

Brood size and hatching success of the euphausiids *Euphausia pacifica* and *Thysanoessa spinifera* from the Oregon coast population

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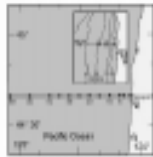
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Questions? Ask to Jaime

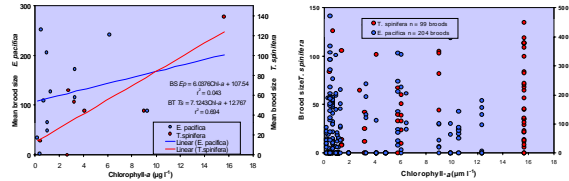
Abstract: The brood size and egg hatching success of *Thysanoessa spinifera* Holmes and *Euphausia pacifica* Hansen were studied under laboratory conditions from specimens collected in the Oregon upwelling region. Fecundity was estimated on thirteen oceanographic cruises (July, 1999 to September, 2001). Brood size (eggs fem⁻¹) was higher for *E. pacifica* (137.6 eggs) than for *T. spinifera* (109.6 eggs), *Euphausiapa* had a larger average percentage of female weight as eggs (9.6%) than *T. spinifera* (3.6%), suggesting that the former species expends about 2.7 times more energy in reproduction. Average egg hatching success (EHS) was 51.4% (n=15 broods) for *E. pacifica* and 16.3% (n=8 broods) for *T. spinifera*. Hatching success for both species showed very high variability between females, even when they were collected at the same station and incubated at the same experimental temperature (10.5° ± 0.5°C). We found a significant correlation between the brood size and Chl-a concentration (µg Chl-a l⁻¹) for *T. spinifera* (r=0.69), but not for *E. pacifica* (r=0.04). This suggests the former species may get most of its energy for reproduction from herbivory, while the latter perhaps also depends upon other food resources like zooplankton (amivory) or marine snow. *Thysanoessa spinifera* is a neritic species and usually spawns in coastal regions during upwelling events with high Chl-a concentration, while *E. pacifica* usually is evenly distributed over the continental shelf and off-shelf, sometimes inhabiting and reproducing in regions with lower Chl-a concentration.



Area of study

The Newport hydrographic line (NH) located at 44° 40'N, Oregon, USA has 12 stations from NH1 to NH60, the number indicates the distance from the coast in nautical miles. Purple females, ready to spawn, were collected during the night mainly in the NH5, NH15, NH20, and NH25 stations (the number indicates the distance from the coast in nautical miles). Females were transported to Hatfield Marine Science Center's cold room (10.5°C ± 0.5°C) and incubated for at least 48 h. Additionally, we analyzed old zooplankton samples collected every two weeks during January 1970 to July 1972 along the NH-line to estimate the abundance in the field of the eggs for the two dominant euphausiid species.

Relationship between mean brood size and mean Chl-a concentration at the stations where the purple females were collected



We used surface Chl-a for Elkhart cruises and 10-m depth Chl-a concentration for the LTOP and Mesoscale cruises to correlate to brood size of both euphausiid species. We found a significant correlation between the average brood sizes per cruise and Chl-a concentration (µg Chl-a l⁻¹) at the station where the females were collected for *T. spinifera* (r=0.69, p-value = 0.019, d.f.=6), but not for *E. pacifica* (r=0.04, p-value = 0.52, d.f.=11). This suggests the former species may get most of its energy for reproduction from herbivory, while the latter perhaps also depends upon other food resources like zooplankton (amivory) or marine snow (sensu Ohman 1984; Dilling et al. 1998). This relationship is possibly associated with their inshore-offshore distribution within the Oregon upwelling region. *Thysanoessa spinifera* is a neritic species and spawns in coastal regions during upwelling events with high Chl-a concentration, while *E. pacifica* usually is evenly distributed over the continental shelf and off-shelf, sometimes inhabiting and reproducing in regions with lower Chl-a concentration (see maps below).

Estimating the fecundity (eggs fem⁻¹ d⁻¹) of *Euphausia pacifica* from brood size and proportion of purple females in the population

Theoretical considerations: There is an unstated assumption in past attempts to measure fecundity that the oocytes present in the ovary equal all eggs the female will produce that season. Another common assumption is that some of the small oocytes in the ovary are never released, but are reabsorbed after one spawning episode. Those assumptions apparently sub-estimated fecundity of the euphausiid because a female can produce several broods within a reproductive season.

According to Ross et al. (1982) if there is not synchrony in the spawning of individual females and all periods are fertile, the proportion of purple female (stage IV) in the population that release eggs in a 24 h period is equivalent to the daily frequency with which an individual female releases eggs. The inverse of this frequency is the interval in days between broods (D). The average proportion of the purple females (stage IV) of *Euphausiapa* in the female population during the reproductive season 1970-1972 along the NH-line was p = 0.2228 which is equivalent to an interval of ~ 4.5 days between broods (assuming a binomial distribution with a mean equal to p (µ=p) or X/N) and a standard deviation σ = √(p(1-p)). The fecundity, the amount of energy of material an individual invest over a life span can be calculated from preserved samples if we have a reliable estimation of the proportion of females stage IV it is possible to have an estimation of the interval between broods using preserved samples.

$$F = E / (D \cdot p)$$

Where F is fecundity expressed as eggs per reproductive season
E = number of eggs per brood (egg brood⁻¹)
T = length of time during spawning season when brood interval was valid (days)
D = interval in days between broods in days (D=1/p)

Using available laboratory and field information we estimated the fecundity of *E. pacifica* in the Oregon upwelling system. The average brood size, estimated under laboratory conditions, is 136.5 eggs brood⁻¹ (n=13 broods) during 1999 to 2001 period. The duration of the spawning season during 1971 (sampled every two weeks) was from early March to early November (231 days), the average proportion of purple females during the reproductive season was p = 0.2228, which is an inter-brood period of 4.5 days (1/p), therefore the fecundity is:

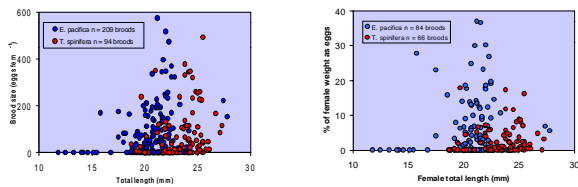
$$F = 136.5 (231 \text{ d})(4.5 \text{ d}) = 7007 \text{ eggs per female per reproductive season} = 934 \text{ eggs fem}^{-1} \text{ mo}^{-1}, \text{ or } 31 \text{ eggs fem}^{-1} \text{ d}^{-1}$$

Ross et al. (1982) reported similar fecundities for this species: small females < 17 mm 1000 eggs mo⁻¹, large females 1850 eggs mo⁻¹.

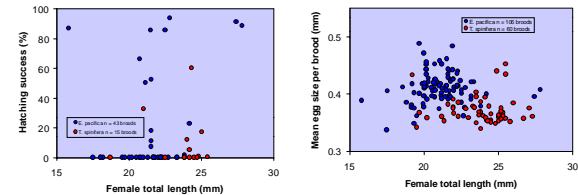
References

Dilling L, Wilson J, Steinberg D, Allalé A. 1998. Feeding by the euphausiid *Euphausia pacifica* and the copepod *Cyclops pacificus* on marine snow. Mar Ecol Prog Ser. 170: 189-201.
Ross RM, Daly KL, English TS. 1982. Reproductive cycle and fecundity of *Euphausiapa*. Limnol. Oceanogr. 27: 304-314.
Ohman M. 1984. Omnivory of *Euphausiapa*: the role of copepod prey. Mar Ecol Prog Ser. 19: 125-131.

Euphausiid brood size and egg hatching success



Fecundity was estimated on thirteen oceanographic cruises (July, 1999 to September, 2001). Brood size (eggs fem⁻¹) was higher for *E. pacifica* (137.6 eggs, range 7 to 575, n=108) than for *T. spinifera* (109.6 eggs, range 6 to 491, n=76). *Euphausiapa* had a larger average percentage of female weight as eggs (9.6%) than *T. spinifera* (3.6%), indicating the former species may expend about 2.7 times more energy in reproduction. *T. spinifera* usually larger and more robust (female average total length 23.4 mm) than *E. pacifica* (female average total length 20.8 mm).

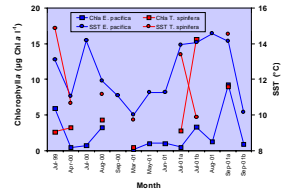
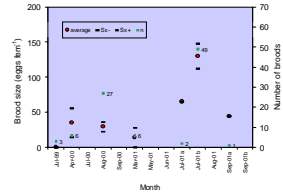
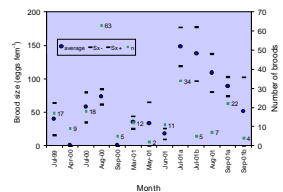


Egg hatching success (EHS) estimated under laboratory conditions, including the broods of which eggs did not hatch (EHS=0), indicates *E. pacifica* had higher average egg hatching success (30% n=27 broods) than *T. spinifera* (6.2%, n=21 broods). Excluding the broods that did not hatch, the average EHS was 51.4% (n=15 broods) for *E. pacifica* and 16.3% (n=8 broods) for *T. spinifera*. Hatching success for both species showed very high variability between females, even when they were collected at the same station and incubated at the same experimental salinity (32-33) and temperature (10.5° ± 0.5°C).

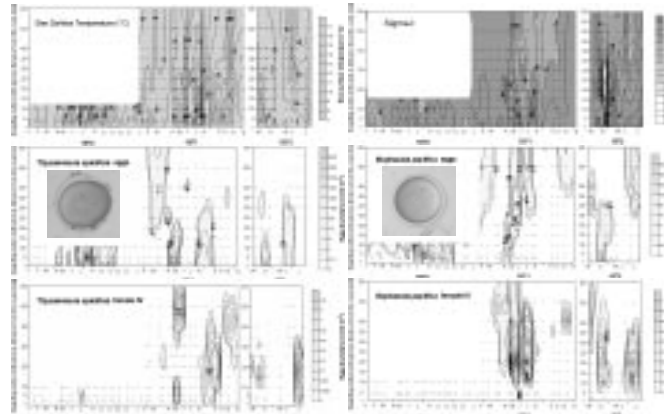
The average egg diameter per brood of both species was measured under laboratory conditions. The average diameter of the egg for *E. pacifica* was larger (0.411 mm, s_d=0.003, n=102 broods) than for *T. spinifera* (0.372 mm, s_d=0.003, n=60 broods), indicating it is possible to identify them by their size and by differences in the external appearance of the chorion. The eggs of *T. spinifera* were sticky and usually attached to the bottom of the bottles during incubations. The size of egg for each female is also very variable and suggest that the individual eggs have different probability to hatch due they have different amount of yolk material.

Cruise-to-cruise brood size variability (1999-2001)

The average brood size per oceanographic cruise for both species were larger for experiments done during 2001 than during the previous two years (1999 & 2000). Usually during the cruises of July and August were attained the highest brood size. Variability within each cruise can be very high (indicating by the standard error S_d) suggesting female-to-female differences perhaps associated to the female size, the female's health condition, recent feeding status, and/or genetic differences.



Euphausiid egg and females ready to spawn abundance in the field (NH line 1970-1972)



Purple female (stage IV) of *Euphausiapa* with mature ovary ready to spawn

Inshore-offshore and a seasonal spawning for the euphausiids *T. spinifera* and *E. pacifica* along the Newport Hydrographic line

Thysanoessa spinifera spawns at on-shelf region excepting during early 1971 when eggs were spawned off-shore (20 to 60 nm from the coast perhaps associated to a cold plume). Spawning regions of this species were usually associated to temperatures < 10°C. *Euphausiapa* spawns in both, on-shelf and off-shelf region releasing their eggs over a wider temperature range (8 to 16°C). Temporal and spatial distribution of eggs and purple females ready to spawn (stage IV) had similar distribution for both species. Inside the maps of the distribution of the eggs are shown the pictures of just spawned eggs (single cell stage) for each species.