# Brood size and egg production rates for *Euphausia pacifica* with a comparison of laboratory and field estimations of fecundity


**Jaime Gómez-Gutiérrez[1,2], Leah Feinberg[4], Tracy Shaw[4], William T. Peterson[3],**

[1] Departamento de Plancton y Ecología Marina, Centro Interdisciplinario de Ciencias Marinas, A.P. 592, C.P. 23000 La Paz, Baja California Sur, México

[2] *Present address*: College of Oceanic and Atmospheric Sciences, Oregon State University, 104 Ocean. Admin. Building, Corvallis, OR, 97331-5503 USA, e-mail jgomezgu@coas.oregonstate.edu

[3] NOAA/NMFS, Hatfield Marine Science Center, 2030 South Marine Science Drive, Newport, OR 97365, USA e-mail: bill.peterson@noaa.gov, fax (541) 867-0389

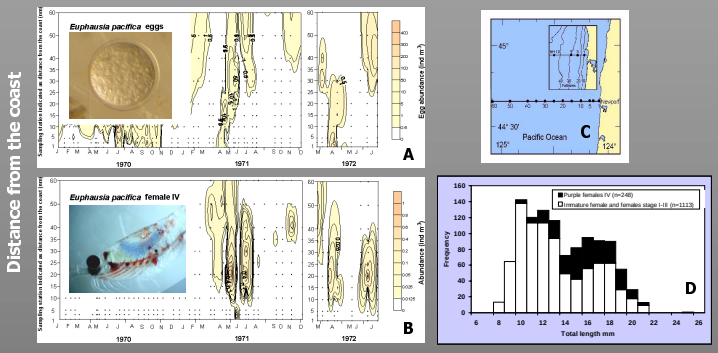
[4] Cooperative Institute for Marine Resources Studies, Hatfield Marine Science Center, 2030 S. Marine Science Drive, Newport, Oregon 97365, USA



**Abstract.** The most difficult variable in estimating the fecundity of euphausiids is the interbrood period. Previous estimations of fecundity using the oöcite number inside the female underestimate it because they assume the females spawn one or two times per year. Few direct observations have been made of live euphausiids to estimate mean brood size and interbrood period (Stuart 1992). Previous studies concluded that euphausiids spawn several times within a reproductive season (Ross *et al.* 1982). We measured the fecundity of *Euphausia pacifica* from specimens reared in the laboratory (from eggs to adulthood) and females collected from the field. For the animals raised in the laboratory, the average brood size and interbrood period were 66 eggs fem$^{-1}$ and 6.5 days. Females collected in the field and maintained in the laboratory had an average brood size and interbrood period of 156 eggs fem$^{-1}$ and 6.4 days. Assuming that these animals would be reproductively active for the entire spawning season (231 days), these experiments indicate that fecundity would be on the order of 2,345 to 5,630 eggs fem$^{-1}$ for the reproductive season.

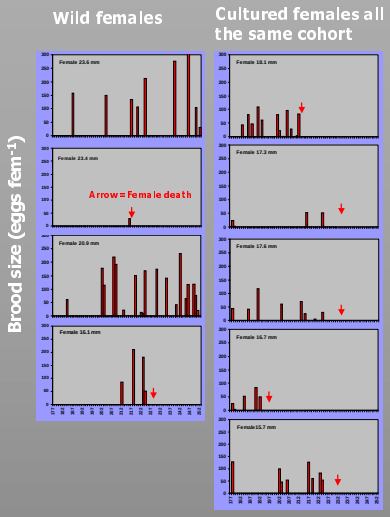
We compared the laboratory measurements with estimates of fecundity for *E. pacifica* from more than 30 oceanographic cruises (July 1999 to July 2002) in the coastal upwelling zone off central Oregon. Brood sizes of females incubated for 48 hours had an overall average of 141 eggs fem$^{-1}$. This value represents 17.3% of the female's body weight per brood. Using the proportion of purple females (stage IV) along the Newport Hydrographic line (1971) and the average brood sizes, we were able to estimate fecundity of *E. pacifica* using the method and assumptions proposed by Ross (1982). The average proportion of purple females during the reproductive season (March-October sampled biweekly) was p= 0.223, which indicates an interbrood period of 4.5 days. Therefore, the fecundity was estimated to be 7,238 eggs per female per reproductive season. Though both methods support a multiple spawning hypothesis, euphausiids showed high variability in spawning frequency and brood size.


## Spawning season of *E. pacifica* along the Newport Hydrographic line




Abundance of eggs (A) and purple females (stage IV) (B) sampled every two weeks along the Newport Hydrographic line (C) during 1970-1972. Size frequency distribution of the total length mm of immature and stage I-III female (n=865) empty bars and ripe, stage IV females (n=248) during 1971 (n=1113 females) (D). The proportion of purple females p=248/1113=0.2228 equals an inter-brood period of 4.5 d$^{-1}$. The size of first maturity was 10 mm total length.

## Comparison of the brood size and interbrood period for wild and cultured females under laboratory conditions 10.5°C.




| Average values | Wild females (n=4) | Cultured females (n=7) |
|---|---|---|
| No. of spawns during the experiment | 8.3 | 5.7 |
| Total of eggs produced during experiment period | 1051 | 292 |
| Brood size (eggs fem$^{-1}$) | 156 | 66 |
| Interbrood period (d$^{-1}$) | 6.4 | 6.5 |
| Female total length (mm) and range | 21 (16.1-23.4) | 17 (15.7-18.1) |
| Fecundity assuming a spawning season of 231 days (eggs fem$^{-1}$ year$^{-1}$) | 5630 ~36 spawning | 2345 ~35.5 spawning |

There is an unstated assumption in past attempts to measure fecundity that the oöcytes present in the ovary equal all the eggs the female will produce that season. Another common assumption is that some of the small oöcytes in the ovary are never released, but are reabsorbed after one spawning episode. Those assumptions apparently under-estimated fecundity of the euphausiid because a female can produce several broods within a reproductive season (Stuart 1992).

According to Ross et al. (1982) if there is no synchrony in the spawning of individual females and all females are fertile, the proportion of purple females (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 purple females (stage IV) of *Euphausia pacifica* in the female population during the reproductive season 1971-1972 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 ($\mu$=p, or X/N) and a standard deviation $\sigma = \sqrt{p(1-p)/N}$. The fecundity, the amount of energy or material an individual invests over a life span can be calculated from preserved samples if we have a reliable estimation of the proportion of stage IV females. It is then possible to have an estimation of the interval between broods using preserved samples.

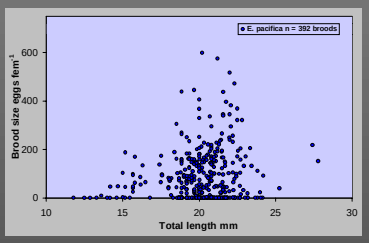
$$F = E\,(T/D)$$

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 141 eggs brood$^{-1}$ (n=392 broods) during the 2000 to 2002 period. The duration of the spawning season during 1971 (sampled every two weeks) was from early March to early November (231 days) and this seasonality is reflected in recent sampling as well (Leah and Peterson in prep.). Using the average proportion of purple females during the 1971 reproductive season we arrive at an inter-brood period of 4.5 days (1/p), therefore the fecundity is:

F = 141 (231 d /4.5 d) = 7238 eggs per female per reproductive season = 603 eggs fem$^{-1}$ mo$^{-1}$, or 20 eggs fem$^{-1}$ d$^{-1}$

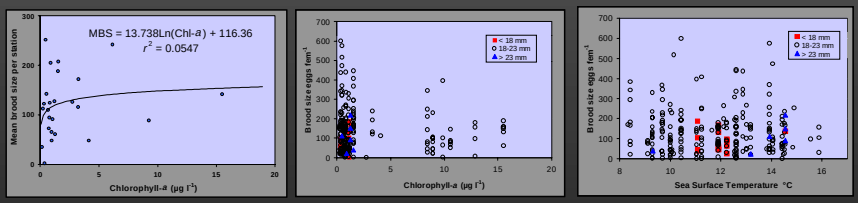
Ross et al. (1982) reported larger fecundities for this species: small females < 17 mm = 1000 eggs fem$^{-1}$ mo$^{-1}$, large females = 1850 eggs mo$^{-1}$.




Some authors report a linear regression between brood size and total length or weight. Our data indicate that brood size, as a function of female total length, is normally distributed. Non significant linear correlations between brood size and Chl-*a* (p=0.5) and brood size vs. sea surface temperature (p=0.62) suggest that other variables such as carnivory, mating or female maturation stage at time of the collection impose very high variability in female production, even within the same station and environmental conditions. *Euphausia pacifica* can invest in average about 15% of her body weight on eggs per batch. Non significant correlations between brood size and several individual variables suggest that brood size is associated with multiple variables. We did a multiple linear regression to predict brood size of *E. pacifica*.

Brood size = -66.73-4.02*Chl-*a* (µg l$^{-1}$) + 21.79*Pheopigment (µg l$^{-1}$) −4.18 SST (°C) + 12.62 * Female total length (mm)

The model explains only 6.92% of the variability of the brood size (p=0.016, d.f. = 169)




## CONCLUSIONS

- The estimation of fecundity per season is much higher using the method proposed by Ross et al. (1982) than the estimation based on direct observation of brood size and interbrood period of females collected in the field and reared from eggs under laboratory conditions. However, a very high female-to-female variability imposes a large degree of variability that can not be explained by the environmental variables measured.
- It is difficult to estimate the brood size from females collected in the field because they may start spawning before or during collection, therefore underestimating it.
- Brood size vs. total length has a normal distribution suggesting a maximum of the reproductive activity at sizes between 18 and 23 mm
- The size of first maturity was 10 mm estimated from preserved sampled and 15 mm (9 months) from females reared from eggs in the laboratory.

## References


Ross RM, Daly KL, English TS. 1982. Reproductive cycle and fecundity of *Euphausia pacifica*. Limnol. Oceanogr. 27: 304-314.

Stuart V. 1992. Fecundity of *Euphausia lucens* (Hansen) - Laboratory evidence for multiple broods. J. Exp. Mar. Biol. Ecol 160(2): 221-228.