Vol. 112: 235-240, 1994 | MARINE ECOLOGY PROGRESS SERIES Mar. Ecol. Prog. Ser. | Published September 29

Plankton studies in Buzzards Bay, Massachusetts, USA. IV. Tintinnids, 1987 to 1988

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ABSTRACT: Tintinnids were collected from Buzzards Bay, Massachusetts, USA, from October 1987 to September 1988. Tintinnids were collected by screening 3 l of seawater with a 20 µm mesh. Eight stations throughout the bay were sampled at monthly or twice-monthly intervals. A total of 30 species of tintinnids were recorded, half of which were members of the genus *Tintinnopsis*. Tintinnid abundances ranged from 0 to 3.3×10^3 cells l^{-1}. Tintinnids were least abundant at the Cape Cod Canal and in northern Buzzards Bay, and most abundant at the New Bedford sewage outfall. Unlike dinoflagellates, tintinnids did not show higher abundances in New Bedford Harbor than in the main part of the bay. The effect of screening tintinnid samples with a 20 µm mesh screen was examined by comparisons of abundance of tintinnids in screened and unscreened whole-water samples concentrated by gravitational sedimentation. Tintinnid abundance estimates were significantly higher in the screened samples.

KEY WORDS: Tintinnids · Buzzards Bay · Microplankton

INTRODUCTION

Since the introduction of the microbial loop concept (Azam et al 1983), planktonic marine ciliates have received increasing attention (reviewed by Pierce & Turner 1992). Tintinnids are an important component of planktonic ciliate community. They are a link between the microbial and metazoan food webs, providing a pathway between bacterial and nanoplanktonic production and zooplankton and fish biomass.

Although tintinnids have been examined from several estuaries in the coastal New England region, Buzzards Bay has been largely ignored. Unlike the nearby Narragansett Bay and many other estuaries examined, Buzzards Bay has limited freshwater influx and is generally well-mixed during the entire year.

As part of a larger study of plankton in Buzzards Bay (Borkman & Turner 1993, Borkman et al. 1993, Turner & Borkman 1993, Pierce & Turner 1994) we here describe for the first time community structure and seasonality of tintinnids.

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METHODS AND MATERIALS

Details of sampling procedures, station locations, and sample processing are presented in Pierce & Turner (1994, this issue). Briefly, samples were collected from Buzzards Bay, Massachusetts, from October 1987 to September 1988. Eight stations were sampled at monthly or twice-monthly intervals. Water samples were collected from just below the surface, with a Niskin bottle. Subsamples of 3 or 4 l were screened with a 20 µm mesh Nitex screen and preserved with 1% acid Utermöhl's solution (Guillard 1973). In the laboratory, microplankton samples were gravimetrically settled to aliquots of 50 to 150 ml. Subsamples were counted in a Sedgwick-Rafter cell with a phase contrast compound microscope. Samples were counted at 100× magnification, but the long working distance objectives on the microscope allowed specimens to be examined at up to 400× magnification when necessary for identification. All identifications were made on the basis of lorica morphology. For species identification Kofoid & Campbell (1929) was the primary taxonomic reference, with Gold & Morales (1975a, b, 1976) specifically useful for Buzzards Bay.

Table 1. Tintinnid occurrences in Buzzards Bay, October 1987 to September 1988. Maximum abundance at any station. Number is logarithm of the order of magnitude of tintinnid abundance in cells l^{-1}. E: only empty loricae were observed

Taxon	1 Oct 1987	20 Oct	24 Nov	16 Dec	8 Jan 1988	2 Feb	1 Mar	5 Apr	3 May	7 Jun	21 Jun	13 Jul	27 Jul	10 Aug	23 Aug	6 Sep	20 Sep
Codonella sp.			3	2	2	2										1	1
Coxliella lacinosa				1													
Eutintinnus pectinis													2	2			
Eutintinnus spp.											1	1	2	1			
Eutintinnus C13S2													2			1	
Favella arcuata															2		
F. ehrenbergii		0								2							
Helicostomella subulata		1										1	1	1	3	2	2
Metacylis angulata													2	2		1	1
M. annulifera												1		2			
Metacylis C13S2													1	1	2		
Stenosemella oliva	2	1	2	2	2	2	1	1	2	2	2	2	2	1	1	2	3
S. ventricosa			1	0	1											3	
Stylicauda platensis	2	1										1	2	1	2	1	1
Tintinnidium fluviatile			1				1						2				
Tintinnopsis acuminata	1	2	2	1	1			1	2	1	2	2	2	1	2	2	1
T baltica			1	1	1			2	2		1		1		1	2	1
T. beroidea		1	0						2	1		2	1		1	1	1
T. dadayi	1		0										1	1		1	1
T. kofoidi			1	1							2	1	1			1	1
T. levigata				1							2		1				
T. minuta		2								2	2	2	2			1	2
T. nucula						E											
T. parva	2	2	1	1	1	1	1	2	2	2	2	1	1			1	1
T radix											0		2	2	2	2	1
T rapa	2	1	1	1	1	1	1	2	3	2	2	2	1		1	2	1
T. sufflata	1	1	1	0				0		1	2	1			2	1	
T. tubulosa				1	2	1	1	2						1	1	1	2
T. tubulosoides			1	2	3	2	2	3	2	1							
T vasculum	1		1	2	1	2	2	2	2				1		1	1	1
Total tintinnids	3	2	3	2	3	3	2	3	3	3	3	3	3	3	3	3	3

Possible bias due to the use of a 20 µm mesh for concentrating tintinnid samples was investigated by comparison of screened and settled whole-water samples. In addition to samples for this study, 800 ml water was also withdrawn from the same Niskin bottles and preserved with 1% Utermöhl's solution without screening; thus abundances should be similar in both sets of samples, unless there were effects associated with screening. Fifteen sample pairs were checked for bias in tintinnid abundances along with the dinoflagellates in the previous paper (Pierce & Turner 1994). Of these, 8 samples had sufficient numbers of tintinnids to allow comparisons. The remaining 7 samples were dominated by dinoflagellates almost to the exclusion of other protists in the >20 µm size fraction, thus no comparisons could be made for tintinnids in these samples. For statistical analyses the comparison was considered to be a special case of randomized complete blocks design, thus a 2-way ANOVA for paired comparisons was done for each group (Sokal & Rohlf 1981, p. 357)

RESULTS

A total of 30 species of tintinnids were recorded for Buzzards Bay (Table 1). Tintinnid abundances ranged from 0 to 3.3×10^3 cells l^{-1}. Total tintinnid abundances showed no seasonal trends, and could vary by an order of magnitude between sampling dates (Fig. 1). Spatial variations were also pronounced, and samples collected on the same day varied by as much as 2 orders of magnitude between stations. Annual means by station (Fig. 2) showed 2 trends: tintinnids were significantly more abundant at the New Bedford sewage outfall (Stn 7), and were significantly less abundant at the Cape Cod Canal (Stn 2) and nearby Cleveland Ledge (Stn 4).

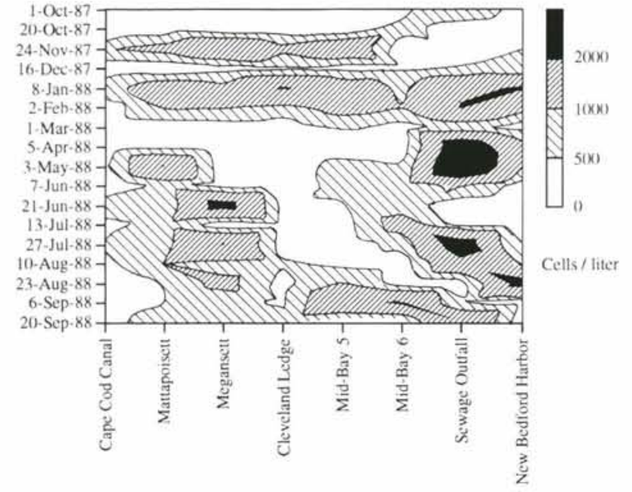

Fig. 1. Total tintinnid abundance (cells l^{-1}) by station, October 1987 to September 1988

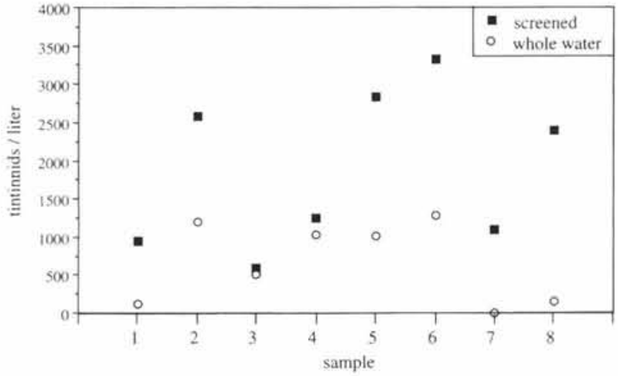

Fig. 3. Effects of screening with a 20 µm mesh on tintinnid abundance estimates

Ten genera of tintinnids were identified during the study period. The genus *Tintinnopsis* was the dominant genus, both in numbers of individuals, and number of species represented. Fifteen of the 30 species belonged to this genus, and half of the *Tintinnopsis* species were present throughout the year (Table 1). Tintinnid species from 3 genera remain unidentified, and may represent new species. These are referred to as *Codonella* sp., *Eutintinnus* C13S2, and *Metacylis* C13S2 (C13S2 refers to the sample in which they were first found). Further study is necessary before the taxonomic status of these tintinnids can be clarified. The 8 species of tintinnids present in the bay throughout the year were *Stenosemella oliva*, *Tintinnopsis acuminata*, *T. baltica*, *T. parva*, *T. rapa*, *T. sufflata*, *T. tubulosa*, and *T. vasculum*. Five genera found in Buzzards Bay were only present in the summer months: *Eutintinnus*, *Favella*, *Helicostomella*, *Metacylis*, and *Stylicauda*. Of these, only *H. subulata* exceeded 10^3 cells l^{-1}. The rest were often localized in distribution and abundance.

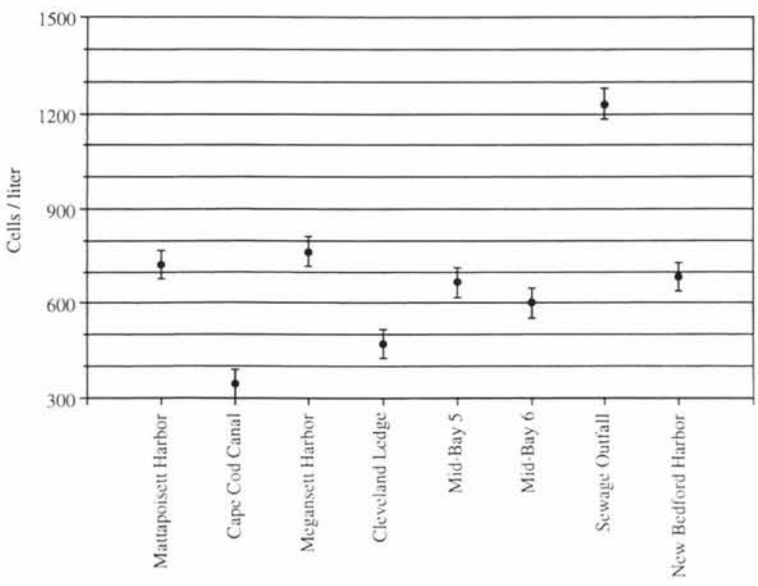

Fig. 2. Tintinnid annual mean abundance by station. Error bars are 95% comparison intervals. Means with error bars that do not overlap are significantly different (Sokal & Rohlf 1981)

Three species of tintinnids were very abundant in the colder months of the year. The unidentified *Codonella* species was abundant from November to February. Specimens of this species were observed in conjugation, and some appeared to be parasitized by dinoflagellates. A few individuals of *Tintinnopsis radix* in other samples were also observed with dinoflagellate parasites. These 2 species were the only tintinnids observed with these parasites. *Stenosemella ventricosa* was very abundant on 6 September 1988. This species had been previously recorded in the bay only in low numbers from November to January. *Tintinnopsis tubulosoides* was the dominant winter-spring tintinnid. It was only present from November to June, and reached peak abundances in January and April.

An examination of the effects of screening with a 20 µm mesh on tintinnids showed that this is an important technique for sampling tintinnid populations. Tintinnid abundance estimates were significantly higher in the screened samples (2-way ANOVA for paired comparisons, $p = 0.0037$; Fig. 3). Tintinnid abundance estimates from whole-water samples were 0 to 84.5% (mean = 38.4%) of comparable screened samples, resulting in a mean underestimation of 61.6% in the whole-water samples.

DISCUSSION

Tintinnid populations in Buzzards Bay showed patterns of peaks and minima similar to those of other populations in coastal waters along the northeastern coast of the United States (Hargraves 1981, Capriulo & Carpenter 1983, Middlebrook et al. 1987, Sanders 1987, Verity 1987). The present survey covered more stations synoptically than any of these previous studies, and it is apparent that the spatial variations on any given date could be as great as seasonal variations. For example, on 21 June 1988 tintinnids were absent from New Bedford Harbor (Stn 8), but were at their annual peak in Megansett Harbor (Stn 3). Fluctuations of over an order of magnitude were not uncommon between stations or over a 2 wk period.

Tintinnids were not significantly more abundant in New Bedford Harbor (Stn 8) than in other parts of the bay (Fig. 2). Instead, tintinnids were significantly more abundant at the New Bedford sewage outfall (Stn 7) than at any other station. Tintinnid abundances have been found to be increased by the combination of increased nutrients and hydrocarbons (Dahl et al. 1983, Dale 1988, 1991).

Fluctuations in abundances of tintinnid populations by an order of magnitude or more over periods of 1 to 2 wk are characteristic. Gold & Morales (1976) found 4 species of tintinnids in the Woods Hole region that appeared suddenly in the plankton, remained for approximately 2 wk, and abruptly disappeared. Graziano (1989) also found that tintinnid populations in the North Irish Sea were characterized by abrupt appearances and disappearances of many species. These large abundance fluctuations over such short periods may imply that patchiness could confuse the seasonal signal. Alternatively, the change may be real, suggesting that even sampling every 2 wk may miss some events, especially during the warmer months. Stoecker et al. (1984) found that patches of tintinnids and dinoflagellates occurred both vertically and horizontally over scales of meters to tens of meters within a Cape Cod salt pond. While patchiness may account for some of the short-term variation, the same general seasonal cycle was observed over 4 annual cycles in Narragansett Bay (Verity 1987), and appears to represent actual changes in tintinnid abundances.

Estuarine tintinnid communities are composed of numerous species coexisting at the same time. Many of these species appear capable of rapid population growth when conditions are favorable. These conditions may include favorable water temperature, food availability, predation impacts, and competition for resources with other tintinnids and other organisms. Occasionally conditions were right for one species to dominate, resulting in the various peaks which were observed. An underlying trend of slightly higher numbers of both individual cells and species appears to be related to a seasonal parameter, possibly temperature. Feeding rates, growth rates, and food availability may be coupled with increasing temperatures (reviewed in Pierce & Turner 1992). These factors could combine in warmer months, resulting in a greater number of localized blooms, and possibly explaining the pattern observed in Buzzards Bay. Conversely, poor conditions in the winter may favor 1 or 2 species adapted for these conditions, and in the absence of competition and the reduction of metazoan predation pressure, these species may increase.

The abundance of one small tintinnid, *Tintinnopsis minuta*, was probably underestimated. Although this species was abundant in the spring and summer, the diameter of the lorica was only 13 to 18 µm. Since the samples were screened onto 20 µm mesh, many specimens were probably lost. This species was found to be very abundant in both Narragansett Bay (Hargraves 1981, Verity 1987) and Chesapeake Bay (Brownlee & Jacobs 1987). The underestimation of the abundance of small tintinnids may have important food web implications as the size of food particles consumed by tintinnids is proportional to lorica diameter (Spittler 1973). Thus *T. minuta* may have a different trophic role from most other tintinnids, and may function trophically like many aloricate choreotrichs.

Cape Cod appears to be an effective barrier to the distribution of tintinnids despite the presence of the Cape Cod Canal. Of the 30 species of tintinnids present in Buzzards Bay, 73% were also present in Narragansett Bay (Hargraves 1981, Verity 1987), while only 38% of Buzzards Bay species were found in a Gulf of Maine estuary (Sanders 1987). Ten of the tintinnid species found in Buzzards Bay appear restricted to the south side of Cape Cod and points further south (Table 2). These were *Favella arcuata*, *Favella ehrenbergii*, *Metacylis angulata*, *M. annulifera*, *Stylicauda platensis*, *Tintinnopsis dadayi*, *T. radix*, *T. sufflata*, *T. tubulosa*, and *T. vasculum*. All tintinnid species which were present both north of Cape Cod and in Buzzards Bay were also found further south.

The isolating effect of Cape Cod is also suggested by taxa not found in this study. The genera *Parafavella* and *Ptychocylis* are typical components of the plankton of northern hemisphere cold waters (Pierce & Turner 1993). These genera are common in the Gulf of Maine (Bigelow et al. 1940) and its estuaries (Sanders 1987), and have also been found in Narragansett Bay (Verity 1987) and Long Island Sound (Gold & Morales 1975b) as rare vagrants in the winter months. If the Cape Cod

Table 2. Previous records of tintinnid occurrences along the United States east coast. Only species present in Buzzards Bay are listed

	Bay of Fundy (Middlebrook et al. 1987)	Damariscotta River (Sanders 1987)	Woods Hole (Gold & Morales 1976)	Buzzards Bay (This study)	Narragansett Bay (Hargraves 1981, Verity 1987)	Long Island Sound (Capriulo & Carpenter 1983)	New York Bight (Gold & Morales 1975a, b)	Chesapeake Bay (Brownlee & Jacobs 1987)
Codonella sp.				×				
Coxliella lacinosa				×				
Eutintinnus pectinis		×	×	×	×			×
Eutintinnus C13S2				×			×	
Favella arcuata				×				
F. ehrenbergii			×	×	×	×	×	
Helicostomella subulata	×	×	×	×	×	×	×	
Metacylis angulata				×	×		×	
M. annulifera				×	×	×	×	
Metacylis C13S2				×				
Stenosemella oliva	×	×	×	×	×	×	×	
S. ventricosa	×		×	×	×		×	
Stylicauda platensis			×	×	×		×	
Tintinnidium fluviatile		×	×	×	×	×	×	
Tintinnopsis acuminata	×	×	×	×	×	×	×	
T. baltica	×	×	×	×	×	×	×	×
T. beroidea	×			×	×	×	×	×
T. dadayi			×	×	×		×	×
T. kofoidi		×		×	×		×	
T. levigata		×	×	×	×		×	
T. minuta		×	×	×	×	×	×	×
T. nucula		×	×	×	×	×		
T. parva	×			×	×	×	×	×
T. radix			×	×				×
T. rapa	×	×	×	×		×	×	×
T. sufflata			×	×	×			
T. tubulosa				×	×	×	×	
T. tubulosoides	×	×		×	×	×	×	
T. vasculum			×	×	×	×	×	

Canal was a conduit for the introduction of cold-water tintinnids into Buzzards Bay, these genera would almost certainly have been observed in this study. The decreased abundance of tintinnids at the Cape Cod Canal (Stn 2) and Cleveland Ledge (Stn 4) stations may also be due to the influence of the Canal, but its cause is still a mystery. Thus it appears that Cape Cod is still an effective barrier to the distribution of tintinnids despite the presence of the Cape Cod Canal. This situation is quite different from that of the dinoflagellate *Alexandrium tamarense*, which appears be transported into Buzzards Bay from the Cape Cod Canal (Pierce & Turner 1994).

The factors controlling tintinnid distributions in Buzzards Bay are still unclear. Although there were some patterns, such as the presence of certain genera only during the summer months, and bay-wide blooms of certain other species, the bulk of the signal seemed to be spatial and temporal patchiness. This may be in part due to the sampling regime, but dinoflagellates from the same samples did not show the chaotic distribution patterns that tintinnids did.

It is interesting to note that while temperature did not appear to directly correlate with total tintinnid abundance, only a fraction of the tintinnid species observed in the bay were present for most of the year. Only 8 of the 30 taxa identified were present for most of the year. All the rest were either very rare, or were restricted to certain times of the year. Thus, although temperature may not be important in controlling total abundance, it was probably a major influence on species composition.

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This article was presented by D. A. Caron (Senior Editorial Advisor), Woods Hole, Massachusetts, USA

Manuscript first received: January 22, 1993
Revised version accepted: May 17, 1994