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 role 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 μm mesh size. A 10 cm diameter Bongo net with 53 μm 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* (Giesbrecht) eggs, subsamples (1/100) from the 53 μm 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 estim-ated from samples of the 200 μm 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-

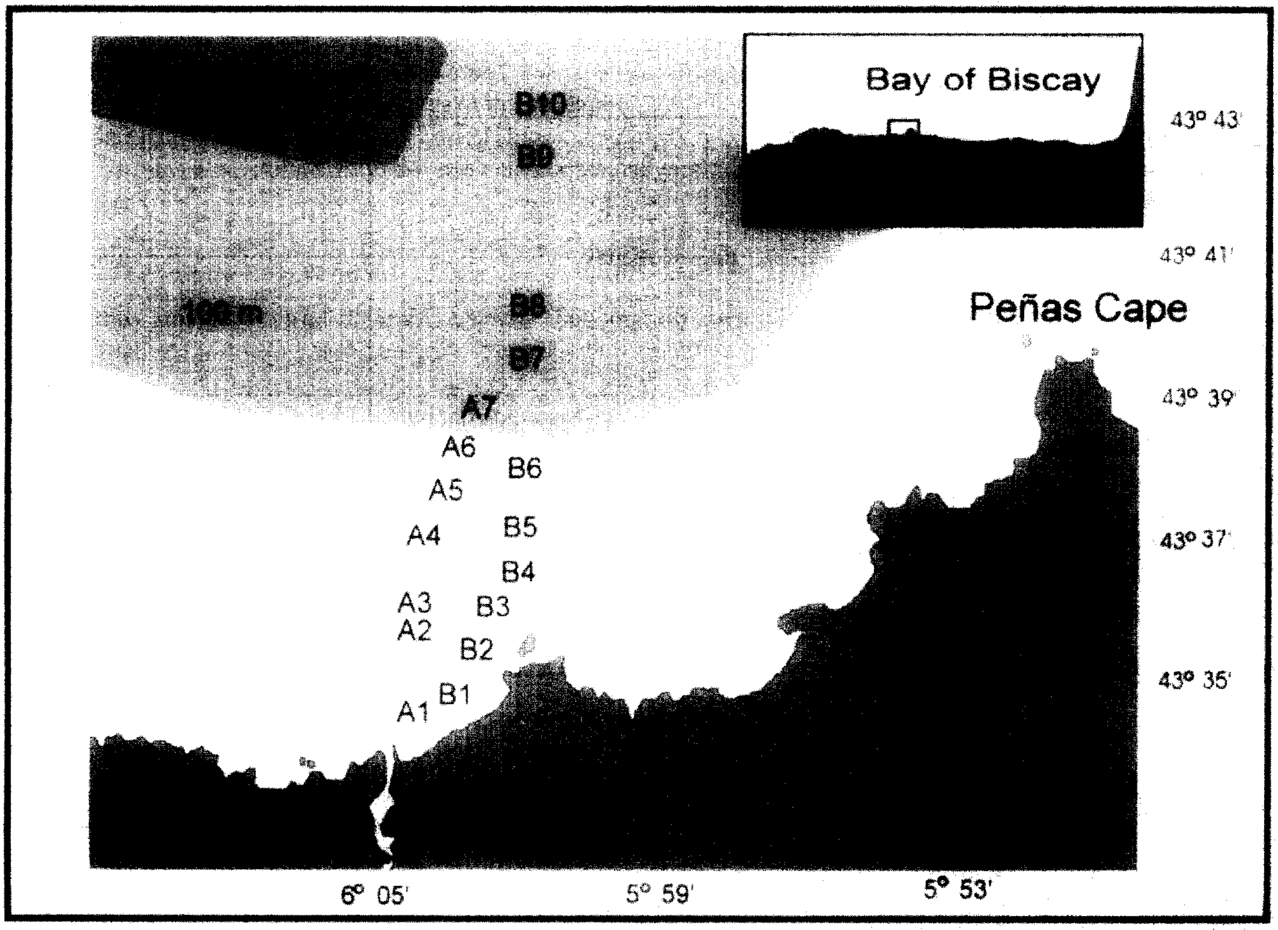

Figure 1. Map of stations. Numbers represent CTD casts.

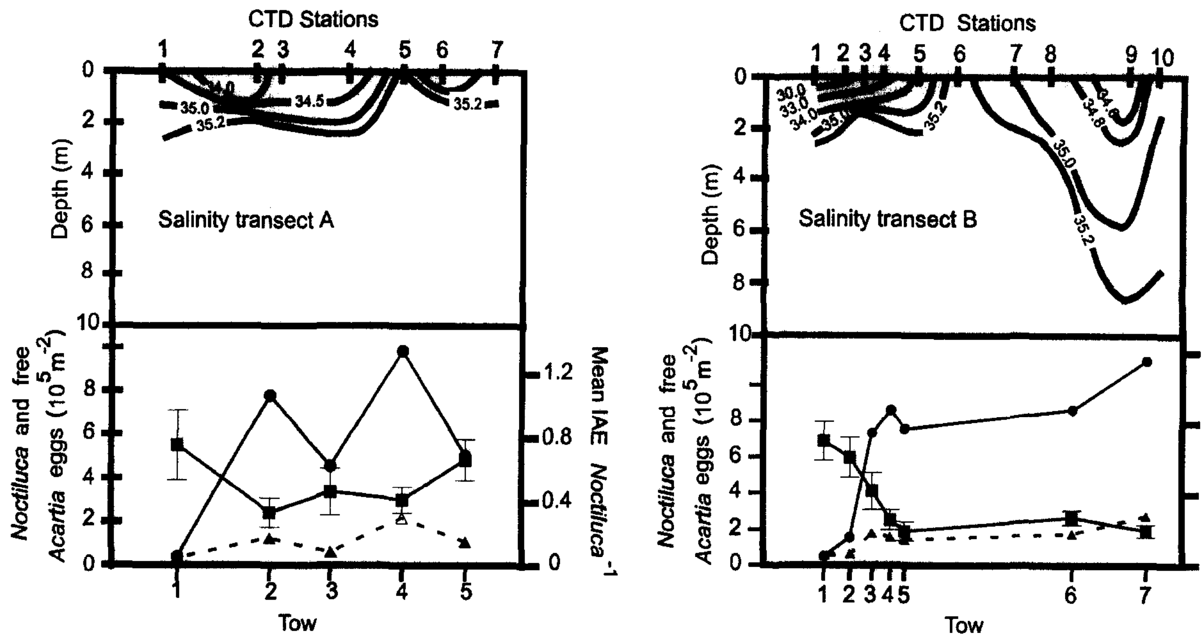

Figure 2. Salinity profiles, abundance of *Noctiluca scintillans* (circles) and free *Acartia clausii* eggs (triangles), and mean ingested *Acartia clausi* eggs per *Noctiluca* (squares) along transects A and B. Tow positions on the axes correspond to the mid point of each haul. IAE: ingested *Acartia* 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. clausi 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) crustacean eggs. The abundance of *Acartia clausi* 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 clausi* constituted on average 72 % of the standing stock of females of broadcast spawning copepods (*table I*). The number of *A. clausi* 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. clausi* 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 indv. 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 ± SE
Transect A								
Adult female *A. clausi*	3.5	2.3	2.4	0.8	1.6	–	–	2.1 ± 0.5
Total *A. clausi* eggs	65.3	382.4	270.1	622.2	442.2	–	–	356 ± 92
% IAE	45	67	77	65	75	–	–	66 ± 5
% female *A. clausi* (*)	100	77	44	19	30	–	–	54 ± 15
Transect B								
Adult female *A. clausi*	11.1	4.9	5.6	4.2	3.0	6.4	29.3	9.2 ± 3.5
Total *A. clausi* eggs	146.3	299.7	951.2	721.4	517.9	765.3	846.4	607 ± 112
% IAE	60	79	81	78	72	79	67	74 ± 2.9
% female *A. clausi* (*)	99	93	97	96	92	68	86	90 ± 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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