes, Pseudeuphausia***, and ***Stylocheiron*** brood their eggs and hatch in the early metanauplius phase as pseudometanauplii or as metanauplii. Diagrams from the life cycle of the euphausiids were taken from the CD's Euphausiids of the World Ocean (Brinton *et al.*, 2000). Red arrows and text are results from this study.

Brood sacmspawning species



Four different egg hatching mechanisms have been observed under laboratory conditions in three broadcast spawning species and one brood sac spawning species: named backward, forward, flipping, and back off hatching mechanisms.

Mature females

Euphausia pacifica

Thysanoessa spinifera

Thysanoessa inspinata

Mature females ready to spawn of *E. pacifica* have a characteristic purple coloration. *Thysanoessa spinifera* has a blue-green ovary before spawning and females of *T. inspinata* does not have a colored ovary just before the spawning.

Nematoscelis difficilis

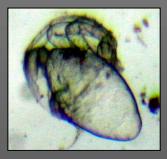
The embryos always hatch progressively from the distal end toward the proximal end of the ovigerous sac. The time between hatching of the first and last embryo may reflect the time the females require to lay a clutch of eggs (< 2 h) .

Twitching embryo

Twitching embryos with a nauplius 1 sometimes have a red coloration in the posterior end of the naupliar body. I have the hypothesis that this red coloration is caused for an active enzyme that helps to break the chorion during the backward hatching of the embryo.

Normal hatching

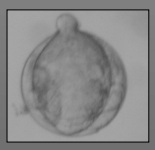
Backward hatching mechanism In broadcast spawning species when ready to hatch, the N1 pushes against the chorion with the posterior part of the abdomen producing a protuberance. The pressure breaks the chorion, and the nauplius pushes itself backward with the first and second antennae and mandible to slide from the chorion. After about ¾ of the body is outside, the nauplius brings all the appendages together to move backward without becoming stuck in the chorion. Hatching time of the of the N1 in the three broadcast species at 10ºC was about 35-40 h.



Backward hatching, Nauplius 1 35-40 h after spawning at 10ºC

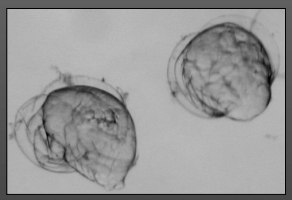
Several broods of ***N. difficilis*** hatched backward as nauplius 2 (N2), rather than as PMN or MN (47 h). This is considered an earlier hatching schedule for this species.

Early Backward hatching as N2

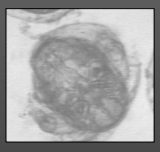


Back off hatching mechanism Normal hatching of ***N. difficilis***, a brood-sac spawner, show different hatching mechanism than broadcast spawners; the PMN or MN embryos extended and contracted their pairs of first and second antennae in a swimming movement, breaking the chorion in almost two equal halves joined by one small section in the anterior part of the chorion. Hatching time in brood-sac species was about 55-60 h as PMN and about 84 h as MN after spawning.

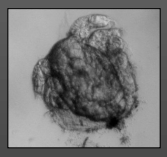
Normal Push off hatching as PMN or MN



Delayed hatching

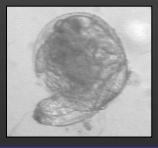


Forward hatching Metanauplius
200-220 h after spawning



Forward hatching Metanauplius
Nauplius 2 (>120 h)
MN >180 h after spawning

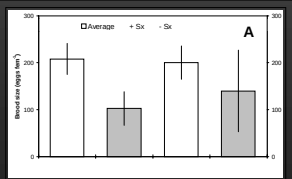
Forward hatching Nauplius 2
106 h after spawning

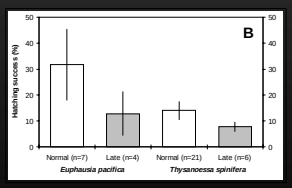


Flipping hatching Calyptopis 1
232-247 h after spawning

The N2 and MN in broadcast spawning species break the chorion with the first and second antennae, hatching forward, and the C1 breaks it with the telson spines and by flipping of the abdomen, resembling the decapod hatching mechanism.

Comparison of the brood size (A) and hatching success (B) of the broods from females that hatched normal (backward hatching mechanism) and late hatching (forward or flipping hatching mechanism) for *Euphausia pacifica* and *Thysanoessa spinifera* under laboratory conditions (10ºC). Data set includes only females collected at the same date and same station where normal and late hatching were observed. Vertical lines are standard error (S_x).





CONCLUSSION. Both, brood-sac and broadcast spawning strategy in euphausiids have shown very high flexibility in the hatching time schedule. It is proposed that, if the backward hatching mechanism fails in broadcast spawning species and back off hatching mechanism fail in brood sac spawning species, alternate hatching mechanisms can be used by the euphausiid. However, early hatching in brood-sac spawning strategy and late hatching in broadcast spawning strategy are usually associated with low embryo hatching success and considered as optional hatching modes for euphausiids.

Hatching success of embryos is an important biological index to quantify the larval recruitment of the population when it is estimated from spawning of females recently collected from the ocean (< 24 after collection). Even hatching success of embryos of crustaceans is relatively easy to obtain under laboratory conditions; its biological significance on the population recruitment is less obvious. Hatching mechanisms may partially explain the high variability observed during hatching success experiments.