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

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(Received 6 October 1997, revised 21 August 1998, accepted 8 September 1998)

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


*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% tetaborate-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 estimated 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.](image)
NOCTILUCA PREDATION ON ACARTIA EGGS

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.

In this study Noctiluca abundance ranged from $39 \times 10^3$ to $1138 \times 10^3$ 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^-3) of female Acartia and total Acartia eggs. % IAE: percentage of total Acartia eggs ingested by the population of Noctiluca.

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

(*): 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^-3) 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].

Acknowledgements

The authors are grateful to Jose Luis Acuña, Emilio Fernández and Gotram Uhlig for their helpful suggestions and criticisms of the manuscript. They also thank all the members of the B.O.S Department (Ecology and Zoology Laboratories) who were involved in sampling procedures for their enthusiastic and generous help during the cruises. Financial support for this project and for a fellowship to R. G.-Q. was provided by the Consejería de Agricultura y Pesca; Gobierno del Principado de Asturias; Spain.

REFERENCES