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Abundance, Species Composition, Biodiversity, Size and Ecology of Tintinnids in Doha Harbour (Arabian Gulf)

Abstract: The qualitative and quantitative dynamics of the tintinnid community in Doha Harbour (Arabian Gulf) were studied monthly for 13 months. The results showed that the harbour was characterized by a tintinnid community with a comparatively great number of species (76 spp.) and high divesity (diversity index: up to 2.96). The standing crop appeared to be very low (35-2529 cells/m^3) showing a bimodal peak of abundance in February and November at a temperature of 18.4-21.5°C. A few species were responsible for the bulk of the tintinnid abundance, while frequently existing species attained temporary abundance. The biometric measurements reflected a wide range of variations among the different species in lorica length (34.9-297.5µm), oral diameter (20-97µm) and volume (0.06x10^5-15.13x10^{5}µm^3). Significant correlation was found between tintinnid abundance and temperature, nitrite, nitrate and phosphate, while with dissolved oxygen, ammonia and silicate the correlation was not significant.

Keywords: Tintinnids - Abundance - Species Composition - Biodiversity - Marine Environment - Arabian Gulf - Doha Harbour

الكثرة العددية، التركيب النوعى، التنوع البيولوجى، الحجم وبيئة الجرسيات فى ميناء الدوحة، الخليج العربى

محمد موسي درغام - نجوى السيد عبد العزيز

المستخلص:الجرسيات حيوانات أولية هدبية، وهى من المكونات الرئيسية للعوالق الحيوانية الدائمة فى البيئة البحرية، ولها أهميتها فى السلسلة الغذائية، كما تلعب دورا كبيرا فى الأنشطة البيئية البحرية المتنوعة. وبالرغم من أهمية هذه الحيوانات إلا أنهالم تلق الاهتمام المناسب ولم تسبق دراستها فى الخليج العربى بصفة عامة. لذلك خصص هذا البحث لدراسة الجرسيات بشىء من التفصيل وتتبع ديناميكية مجتمعها من حيث الكثافة العددية والتركيب النوعى والتنوع البيولوجى وتغير الحجم، وربط ذلك بالظروف البيئية السائدة فى المنطقة، خاصة ميناء الدوحة. أجريت الدراسة بصفة منتظمة شهريا فى الفترة من ديسمبر 1987 إلى يناير 1989, وقد جمعت العينات اللازمة عند تسعة مواقع تمثل الظروف البيئية المتنوعة فى ميناء الدوحة. ومن خلال فحص النتائج تبين مايلى:

أولا: مجتمع الجرسيات فى ميناء الدوحة يتكون من عدد كبير نسبيا من الأنواع (76 نوعا) تنتمى غالبيتها إلى المياه المعتدلة والدافئة، وقد اختلف عدد الأنواع التى سجلت شهريا بدرجات متفاوتة بين 15 و 39 نوعا. ومن تكرار عدد مرات التواجد الشهرى للأنواع على امتداد فترة الدراسة أمكن تقسيمها إلى أربع مجموعات: أنواع معمرة (12 نوعا) تتواجد من 9 – 13 شهرا، أنواع متكررة التواجد (22 نوعا) من 5 –8 شهور مستمرة أو متقطعة، أنواع قليلة التواجد (11 نوعا) لفترة محددة من 3 – 4 شهور، أنواع نادرة (31 نوعا) شوهدت خلال شهر واحد أو شهرين..

وبالمقارنة بمناطق بحرية أخرى فإن عدد أنواع الجرسيات فى ميناء الدوحة أكبر بكثير ويرجع ذلك إلى قدوم أنواع كثيرة من خليج عمان مع التيار الداخل منه إلى الخليج العربى، حيث تم التعرف على عدد من الأنواع التى تعيش عادة فى مياه البحر المفتوح بعيدا عن الشاطئ، وهذا ما يفسره التشابه الكبير فى التركيب النوعى لهذه المجموعة بين الخليجين.

ثانيا: الكثافة العددية للجرسيات كانت منخفضة جدا (35 – 2529 خلية / متر3) عن مثيلاتها فى المناطق الأخرى، إلا أن التوزيع الموسمى للمحصول القائم أظهر وجود فترتين لازدهار هذه الحيوانات فى ميناء الدوحة وهما شهر فبراير ونوفمبر عندما تصل درجة حرارة الماء إلى معدلات منخفضة (18,4 – 21,5درجة مئوية). ويرجع عدم قدرة الجرسيات على النمو الجيد فى ميناء الدوحة إلى الارتفاع الكبير فى كل من درجة الحرارة التى ترتفع أحيانا إلى 34 درجة مئوية والملوحة (41 – 43 جزء فى الألف).

ثالثا: من قياس أغلفة عدد كبير من الأنواع المسجلة فى ميناء الدوحة أمكن لأول مرة حساب حجم كل نوع على حده ومقارنته بنظائره فى أماكن متعددة حيث تبين وجود اختلافات كبيرة فى حجم كل نوع مع اختلاف الظروف البيئية الأمر الذى يؤكد تأثير هذه الظروف على معدل نمو أنواع الجرسيات، ومن خلال حساب الحجم الكلى للجرسيات طوال فترة الدراسة وجد أن التغير الموسمى له يتشابه إلى حد كبير مع التغير الموسمى للكثافة العددية لها.

رابعا: أوضحت الدراسة التنوع الكبير فى مجتمع الجرسيات فى الميناء حيث تراوحت قيم معامل التنوع البيولوجي ما بين 1,48 – 2,96 ، وهذا يشير بدوره إلى تعدد سيادة الأنواع فى الشهور المختلفة، وكان ذلك واضحا من خلال العلاقة العكسية والطردية بين التغير الشهرى فى كل من عدد الأنواع ومعامل التنوع البيولوجى.

وقد أوضح البحث وجود علاقات متباينة بين ديناميكية مجتمع الجرسيات فى ميناء الدوحة والعوامل البيئية السائدة بها، وأشارت قيم معامل الارتباط إلى علاقة وطيدة بين الكثافة العددية للجرسيات وكل من درجة الحرارة، تركيز النترات، النتريت، الفوسفات، بينما كانت العلاقة مع الملوحة، الأمونيا، الأكسجين الذائب والسليكات ضعيفة..

كلمات مدخلية: الجرسيات – كثافة عددية – تنوع بيولوجي – بيئة بحرية – الخليج العربي – ميناء الدوحة

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Introduction

Tintinnids are a prominent component among marine zooplankters (Cosper, 1972), making a significant contribution to the biological economy of the sea, particularly at lower trophic levels (Krishnamurthy, *et al.* 1979) and in biological and nonbiological activities in the marine habitat (c.f. Verity, 1987). The vast majority of these ciliates belongs to the pelagic marine fauna of both oceanic and neritic waters of all oceans and are numerically important second trophic level feeders (Zeitzschel, 1967). Although tintinnids in different world seawaters have attracted great attention, they have received little concern in the Arabian Gulf (Gulf region) and their knowledge in this region is still unsatisfactory. Martini (1969) identified tintinnid species in plankton samples collected once from the Gulf region and Arabian Sea by the RV Meteor. The seasonal occurrence and dominance of tintinnids in the Arabian Gulf and Gulf of Oman were reported by Dorgham (1990) and their total standing crop in Doha Harbour was estimated by Dorgham and Hussein (1991).

The present investigation may be considered the first comprehensive study, which was conducted to expand the knowledge of tintinnids in the Arabian Gulf, including their species composition, numerical abundance, size variations and biodiversity. It aimed also to follow the variations in the community dynamics in relation to the prevailing environmental conditions and their contribution to the total zooplankton in coastal tropical seawater (Doha Harbour).

Materials and Methods

Doha Harbour is the main Harbour in the State of Qatar, occupying about 20 km^2 with depth range of 4-15 m. It includes two small bays directly open to the Gulf water. The first bay containing Stations 6, 7 & 8, is affected by domestic wastes discharged from a big Sheraton Hotel and the second one, which contains station 1, is affected by oil pollution and other wastes resulting from the shipping activities. The other stations are located outside the two bays.

Zooplankton samples were collected monthly during the period from December 1987 to January 1989 by surface hauls at 9 stations (Fig. 1), using a fine plankton net (25(μm mesh size). Tintinnid species were identified. The standing crop was estimated from the mean count of three 1ml aliquots of the concentrated samples and the total volume of tintinnids was calculated based on the lorica size of the identified species. The diversity index of tintinnid community ($H'=\Sigma(Pi \ln Pi)$ was determined according to Shannon and Weaver (1963), evenness ($J=H'/Hmax$,) according to Pielou (1977) and the number of species was considered as an index of species richness. Correlation between the tintinnid community and the environmental parameters was also calculated. The similarity in species compositions between the different stations was found following Sorensen (1948):

$$S = \frac{2C}{a + b} x\ 100$$

where a = number of species at a station, b = number of species at another station, c = number of common species between the two stations.

Water temperature, salinity, dissolved oxygen, nitrate, nitrite, ammonia, reactive phosphate and reactive silicate were measured in the duration of the present study (Dorgham, 1990).

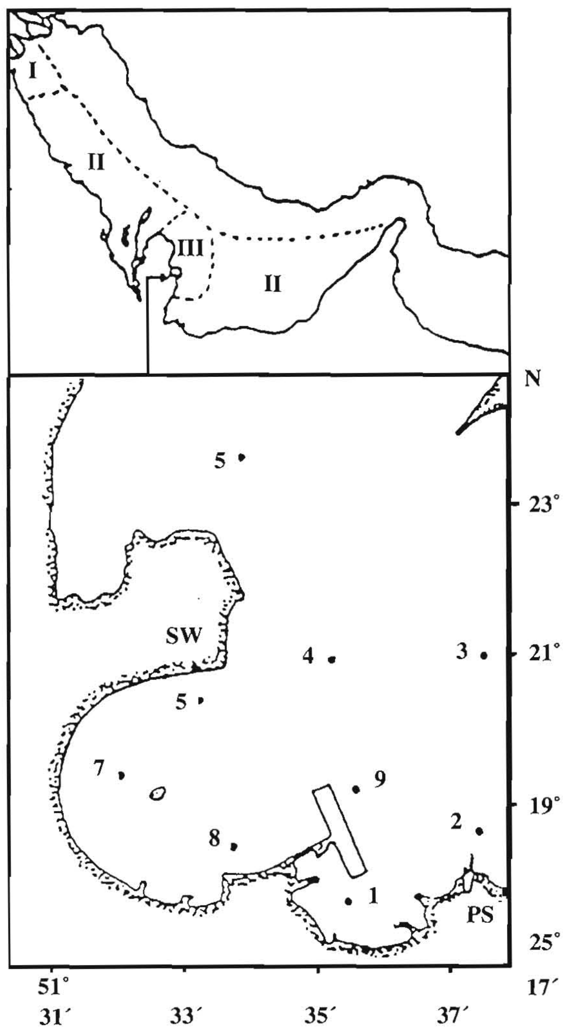

Fig. 1: Doha Harbour and positions of sampling stations

Results

Environmental conditions:

The surface water temperature showed a seasonal pattern of variations similar to that usually known in tropical regions, attaining the lowest value (15.7°C) in January, and the highest ones (30.2-33.9°C) in summer, with a maximum in August (33.9°C). Regardless of the wide seasonal variations of water temperature, salinity fluctuated over the year within a clearly narrow range (41.3- 43.2 ppt). Dissolved oxygen sustained usually low values, varying from 3.2 to 5.2 mg/L.

Nutrient salts were generally low, except a few relatively high concentrations. The monthly average nitrate varied from a minimum of 0.09μM to a maximum of 0.27μM, nitrite 0.003 - 0.15 μM and ammonia 0.09 - 0.33 μM. A similar pattern of temporal variations was observed for phosphate and silicate, which fall within the range of 0.02 - 0.27 μM and 3.69-6.65 μM respectively.

Species composition and abundance

The tintinnid community comprised a total of 76 species, *Eutintinnus* and *Tintinnopsis* were represented by the largest number of species (15 spp. each), followed by *Favella* (11 spp.), *Codonellopsis* (6 spp.) and *Coxliella* (5 spp.). The number of species demonstrated wide monthly variations from 15 species in January to 39 species in November (Fig. 2). Regardless of the order of their abundance, the frequent distribution of tintinnid species showed four groups in the study area (Table 1).

1- Persistent species (12 spp.), found continuously during at least 9 months of the study period,

2- Frequent species (22 spp.), occurring during 5-8 months continuously or intermittently,

3- Less frequent species (11 spp.), usually existing for 3-4 months,

4- Rare species (31 spp), which were occasionally recorded in one or two months.

The majority of the recorded species are neritic temperate and/or warm water forms. However, several oceanic species were identified in the area indicating their transference from the offshore waters by prevailing active semi-diurnal tidal current and water exchange between the Gulf of Oman and the Gulf region. These species were *Codonellopsis pusilla, C. schabi, Codonella aspera, C. nationalis, Cyttarocylis cassis, Undella hyalina,, Salpingella attenuata, Proplectella acuta and P. angustior.*

The diversity index in Doha Harbour fluctuated between 1.48 and 2.96. Two levels of diversity were distinguished, the higher one (2.07-2.96) appeared from May to October at a temperature range of 27.8-33.9°C and the lower (1.48-1.91) coincided with the decrease of water temperature to 15.7 - 24.8°C from December and April (Fig.2). The monthly number of species showed either a similar or opposite trend of variation to that of the diversity index, a pattern which is likely attributable to differences in the number of the dominant species every month and their roles in the total count of tintinnids. The monthly variations of evenness values showed an approximately similar pattern to those of the diversity index, varying between 0.95 and 1.9 (Fig. 2).

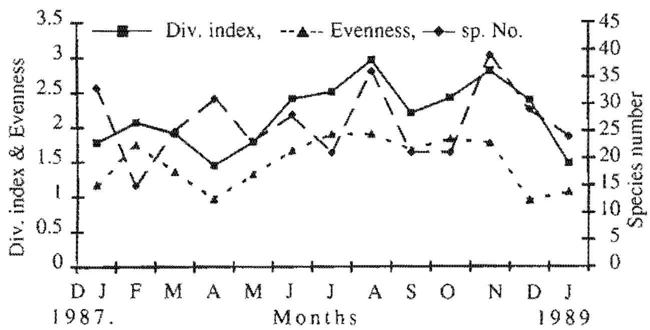

Fig. 2: Monthly values of diversity and evenness indices and species number of tintinnids in Doha Harbour

The standing crop of tintinnids in the whole area ranged from a minimum of 35 to a maximum of 2529 cells/m^3. The monthly average abundance for the whole area showed two peaks in February (1214 cells/m^3) and November (893 cells/m^3) (Fig. 3). The multidominant species was the characteristic feature of tintinnids. The February peak was dominated by *Favella composita* (39.4% of total tintinnids), *Tintinnopsis directa* (13.35), *Metacylis meresckowskii* (12.2%) and *Eutintinnus lusus-undae* (7.2%). The leading species of the November peak comprised *T. levigata* (20.8%), *T. cylindrica* (11%), *Helicostomella subulata* (9.6%), *T. fimbriata* (7.3%), *T. butschlii* (6.4%), *Stenosemella ventricosa* (6.3%), *T. lobiancoi* (6.2%) and *T. lohmanni* (5.3%). Other species dominated in other months such as *E. lusus-undae* (December-April), *E. medius* (December and January), *E. latus* (May), *E. tubulosus* (December) *E. fraknoi* (October and December), *F. composita* (January and April), *F. azorica* (January, July and August), *Codonellopsis*

Table 1; Frequency of occurance (number of months) of tintinnid species in Doha Harbour

Species	Months
Perennial (12 spp.)	
Favella helgolandica	13
Eutintinnus lusus-undae	12
Favella azorica	11
Metacylis mereschkowskii	11
Tintinnopsis cylindrica	11
T. lobiancoi	10
T. lindeni	10
Amphorides brandtii	9
Eutintinnus fraknoi	9
E. ,tubulosus	9
Helicostomella subulata	9
Tintinnopsis butschlii	9
Frequent (22 spp)	
Amphorellopsis acuta	8
Codonellopsis ostenfeldii	8
Coxliella annulata	8
Eutintinnus latus	8
Favella composita	8
Tintinnopsis beroidea	8
T. nana	8
T. directa	7
T. fimbriata	7
T. lohmanni	7
Eutintinnus medius	7
Coxliella ampla	6
Eutintinnus elegans	6
E. macilentus	6
Favella ehrenbergii	6
Coxliella meunieri	5
Eutintinnus tenuis	5
Favella adriatica	5
F. campanula	5
Helicostomella longa	5
Stenosemella ventricosa	5
Tintinnopsis levigata	5
Less frequent (11 spp)	
Codonellopsis schabi	4
Favella markuzowskii	4
Metacylis jorgenseni	4
Codonella aspera	3
Coxliella mousseni	3
Eutintinnus apertus	3
E. iniqualis	3
E. perminatus	3
E. procurrereus	3
Stenosemella nivalis	3
Undella hyalina	3
Rare (31 spp)	
Codonellopsis americana	2
C. pusilla	2
Coxliella decipiens	2
Eutininnus elongatus	2
E. pinguis	2
Favella panamensis	2
Proplectella acuta	2
P. angustior	2
Rhabdonella spiralis	2
Salpingella attenuata	2
Tintinnidium neopolitanum	2
Tintinnopsis brandti	2
T. plagiostoma	2
Amphprides amphora	1
Codonella brevicollis	1
C. nationalis	1
Codonellopsis cylatthensis	1
C. ecaudata	1
Cyttarocylis cassis	1
Epicancella sp.	1
Eutintinnus colligatus	1
Favella jorgensenii	1
F. serrata	1
F. taraikaensis	1
Tintinnopsis adriatica	1
T. nucula	1
T. radix	1
Undella clevei	1
U. dohrni	1
U. longa	1
Undellopsis subangulata	1

ostenfeldii (December), *Amphorides brandtii* (May), *H. subulata* (May) and *T. lohmanni* (July) . Significant correlation was observed between tintinnid abundance and temperature (r = 0.4604 at p = 0.1), nitrate (r = 0.7393 at p = 0.01), nitrite (r = 0.5279 at p = 0.1) and reactive phosphate (r = 0.6426 at p = 0.02). On the other hand, the correlation with salinity, dissolved oxygen, ammonia, reactive silicate and phytoplankton density was not significant (r = 0.346, 0.269, 0.216, 0.226 and 0.138 respectively at p = 0.1).

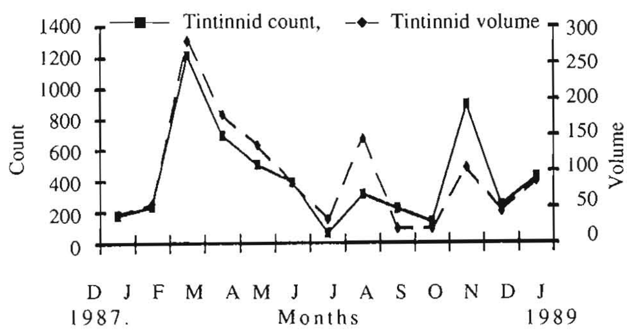

Fig. 3: Monthly average count and volume of tininnids in Doha Harbour

Biovolume and diversity index:

The length and oral diameter of tintinnid loricae in Doha Harbour indicated wide interspecific variations. The narrowest oral diameter (20µm) was recorded for *Salpingella attenuata* and *T. nana,* while the widest ones appeared for *F. adriatica,* (106µm), *F. ehrenbergii* (97.5µm) and *F. jorgensenii* (97.2µm) (Table 2). Regarding the length, *T. nana* attained the shortest lorica (34.9µm) and *Rhabdonella spiralis* had the longest one (297.5µm). The biometric variations of the different species were wide; 38% and 32.7% of the measured species had oral diameter within the range of 30-40 µm and 40-50 µm respectively (Fig. 4), while the lengths fall within several ranges (Fig. 5). The ratio between the length and oral diameter varied widely among the different genera, while for the species of the same genus the ratios were mostly very close. As shown in Table 2, *Eutintinnus* spp exhibited the highest ratio as compared to those of other genera, while *Favella* spp. sustained the lowest one. On the other hand, the correlation coefficient between the lengths and oral diameters of the measured species (53 spp.) was significant ($r = 0.359$ at $p = 0.01$). The lorica of *Favella ehrenbergii* sustained the greatest volume (15.13x105µm^3) followed by *F. jorgensenii* (14.04x10^{5}µm^3) and F. taraikensis (12.9x10^{5}µm^3), while *H. longa* showed the smallest volume (0.06x105µm^3) and *F. markuzowskii* (Table 2).

The total volume of tintinnids calculated from lorica size coincided in temporal distribution with that of the cell counts (Fig.3). It varied between a minimum of 19.3x106 µm^3 during August-October and a maximum of 280.1x10^6 µm^3.in February. The ratio between the total volume and total count also varied widely throughout the study period (8.8-52.6) indicating wide seasonal variations of lorica size.

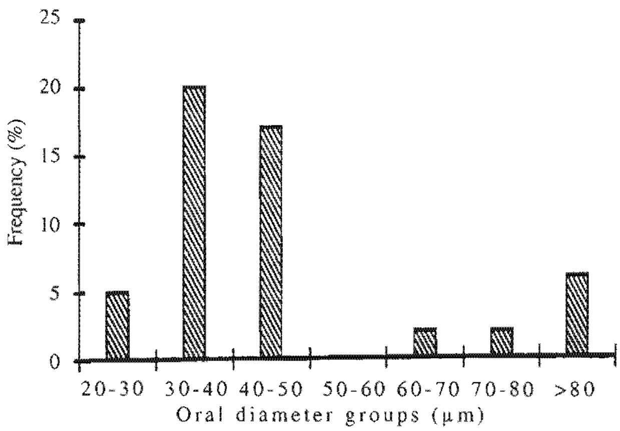

Fig. 4: Frequency of different oral diameter groups among tininnid species in Doha Harbour

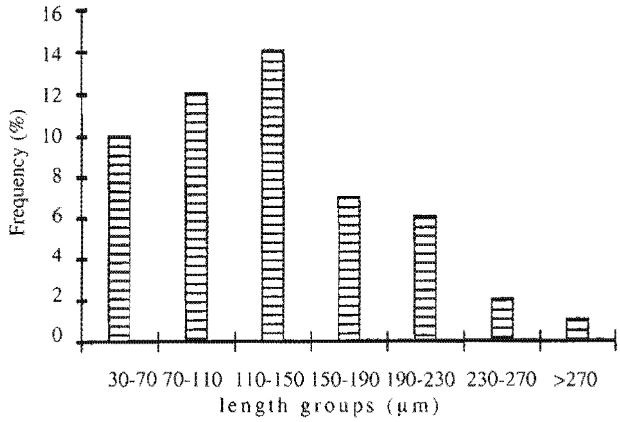

Fig. 5: Frequency of different length groups among tininnid species in Doha Harbour

Discussion

The role of tintinnids in seawater differs widely in the different habitats (Paranjape, 1987). As shown from the present study, they had a greatly variable contribution to the surface zooplankton in Doha Harbour, forming monthly between 3.7% and 88.8% with an annual average of 28.6%, while according to Dorgham and Hussein (1991), their contribution in the vertical hauls (1.9-13.8%) was markedly lower. Such difference may indicate the preference of tintinnids for the surface water, where phytoplankton is usually abundant.

Irrespective of its small area, Doha Harbour contained a highly diversified tintinnid community as compared to other tropical and subtropical areas (Table 3). Such a situation may be attributed to allochthonous species which are transferred to the Gulf region through the low salinity surface current from the Gulf of Oman reaching the harbour by the active semidiurnal tidal current. This assumption coincides with the high similarity between the tintinnid communities in the Harbour and the Gulf of Oman and Arabian Sea. Although they have rapid regeneration (Hargraves, 1981) which enable them to establish dense populations at suitable conditions, tintinnids in Doha Harbour sustained a remarkably lower standing crop than different world regions (Table 4). Their abundance peaks occurred in February and November at a temperature range of 18.4 - 21.5°C, indicating low temperature as more preferable for better growth of tintinnids. This is contradictory to the observations of Verity (1987), who stated that the maximum abundance of tintinnids usually occurs at a relatively high temperature. On the other hand, the species diversity of tintinnids was directly related to temperature in Doha Harbour (up to 34°C) and salinity (up to 43 ppt). But in Ismir Bay, an inversely relationship was

Table 2: Average values in μm of length (L), oral diameter (O), volume (x10^5μm^3) and L/O ratio of tintinnid species in Doha Harbour

Species	Length	Oral diam.	Volume	L/O ratio
Amphorellopsis acuta	85	33.3	0.226	2.6
A. brandtii	186.4	36.4	2.69	5.1
Codonella aspera	75	40	1.328	1.9
C. brevicolis	187.5	117	28.2	1.6
Codonellopsis americana	118	37.5	2.96	3.1
C. cylatthensis	125	40	1.732	3.1
C. ecaudata	60	25	0.183	2.4
C. pusilla	94	43	1.787	2.2
C. ostenfeldii	121	38	1.842	3.2
C. schabi	114	39.3	1.977	2.9
Coxliella ampla	62.5	35	0.62	1.8
C. annulata	131	74.5	5.46	1.8
C. meunieri	64	38.8	0.762	1.6
C. meusseni	184	46.5	0.98	1 4
Eutintinnus apertus	162	47.5	1.895	3.4
E . elegans	161	32	1.016	5
E. elongatus	260	40	2.766	6.5
E. fraknoi	189.5	31.7	0.903	6
E. iniqualis	114.3	43.3	0.422	3.3
E. latus	227.8	45.3	2.296	5
E. lusus-undae	226.7	48.3	2.826	4.7
E. macilentus	112.1	31.9	0.446	3.5
E. medicus	199.5	43.8	2.027	4.6
E. penguis	195	40	1.534	4.9
E. perminatus	174	46.2	2.014	3.8
E. procurrereus	162.2	36.8	1.228	4.4
E. tenuis	255	42.5	2.48	6
E.tubulosus	134.2	40.1	1.939	3.3
Favella adriatica	121.7	105.8	1.1	1.2
F. azorica	60	37.5	0.665	1.6
F. campanula	104.6	86.4	7.86	1.2
F. composita	103.8	68.3	5.474	1.5
F. ehrenbergii	170	97.5	15.127	1.7
F. helgolandica	64.3	38	0.722	1.7
F. markuzowskii	192.2	97.2	14.037	2
F. panamensis	143.3	80	0.15	1.8
F. taraikensis	227.5	85	12.903	2.7
Helicostomella longa	59	19.4	0.058	3
H. subulata	100.8	29.2	0.344	3.4
Metacylis mereschkowskii	48	41	0.491	1.2
Rhabdonella spiralis	297.5	73.3	4.4	4.1
Salpingella attenuata	130	20	0.238	6.5
Stenosemella nivalis	49.6	43.8	0.557	1.1
S. ventricosa	46	40	0.527	1.2
Tintinnopsis beroidea	86	42.8	1.642	2
T. brandtii	87	31.8	0.624	2.7
T. butschlii	86	43.4	1.07	2
T. cylindrica	125.4	40	1.603	3.1
T. directa	72.5	37.5	0.91	1.9
T. fimbriata	71.1	46.4	0.468	1.5
T. levigata	112.5	41.2	1.61	2.7
T. lobiancoi	93	38.3	1.031	2.4
T. nana	34.9	20.3	0.142	1.7
Udella hyalina	140	65	4.957	2.2

found when salinity and temperature exceeded 28.2 °C and salinity 22 ppt (Koray and Ozel, 1983). Furthermore, Kimor and Golandsky (1981) supposed that temperature is a determining factor in the seasonal distribution of tintinnids either directly or via their nutritional requirements in the form of the phytoplankton components, which constitute the major food source, while other factors such as oxygen and salinity appeared to have no clear and predictable influence.

It could, therefore, be supposed that the low abundance of tintinnids in Doha Harbour is related to the prevailing abnormally high temperature, high salinity, low phytoplankton density and probably oil pollution which may be produced from the ships occuring in Doha Harbour. This explanation is in agreement with some observations but contradicts with others. It is also to be noticed that factors controlling the abundance and distribution of tintinnids are a matter of debate. Verity (1987) reported that the important environmental conditions controlling the regional and seasonal distribution of tintinnds include biological factors such as food supply and predation beside the prevailing physico-chemical conditions, particularly temperature, salinity and dissolved oxygen. However, on the contrary, Hargraves (1981) indicated that the seasonal abundance of tintinnids could not be associated with changes in salinity, temperature or nannoplankton abundance.

The quality and quantity of phytoplankton as the main food source play a significant role in tintinnid abundance. Although the correlation between tintinnid abundance and phytoplankton density was insignificant ($r = 0.138$, $n = 97$, $p = 0.1$) in Doha Harbour, the temporal distribution of both groups showed a reverse pattern, the higher tintinnid counts coincided with the lower phytoplankton density and vice versa. This is in agreement with Capriulo and Carpenter (1983), who observed weak correlation between tintinnid abundance and phytoplankton density, admitting that the type of food does not appear to be critical for high tintinnid abundance. However, a positive correlation appears to exist between the phytoplankton and tintinnid abundance in time and space in the Gulf of Elat (Aqaba) (Kimor and Golandsky, 1981) and a decrease of tintinnid abundance in offshore waters was accompanied by a decrease in phytoplankton concentrations (Beers, *et al.* 1980). Anyway, the food quality may play a role in the feeding efficiency of tintinnids, since the size of the phytoplankton cells is important in the food selectivity of such group. Tintinnids are the major herbivore microzooplankton and effective grazers in Long Island Sound (Capriulo and Carpenter, 1983), particularly on nannoplankton (Zeitzschel, 1967) including bacteria, small flagellates, coccolithophorides and dinoflagellates (Burns, 1983). According to Taniguchi (1977), dominant diatoms and *Trichodesmium* in the Celebes Sea were too large for most tintinnids to ingest and the food availability for the tintinnids is indicated by the crop of small-sized phytoplankton. This is in agreement with the present study, since diatoms and *Trichodesmium* were also the dominant phytoplankton components in Doha Harbour. However, the cell diameter of many diatom cells are smaller than the oral diameter of several tintinnid species, which may enable ingesting such species. Beers and Stewart (1971) admitted the grazing stress on phytoplankton by microzooplankton, but the maximum size of ingestible food particles for the tintinnids is likely to be limited by oral diameter (Spittler, 1973).

Tintinnid abundance in Doha Harbour showed insignificant correlation with salinity, dissolved oxygen, ammoina and reactive silicate and significant correlation with temperature, nitrate, nitrite and reactive phosphate. The negative correlation with temperature may indicate the reverse relationship, which was clearly shown from the seasonal distribution of tintinnid abundance. The positive correlation with the above mentioned nutrients may indicate a direct relationship, since tintinnids play a pronouced role in nutrient recycling in the marine habitat. This is in agreement with several observations. Harrison (1980) considered tintinnids as primary agents of nutrient remineralisation. Although macrozooplankton are of major importance in sustaining nitrogen supply for primary production in some coastal waters (Harris, 1959 and Jawed, 1973) and in the open ocean (Eppley, *et al.* 1973), microzooplankton in general and tintinnids in particular had also an important role in the regeneration of nutrients (Johannes, 1968; McCarthy, *et al.* 1975; Johansen, 1976; Verity, 1985). Specific ammonia excretion rates of tintinnids are one to two orders of magnitude higher than rates for macrozooplankton (Johansen, 1976). It would be supposed that the effective role of microzooplankton in general and tintinnids in particular in nutrient recycling is related to their active grazing on the phytoplankton, which is the main user of inorganic nutrients.

The variation ranges of length and oral diameter of lorica in Doha Harbour are in agreement with those of Gold (1969), Gold and Morales (1975) for New York Bight and Taniguchi (1977) for Philippine and Cilibes Seas. Significantly different measures were recorded in other world waters (Marshall, 1969; Gold and Morales, 1975; Bakker and Phaff, 1976; Taniguchi, 1977; Krishnamurthy, *et al.* 1979), which may be attributed mainly to differences in the ecological conditions. Gold (1969) and Gold and Morales (1975) reported tha oral diameter of loricae of neritic tintinnids decreases with increasing food availability and length increases with decreasing water temperature and probably because of the limited food supply in nature, the natural tintinnid populations constantly attain the maximum oral diameter, while the length changes seasonally over wide ranges. Similar observations were found for the lorica of *E. fraknoi* in Doha Harbour (Dorgham and Abdel-Aziz, 1999). Smaller diameters (20-40μm) were generally found in the forms occurring in coastal seawater and the large inland polyhaline water (Bakker and Phaff, 1976).

Although 12 species existed as perennial forms in the study area, only 5 species among them had numerical importance, namely *F. composita* forming 16% of the annual average count of total tintinnids, *E. lusus-undae* (14.6%), *T. cylindrica* (6%), *M. mereschkowskii* (4.5%) and *F. helgolandica* (3.6%). This may again indicate that the environmental conditions, particularly high temperature, and high salinity in Doha Harbour are not favorable for the great majority of the existing tintinnid species to establish healthy populations. Although the visual observations indicated that Doha Harbour was affected by surface films of oil and domestic wastes, no measurements had been done to evaluate the levels of such pollution.

Table 3: Number of tintinnid species in different marine habitats

Region	Sp. No	Reference
Gulf of Aqaba	66	Komarovsky, 1960
Gulf of Mexico	55	Balech, 1967
Arabian Gulf	58	Dorgham, 1990
Gulf of Oman	35	Dorgham, 1990
Bengal Bay	49	Damodara & Krishnamurthy, 1985
Quoddy Region	27	Middlebrook, *et al.*, 1987
South Vietnam	72	Shirota, 1966
Rhode Island	31	Verity, 1987
Mediterranean Sea	112	Treouboff & Rose, 1957
Red Sea	108	Halim, 1969
Bodford Basin (Canada)	23	Paranjape, 1987
Long Island Sound	28	Capriulo & Carpenter, 1983
Libanaize Mediterranean Coast	35	Lakkis & Lakkis, 1985
Doha Harbour (Arabian Gulf)	76	***Present Study***

Table 4: Abundance of tintinnids (average or range) in different regions

Region	Count/l	Reference
Arabian Sea	10 - 15	Zeitzschel, 1967
Sea of Japan	15,000	Sorokin, 1977 Capriulo & Carpenter, 1983
Phillipine and Celebes Seas	10 - 100	Tanigushi, 1977
Swedish West Coast	10 - 15	Hedin, 1976
California Current	50	Beers & Stewart, 1967
Eastern Tropical Pacific Ocean	40 - 200	Beers & Stewart, 1971
Southern Californian Bight	18,000	Heinbokel & Beers, 1979
Peruvian Coastal waters	100-1,000	Beers, et al., 1972
Eastern Mediterranean	30,000	Vitiello, 1964
Doha Harbour	2.4	***Present Study***

It seems that the water circulation in the area has a remarkable effect on the distribution of tintinnid species in Doha Harbour. According to the Sorensen index, high similarity was observed throughout the Harbour, where 72-89% of the species appeared at all stations over the year. This is explained by the observations of Hassan and Hassan (1987) who observed that currents near Doha have large dominant diurnal and semidiurnal tidal components, the predominant directions of which are north, south, south-east and north-east respectively. However, the standing crop of tintinnids showed pronounced monthly variations throughout stations with a clear pattern, reflecting uneven distribution in Doha Harbour.

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