

Evidence of heavy predation by *Noctiluca scintillans* on *Acartia clausi* (Copepoda) eggs off the central Cantabrian coast (NW Spain)

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Abstract – A large proliferation of *Noctiluca scintillans* (Dinophyceae: Noctilucidea) was observed in neritic waters off the central Cantabrian coast during late April 1995. Eggs of *Acartia clausi* (Crustacea: Copepoda) were the most conspicuous prey within vacuoles of *Noctiluca*. *Noctiluca* ingested 73 % of the total stock of *A. clausi* eggs. This intense predation on copepod eggs could potentially affect the recruitment of nauplii. The potential impact on the stock of *Acartia clausi* eggs and on the daily egg production of the population is discussed. There is a negative correlation between the average number of ingested eggs by a single *Noctiluca* cell and the abundance of *Noctiluca*. This fact, coupled with the lack of significant correlation between the former variable and the abundance of *Acartia clausi* eggs, suggests that interference processes play a major role in regulating the predator–prey interaction between *Noctiluca* and *Acartia* eggs. © Elsevier, Paris / Ifremer / Cnrs / Ird

Noctiluca / *Acartia* / copepod eggs / predation / Bay of Biscay

Résumé – *Noctiluca scintillans*, prédateur des œufs du copépode *Acartia clausi* au large de la côte cantabrique (Espagne). Une grande prolifération de *Noctiluca scintillans* (Dinophyceae : Noctilucidea) a été observée dans les eaux néritiques de la côte centrale cantabrique à la fin du mois d'avril 1995. Les œufs d'*Acartia clausi* (Crustacé : Copépode) sont la proie la plus évidente dans les vacuoles des *Noctiluca*. Les *Noctiluca* ont ingéré 73 % du total des œufs d'*Acartia clausi*. Cette forte prédation d'œufs de copépodes pourrait éventuellement affecter le recrutement de nauplii. L'impact potentiel sur le stock et sur la production journalière d'œufs d'*Acartia clausi* est discuté. La corrélation est négative entre la quantité moyenne d'œufs ingérés par une seule cellule de *Noctiluca* et l'abondance de *Noctiluca*. Ce résultat, et le manque de corrélation significative entre la variable précédente et l'abondance d'œufs d'*Acartia clausi*, suggèrent que les phénomènes d'interférence jouent un rôle décisif de régulation dans la relation prédateur–proie entre les *Noctiluca* et les œufs d'*Acartia*. © Elsevier, Paris / Ifremer / Cnrs / Ird

Noctiluca / *Acartia* / œufs de copépode / prédation / golfe de Gascogne

MAIN TEXT

Noctiluca scintillans (Macartney) is a large phagotrophic dinoflagellate with cosmopolitan distribution, capable of forming red-tide-like swarms in neritic environments [2, 5, 6, 8, 10, 11]. *Noctiluca* is a voracious predator of a

wide range of prey including copepod eggs [2, 4, 6] while its large size ranging between 200–600 µm diameter [11] excludes it from the prey size range of common neritic copepods.

During a routine ichthyoplankton survey off the Nalón Estuary (northern coast of Spain) a dense swarm of

Noctiluca was detected. The massive ingestion of copepod eggs by that swarm of *Noctiluca* is described in this paper.

Two transects were sampled on 27 and 28 April 1995 (transects A and B respectively) (figure 1). At hydrographical stations, vertical profiles of temperature and salinity were obtained with a SBE 25 CTD probe. Zooplankton samples were obtained between successive hydrographical stations. Oblique hauls were made towing a 40 cm diameter Bongo net with a 200 μ m mesh size. A 10 cm diameter Bongo net with 53 μ m mesh size attached to the larger one was used for microzooplankton samples. Tow depth was 5 m above the bottom or 100 m at deeper locations. Samples were preserved onboard in 4% tetraborate-buffered formaldehyde solution. To estimate the abundance of *Noctiluca* and free *Acartia clausi* (Gies-

brecht) eggs, subsamples (1/100) from the 53 μ m Bongo net were counted under an inverted microscope. The number of eggs ingested by *Noctiluca* was estimated after microscopic inspection of a random subset of the original sample, made up of one hundred individuals. Only intact *Noctiluca*, spherical and undamaged, were considered for analysis. Mesozooplankton abundance was estimated from samples of the 200 μ m net using a Stemple pipette.

There was haline stratification in the upper metres of the water column, derived from the input of freshwater from the Nalón river plume (figure 2). In transect A, two lenses of low salinity water were observed; one close to the coast and the other far from the coast between stations 6 and 7. Transect B showed the same trend, although the latter transect was longer and the lens of low salinity water off the coast was longer and deeper. Salinity gra-

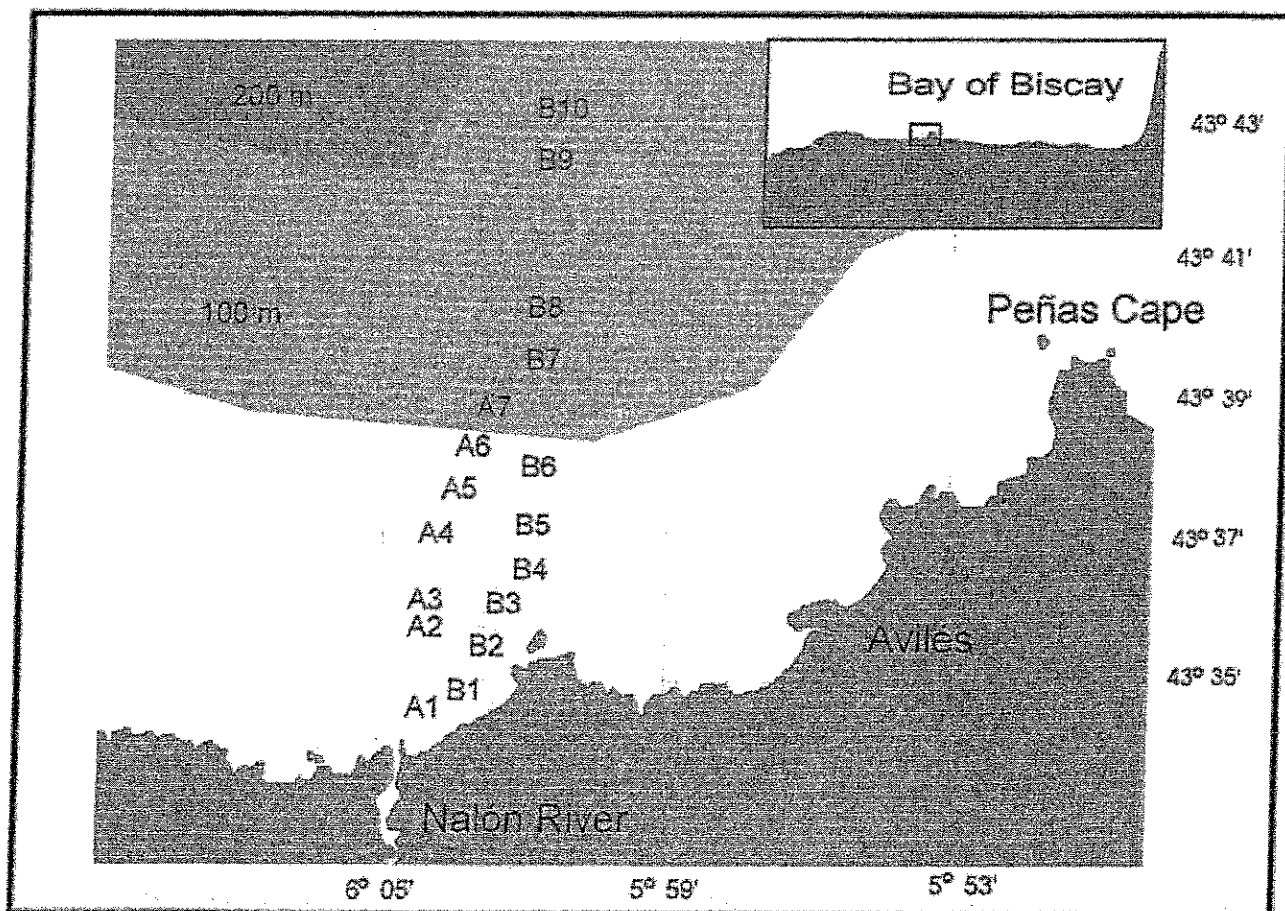


Figure 1. Map of stations. Numbers represent CTD casts

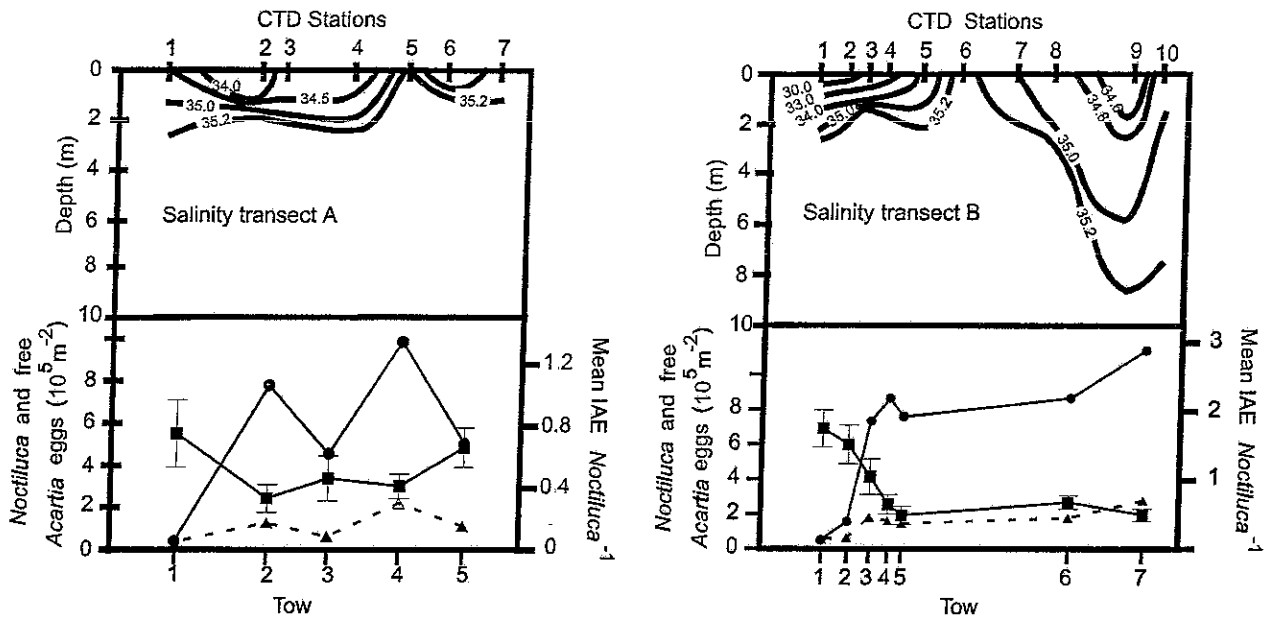


Figure 2. Salinity profiles, abundance of *Noctiluca scintillans* (circles) and free *Acartia clausii* eggs (triangles), and mean ingested *Acartia clausii* eggs per *Noctiluca* (squares) along transects A and B. Tow positions on the axes correspond to the mid point of each haul. IAE: ingested *Acartia* eggs

dient was less than 0.2 (practical salinity scale) from 15 m to the bottom (data not shown). Temperature ranged from 13.4 °C, at station B10, to 11.8 °C, at the bottom of station B6; within the upper 15 m maximum temperature gradient was 0.2 °C in transect A and 0.6 °C in transect B (data not shown).

In this study *Noctiluca* abundance ranged from 39×10^3 to 1138×10^3 cells m^{-2} and increased offshore as is apparent in transect B (figure 2). This distribution pattern could not be related to hydrography within the spatial scale of this survey. The abundance of *Noctiluca* in the central Cantabrian coast is comparable to others reported in the literature [2, 8, 10]. Large proliferations of *Noctiluca* are usually associated with conditions of water column stability, when positive buoyancy is favoured for the organisms. Under calm conditions, *Noctiluca* gathers in the upper metres of the water column [3, 5] like many other red-tide-forming dinoflagellates [9]. This was probably the situation in this study due to the calm conditions and haline stratification in the upper level of the water column (figure 2).

A. clausii eggs were the most conspicuous prey within the vacuoles of *Noctiluca scintillans* (figure 3) although there were also a few larger unidentified (ca. 160 μm) crus-

tacean eggs. The abundance of *Acartia clausii* eggs (73–78 μm diameter) was similar in the two transects and increased offshore, but less dramatically than the abundance of *Noctiluca* (figure 2). *Acartia clausii* constituted on average 72 % of the standing stock of females of broadcast spawning copepods (table I). The number of *A. clausii* eggs within a single *Noctiluca* cell ranged from 1 to 18. On average, 36.0 % of *Noctiluca* cells had eggs within their vacuoles.

Mean ingested eggs per *Noctiluca* at each tow varied between 0.33 and 1.75 and averaged 0.77 (1200 cells inspected) (figure 2); Daan [2] reported a maximum value of 0.6 ingested eggs per *Noctiluca* and most values ranged from 0.1 to 0.4, though these values summarized weekly mean cell contents. *Noctiluca* abundance was inversely related to mean ingested eggs per *Noctiluca* at each station ($r = -0.67$, $p = 0.009$; $n = 12$). The presence of an inverse relationship between mean ingested eggs and abundance of *Noctiluca* suggests intraspecific competition within the population of *Noctiluca*, with cells interfering with each other. Abundance of free *A. clausii* eggs was not significantly correlated to mean ingested eggs ($r = -0.45$; $p = 0.016$; $n = 12$). Both results suggest that intraspecific competition (interference) controls predatory impact in this study.

Table I. Abundance (10^3 indiv m^{-2}) of female *Acartia* and total *Acartia* eggs % IAE: percentage of total *Acartia* eggs ingested by the population of *Noctiluca*.

Station	1	2	3	4	5	6	7	Mean \pm SE
Transect A								
Adult female <i>A. clausi</i>	3.5	2.3	2.4	0.8	1.6	-	-	2.1 \pm 0.5
Total <i>A. clausi</i> eggs	65.3	382.4	270.1	622.2	442.2	-	-	356 \pm 92
% IAE	45	67	77	65	75	-	-	66 \pm 5
% female <i>A. clausi</i> (*)	100	77	44	19	30	-	-	54 \pm 15
Transect B								
Adult female <i>A. clausi</i>	11.1	4.9	5.6	4.2	3.0	6.4	29.3	9.2 \pm 3.5
Total <i>A. clausi</i> eggs	146.3	299.7	951.2	721.4	517.9	765.3	846.4	607 \pm 112
% IAE	60	79	81	78	72	79	67	74 \pm 2.9
% female <i>A. clausi</i> (*)	99	93	97	96	92	68	86	90 \pm 4

(*) Percentage of female *A. clausi* with respect to the total female broadcast spawning copepods. SE: standard error.

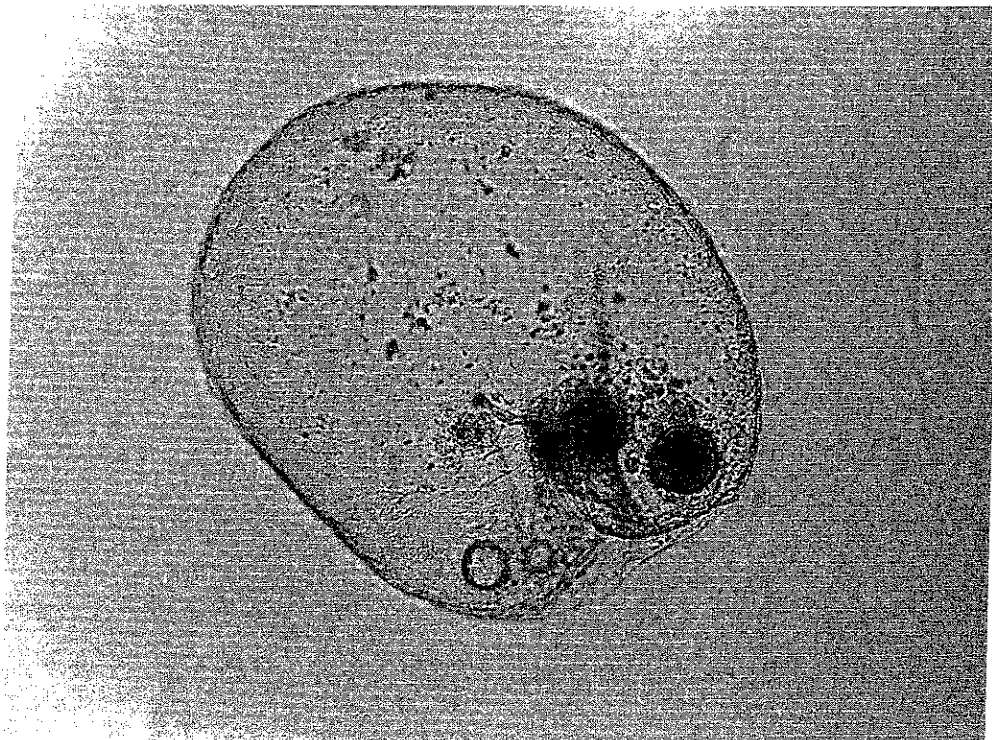


Figure 3. *Noctiluca scintillans* with an *Acartia clausi* egg inside its vacuole (bottom-right).

The percentage of total *Acartia* eggs found inside *Noctiluca* (70 %) is within the range of values reported in the literature (74 % of *A. clausi* eggs [10]; 50 % of *A. tonsa* eggs [6]). This proliferation of *Noctiluca* had obviously not reached the red-tide-like phase, when cells become irreversibly damaged, stop feeding and finally die [10]. Egg consumption rate by the whole *Noctiluca scintillans* population can be estimated from the mean cell contents of *Noctiluca* and the digestion time. If we assume a

digestion time of 55 h [2], the average number of ingested eggs found in this study ($368\,000$ eggs m^{-2}) would yield a digestion rate of $160\,699$ eggs $d^{-1} m^{-2}$. Then, *Noctiluca* ingested 45 % of the stock of *A. clausi* eggs daily, thus playing an important role in the regulation of the hatching of nauplii during periods of high copepod egg production, affecting its potential meso- and ichthyoplankton predators. Predation by *Noctiluca* on the eggs of *Acartia* and other broadcast spawning copepods, such as *Temora*

longicornis and *Centropages hamatus*, has been reported in previous studies for diverse locations [2, 6, 10], suggesting that this mechanism could be widespread and highly relevant to population dynamics of neritic zooplankton.

Besides the magnitude of predation pressure, its impact on the dynamics of the *A. clausi* population depends on the egg production of female *A. clausi*. The average abundance of female *A. clausi* in this study was 6302 individuals m^{-2} . Assuming a maximum egg production rate of 40.4 eggs d^{-1} at 15 °C for a female *A. clausi* and a $Q_{10} = 3$ [7], the maximum egg production rate at the temperature of the surface water layer temperature found in this study would be 33.1 eggs d^{-1} . Therefore, the total maximum egg production of the *Acartia* population would be 208 596 eggs $d^{-1} m^{-2}$, almost balancing the predation by *Noctiluca*, which would be consuming 77 % of the *Acartia* eggs produced daily. Our estimates of egg ingestion based on the conservative digestion time proposed by Daan [2], show that a significant percentage of the eggs produced are depleted by *Noctiluca*. Moreover, the values of mean ingested eggs by a single *Noctiluca* cell and the percentage of eggs ingested by the population reported by Daan [2] are much lower than those reported in this study. Although Daan [2] concludes that changes in individual egg production by adult female copepods would be responsible for the summer copepod population decline more than *N. scintillans* predation, our results suggest

that *Noctiluca* predation on copepod eggs affects the absolute recruitment of nauplii

The calanoid copepod *Acartia clausi* is a common component of the copepod community off the central Cantabrian Coast. It usually has a marked coastal distribution, reaching its highest abundance during spring and averages about 24 % of the total coastal copepod abundance throughout the year off the central Cantabrian Coast [1]. Given that both organisms usually share the same neritic waters and occur in the same season, then it is conceivable that this predation may be a common event in the area if, *Noctiluca* proliferations are rhythmical as in other coastal areas [11].

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