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Spatial and seasonal variations of large tintinnid ciliates in Shenhu Bay of China

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Key words: tintinnid, community structure, dominant species, environmental factor

Abstract

In this study, the spatial distribution and seasonal variation of large tintinnids (>76 µm) were investigated in Shenhu Bay during three seasons of 2012. Of the 36 species identified, 9 were dominant (i.e. *Tintinnopsis radix*, *Leprotintinnus simplex*, *Tintinnopsis japonica*, *Tintinnopsis tubulosoides*, *Leprotintinnus nordqvisti*, *Tintinnopsis beroidea*, *Stenosemella parvicollis*, *Tintinnidium primitivum*, *Tintinnopsis nana*). A clear seasonal shift of the taxonomic composition as well as the lorica size of the dominant species was observed. The highest numbers of tintinnid species occurred in spring, while the highest abundance and biomass occurred in summer. Clustering indicated that the seasonal variations of the community structure were more obvious than spatial variations. Spearman correlation DQDO\VLV UHYHDOHG WKDW GHQLW\ RI SKRVSKDWH DQG WRWDO SKRVSKRUXV significant impact on the tintinnid abundance. Redundancy analysis (RDA) illustrated that temperature, salinity and the nutrient level were the most important abiotic factors affecting the spatial and seasonal pattern of tintinnid communities in Shenhu Bay.

Introduction

Tintinnid ciliates are common components of the SODQNWRQ PLFURSURWR]RDQ FRPPXQLW\ DQG important trophic intermediates from the microbial ORRS WR KLJKHU WURSKLF OHYHOV LQ WKH RFHDQ (Capuzzo 1990, Kamiyama & Tsujino 1996, Godhantaraman 2001). Tintinnids prey on pico- and QDQRSODQNWRQ DQG LQ YLH IURP DERXW P WR particles about half the diameter of their lorica oral openings (Dolan 2000). They can exert a strong JUD]LQJ LPSDFW RQ SKWRSODQNWRQ DVVHPEODJHV and remove large portions of the daily primary production. Whereas tintinnids serve as prey for a YDULHW\ RI PHWD]RDQ SRSODQNWRQ XFK DV FRSHSRGV (Dolan 2010). Tintinnid ciliates have long been considered as ideal organisms for the study of change in the structu UHUFRPSRVLWLRQ RI PLFURZ]RRSODQNWRQ communities due to their characteristic loricae (Dolan 2000, 2010). In contrast to other microorganisms, most tintinnid taxa are not cosmopolitan (Pierce & Turner 1993, Abou Zaid & Hellal 2012). The abundance, biomass and composition of tintinnid communities in coastal waters should be much more variable than those in the open sea, due to the greater variability of influencing factors (Vaqué et al. 1997).

Shenhu Bay is a shallow natural harbor located along the eastern region of Jinjiang, Fujian, southeast &KLQD,WFRYHUV DQ DUHD RI DERXW with a 30.8 NP ORQJ HQWUDQFH RSHQ DQG LV FRQQHFWHG WR WKH Taiwan Strait via an open mouth. Shenhu Bay is geomorphologically a typical ‘ria’ with depth contours roughly parallel to the shoreline. The reduced impact by anthropogenic activities means the original natural environmental landscape of the bay remains undisturbed. The remains of an ancient submerged forest with a 7,500-year history have been found here. In the 1990s, the Shenhu Bay National

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Natural Reserve was established, which has exerted a significant impact on the possibilities to study palaeoclimatological, paleogeographic and paleobiological changes on the coast of the Taiwan Strait. Although there are several ecological reports from Shenhu Bay, only a few studies have been carried out so far on the ecology of PLFURIRRSODQNWRQ FRPPXQLW\DQ TXDQWLWDWLYH on tintinnid community have not been reported from this area.

7R ILOO JDSV LQ XU NQRZOHGJH DERXW WKH HI of tintinnids in Shenhu Bay, we investigated the spatial and seasonal variation in abundance, biomass, composition and diversity of tintinnids. In addition, the present study concerns the determinants of the pattern in tintinnid communities, since tintinnid communities are sensitive to changes in multiple environmental factors (Sanders 1995, Kamiyama & Tsujino 1996, Godhantaraman 2001). The aim of this study is to clarify the spatial and seasonal pattern of the tintinnid communities on a local scale, and to determine what factors are most strongly affecting the spatial and seasonal pattern.

MATERIALS AND METHOD

Study sites

Seven VLWHV ZHUH GHVLJQDWHG I - I 1I - I E) in Shenhu Bay, Fujian, China (Fig. 1). Sites 1-3 were located at the top of the ED\VLWHV DQG LQ WKH PLGGOH VLWHV DQG DW the bay mouth.

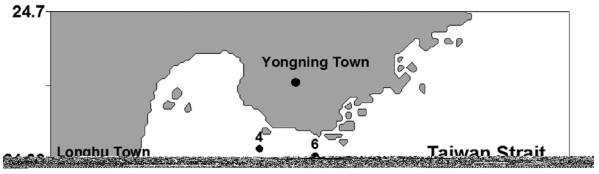

Fig. 1. Location of the study area and sampling sites of tintinnids in Shenhu Bay

Sampling and treatments

Tintinnid samples were collected by vertical tows of 76-μm-PHVK SODQNWRQ QWV IURP 6KHQX %D\LQ May, August and November, 2012, representing the temporal tintinnid communities in spring, summer and autumn, respectively. Volumes of water filtered per sample varied between 0.54 and 1.40 m^3. Samples were obtained and fixed with 5% formaldehyde in plastic bottles. A total of 21 tintinnid samples were analyzed.

3KWRSODQNWRQDQ SODQNWRQF FRSHSRGV ZHUH sampled in May and August from the same sites at which tintinnids ZHUH FROOHFWHG 3KWRSODQNWRQ samples were collected by the same method as tintinnids. Copepods samples were collected by YHUWLFDO WRZV RI WKH SODQNWRQ QHW ZLWK D SRUH size and fixed with 5% formaldehyde in plastic bottles.

At each sampling site, salinity and temperature (T) were measured in situ. Suspended particles (SP, !P S+ GLVVROYHG RUJDQLF FKHPLFDO oxygen demand (COD), active phosphorus (PO_4-P), active silicon (SiO_3-Si), nitrite nitrogen (NO_2-N), nitrate nitrogen (NO_3-N), ammonium nitrogen (NH_4-N) and petroleum pollutant (PP), were determined according to the standard methods presented in the Offshore Marine Chemical Survey Technical Regulations (908 Office of the State Oceanic Administration 2006).

Identification and enumeration

Formaldehyde fixed samples were settled for 48 hours and then concentrated to 50-300 ml (Utermöhl 1958). For the identification and enumeration of tintinnids, 0.1 ml of a well-mixed concentrated VDPSOH ZDV WDNHQ DQG PRXQWHG RQ D PLFURVFRSH slide and examined under a light microscope at a magnification 200×. A total volume of 1 ml concentrated sample was scanned. Tintinnids were identified by lorica morphology and species description according to Kofoid & Campbell (1929, 1939), Hada (1932, 1937, 1938), Nie (1934) and Lynn (2008). The classification system was mainly referred to Lynn (2008). All ciliates were finally identified to WKH OHDVW possible taxa. Lorica dimensions were measured using an ocular micrometer. Tintinnid biomass was estimated from measurements of the lorica and subsequent conversion to biovolume by

assigning approximate geometrical shapes. The volume equation from biovolume to organic carbon:

$$pg\ C = \mu m^3(lorica\ volume) \times 0.553 + 444.5$$

was applied to the data (Verity & Lagdon 1984, Thompson et al. 1999).

Copepods were observed and counted under a GLVVHFWLQJ PLFURVFRSH IURP DVXEVDPSOHV DNHQ ZLWK D wide bore pipette. The subsample volume is selected to ensure counting of at least 200 organisms. Copepodite VWDJHV RI FRSHSRGV ZHUH WDNHQ LQWR account, but not copepod nauplii.

Data analyses

The number of species, abundance and biomass of tintinnids were calculated, and Shannon-Wiener diversity index (*H'*) for each sample was calculated applying the following equation:

$$H' = -\sum_{i=1}^{S}\left(\frac{n_i}{N}\right)\log_2\left(\frac{n_i}{N}\right)$$

where n_i = abundance of the i^{th} species; N = total number of specimens. The distribution pattern of tintinnid communities was displayed using software VXUIHU 7KH DEXQGDQFH RI SKWRSODQNWRQLF copepods was calculated for each sample collected in spring and summer.

Cluster analysis was used to investigate the ciliate community structure using the PRIMER v5.0 (Plymouth Routines In Multivariate Ecological 5HVHDUFK SDFNDJH DFFRUGLQJ WR VSHFLHV FRPS DQG DEXQGDQFH &ODUNH & Gorley 2001). The Bray-Curtis similarity matrix was computed on square root-transformed biotic data and Euclidean distance matrix on ln(x+1)-transformed abiotic data. The group-average clustering was used to divide the ciliate communities into several assemblages, each comprising samples with similar species and abundance. Variances between groups were tested using the submodule ANOSIM (analysis of similarities) in PRIMER v5 (global R values range from 0 to 1, and a higher global R value demonstrates more significant variance). Species with a cumulative contribution of 90% to the average Bray-Curtis similarity within each group was analyzed using the submodule SIMPER (Similarity Percentage Analysis). The significance of the biota-environment correlation waV FKHFNHG XVLQ WKH 5(/$7(

Detrended correspondence analysis (DCA) for the biological data was employed to decide whether linear or unimodal ordination methods should be applied. After that, the detailed relationships between tintinnid communities and environmental factors were revealed by redundancy analysis (RDA) using &DQRFR IRU :LQRZV SDFNDJH WHU %UDDN Smilauer 2002). RDA analysis was conducted based on square root-transformed species-abundance data and ln(x+1)-transformed environmental data. To eliminate collinearity among variables, explanatory variables with a high variance inflation factor (VIF) were sequentially removed until all VIFs were below 20. Subsequently, forward selection was conducted to select the minimum set of environmental variables that could explain a significant amount ($P < 0.05$) of variation. With the forward selection, the significance of correlation with environmental variables was determined by Monte Carlo permutation test (999 permutations). Spearman correlation analysis between tintinnid communities and biotic factors was conducted using statistical program SPSS v17.0.

RESULTS

Physical and chemical variables

Thirteen physical and chemical environmental variables are summarized in Table 1. The depth of the estuary ranged between 4.5 and 14 m. Most of the variables showed clear seasonal differences. :DWHU WHPSHUDWXUH DQG VDOLQLW\ SHDNHG LQ VXPP

Table 1

Statistical summaries of 13 environmental variables from Shenhu Bay

Environmental variables	Mean	Min	Max	SD	Median
Depth (m)	10.01	4.50	14.00	2.76	11.00
Temperature(°C)	23.49	19.60	28.90	3.63	22.40
pH	7.98	7.79	8.10	0.10	8.02
Salinity	32.41	31.00	33.60	0.95	32.80
SP (mg l^{-1})	14.15	4.30	29.00	7.06	12.10
DO (mg l^{-1})	6.92	6.03	7.48	0.36	6.99
COD (mg l^{-1})	0.48	0.15	0.93	0.20	0.45
PO_4-P (mg l^{-1})	0.01	0.00	0.03	0.01	0.01
SiO_3-Si (mg l^{-1})	0.54	0.21	2.32	0.45	0.42
NO_2-N (mg l^{-1})	0.02	0.01	0.03	0.01	0.02
NO_3-N (mg l^{-1})	0.10	0.01	0.22	0.08	0.07
NH_4-N (mg l^{-1})	0.04	0.01	0.13	0.03	0.04
PP (mg l^{-1})	0.01	0.00	0.03	0.01	0.01

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Distribution of tintinnid communities

Tintinnid abundance and biomass showed PDUNHG VHDVRQDO FKDQJHV ZLWK WKH KLJKHVW YDOXHV observed in summer during the temperature maximum and the lowest in autumn (Fig. 2B, C). The distributions of tintinnids were generally patchy and uneven.

In spring, tintinnid abundance ranged from 169.19 to 3411.92 ind. m^{-3}, with an average of 2063.98 ±440.56 ind. m^{-3}. Their biomass ranged IURP WR Ɋ C m^{-3}, with an average of 109.30 ɋ C m^{-3}. Abundance and biomass of tintinnids in spring were high at the top and the mouth of the bay but low in the middle. The distributions of the species number and diversity were almost identical (Fig. 3).

In summer, mean tintinnid abundance was up to 6704.70 ±1108.75 ind. m^{-3}, ranging from 2651.99 to 10856.10 ind. m^{-3}. The mean biomass was 219.28 ɋ C m^{-3}UDQJLQJ IURP WR Ɋ C m^{-3}. High values of abundance and biomass of tintinnids were recorded at the bay mouth and nearby the town of Yongning, while low values occurred at the top of the bay. The higher number and diversity of species occurred at the top and the mouth of the bay, and lower in the middle of the bay (Fig. 4).

Abundance and biomass of tintinnids were dramatically reduced in autumn. The abundance ranged from 237.80 to 539.70 ind. m^{-3}, with an average of 352.23 ±44.48 ind. m^{-3}, and the biomass UDQJHG IURP WR Ɋ C m^{-3}, with an average of 2.38 ɋ C m^{-3}. The abundance of tintinnids was high at the top of the bay and low at the mouth, however the trend of biomass, the number and the diversity of species was exactly the opposite (Fig. 5).

Tintinnid community structure

In order to further investigate the spatial and temporal pattern of tintinnid distribution, cluster analysis was performed, which divided the tintinnid communities into four groups at a similarity level of 34.13% in terms of their temporal distribution in Shenhu Bay in the study period. The dendrogram

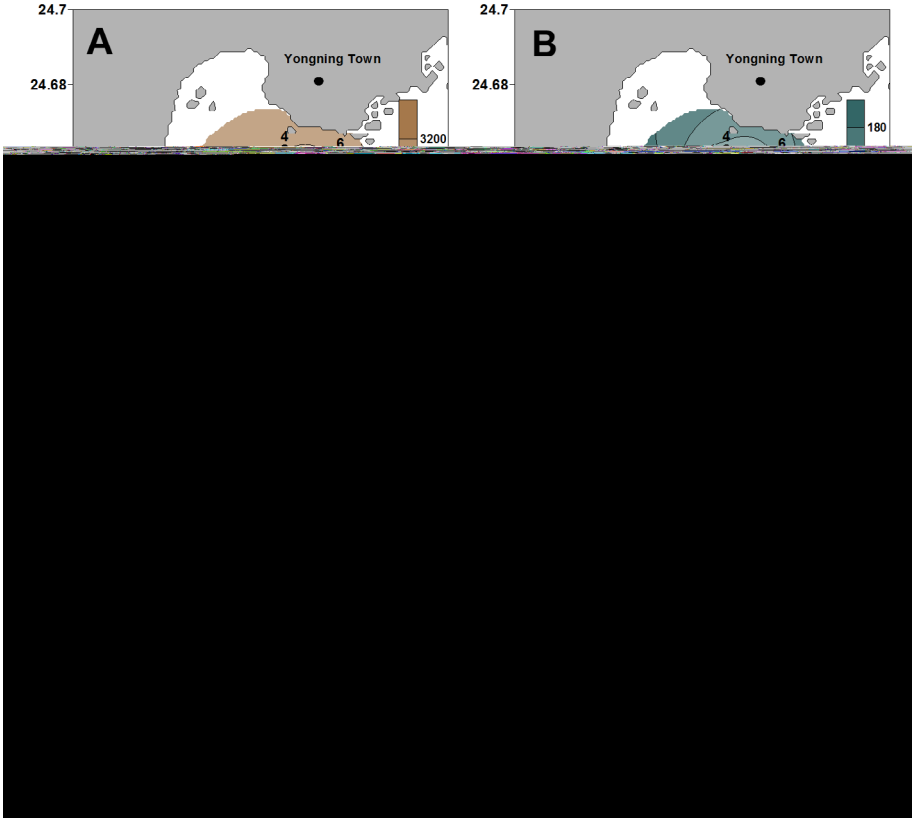

Fig. 3. Distribution of tintinnid abundance (A), biomass (B), species number (C) and Shannon-Wiener diversity (D) in spring in Shenhu Bay

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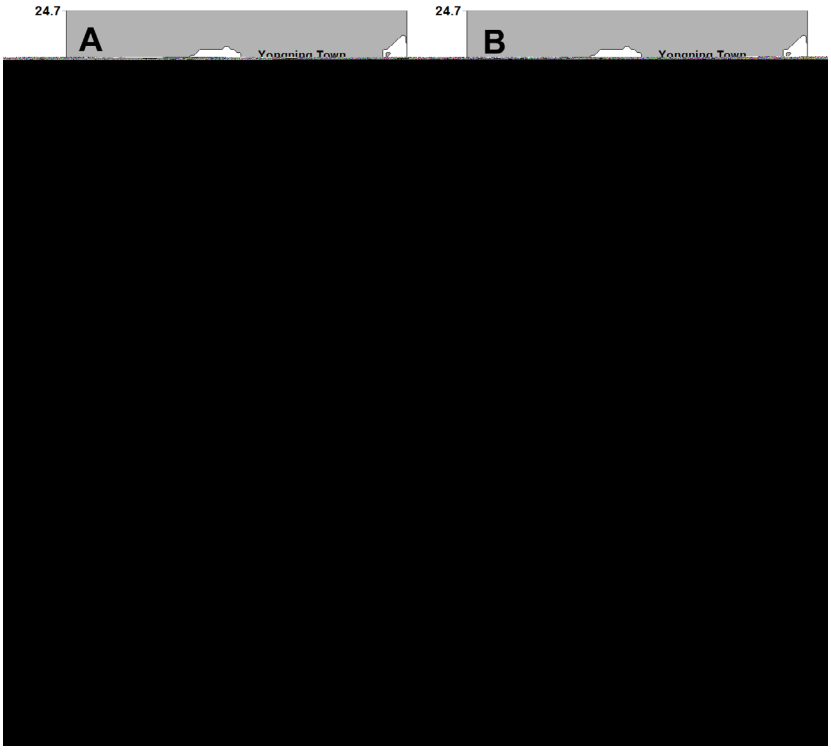

Fig. 4. Distribution of tintinnid abundance (A), biomass (B), species number (C) and Shannon-Wiener diversity (D) in summer in Shenhu Bay

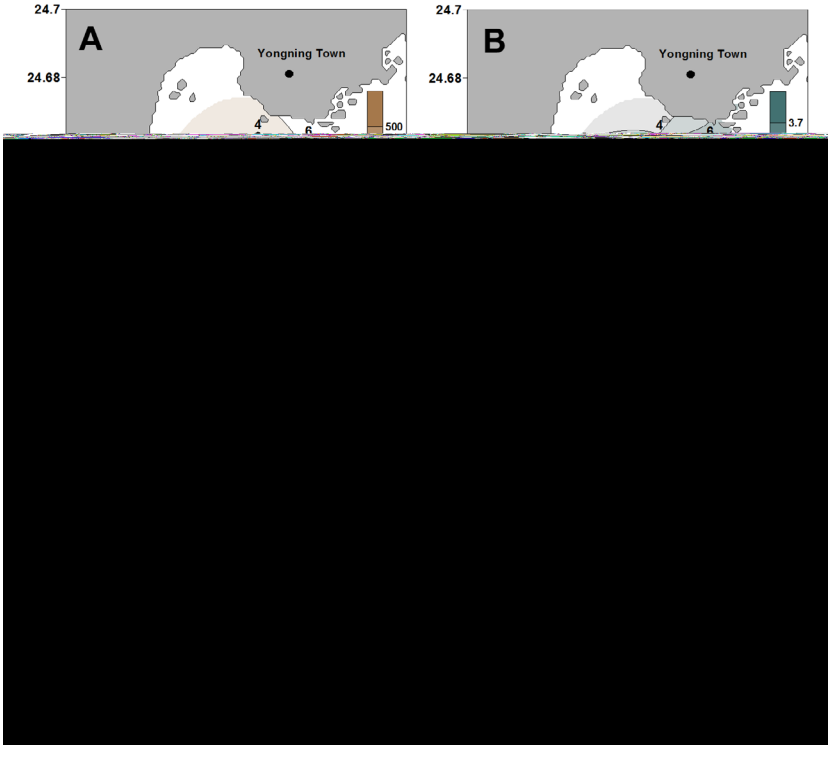

Fig. 5. Distribution of tintinnid abundance (A), biomass (B), species number (C) and Shannon-Wiener diversity (D) in autumn in Shenhu Bay

turbulence, the nutrient level (Capriulo & Carpenter 1983, Sanders 1995, Wang et al. 2013). Capriulo & &DUSHQWHU UHSRUWHG D ZHDN FRUUHODWLRQ EHWZHHQ WLQWLQQLG GHQVLW\ DQG SKRVSKDWH LQ WKH \ in Long Island Sound. Urrutxurtu (2004) found the tintinnid abundance in the Nervio´n River estuary, Spain, was significantly and positively correlated with WHPSHUDWXUH DWD IRU %N oHNPHFH %DLQFLDWH that the abundance of tintinnids was negatively FRUUHODWHG ZLWK WKH DEXQGDQFH RI SKWRSODQNWRQ SRVLWLYHO\ FRUUHODWHG ZLWK WHPSHUDWXUH %DLQ Uye et al. (1996) tested the relationship between tintinnid biomass and chlorophyll in the Inland Sea of Japan and found a significant positive correlation only in autumn, speculating that the tintinnid population was regulated by other factors besides the food supply. In this study, a significant and positive correlation was observed between the abundance of WLQWLQQLGV DQG WKH DEXQGDQFH RI SKWRSODQNWRQ in spring and summer, suggesting that food supply is an important factor affecting the variation of tintinnid communities during these seasons. Also, a negative correlation was observed between the tintinnid DEXQGDQFH DQG WKH FRSHSRG DEXQGDQFH ,W LV OLNHO\ that lower abundance of copepods reduced the predation pressure on tintinnids. However, the correlation was not as significant as that between WLQWLQQLGV DQG SKWRSODQNWRQ VXJJHVWLQJ WKDW WKH bottom-up control of the tintinnid population was dominant during these seasons in Shenhu Bay. Abiotic environmental factors also played an important role in controlling the tintinnid communities, and the dominant factors were different in each season. The nutrient level played an important role in controlling both the spatial and the seasonal pattern of tintinnid communities in Shenhu Bay. The effects of the nutrient level on tintinnid communities may be indirect because it regulates the GHQVLW\ RI SKWRSODQNWRQ V\ in this area.

ACKNOWLEDGEMENTS

:H WKDQN WKH 0DULQH &KHPLVWU\ DERUDWRU\ 3UR Airong Zheng), Xiamen University, China, for providing chemical data and Julie Valentine from Liverpool John Moores University, the UK for improving the manuscript. This study was supported by the National Natural Science Foundation of China (Nos 41276133 and J121005), the special Research Foundation for Public Welfare Marine Program (No. 201005012) and Project GASI-03-01-02-03.

REFERENCES

908 Office of the State Oceanic Administration (2006). Comprehensive survey and assessment technique regulations in offshore area of China. *Marine chemistry survey technique regulations*. Beijing: Ocean Press (In Chinese).

Abou Zaid M.M. & Hellal A.M. (2012). Tintinnids (Protozoa: Ciliata) from the coast of Hurghada Red Sea, Egypt. *The Egyptian Journal of Aquatic Research* 38, 249-268. DOI: 10.1016/j.ejar.2013.01.003.

%DONLV 1 7LQWLQQV 3URWR RD &LOLRSKRUD RI WKH &%N6HNPHFH%DLQWKH6HDRI0DUPDUD *Scientia Marina* 68, 133-142. DOI: 10.3989/scimar.2004.68n133

Capriulo G. M. & Carpenter E J. (1983). Abundance, species composition and feeding impact of tintinnid micro-RRSODQNWRQ0HGWUDO /RQVODQ 6RXQ *Marine Ecology Progress Series* 10:277-288. DOI: 10.3354/meps010277.

ClaUNH .5 *RUOH\ 51 *PRIMER v5: User manual/tutorial*. Plymouth: PRIMER-E.

Dolan J.R. (2000). Tintinnid ciliate diversity in the Mediterranean Sea: longitudinal patterns related to water column structure in late spring-early summer. *Aquatic Microbial Ecology* 22, 69-78. DOI: 10.3354/ame022069.

Dolan J.R. (2010). Morphology and Ecology in Tintinnid Ciliates RI WKH 0DULQH 3ODQNWRQ&RUUHODWHV RI /RULFD LPHQLRQ *Acta Protozoologica* 49, 235-244.

Dolan J.R., Claustre H., Carlotti F., Plounevez S., Moutin T. 0LFURRRSODQNWRQLYHUVLWUHODWLRQVKLSVRIWLQWLQQ ciliates with resources, competitors and predators from the Atlantic Coast of Morocco to the Eastern Mediterranean. *Deep-Sea Research I* 49, 1217-1232. DOI: 10.1016/S0967-0637(02)00021-3.

Godhantaraman N. (2001). Seasonal variations in taxonomic composition, abundance and food web relationship of PLFURRRSODQNWRQLQHVWXDULH DQ PDQURYH ZDWHUV Parangipettai region, southeast coast of India. *Indian Journal of Marine Sciences* 30, 151-160.

+DGD < 7KH 7LQWLQQLGHD IURP WKH VHDV RI 2NKRWVN DQ its neighborhood. Journal of the Faculty of Science. *Hokkaido Imperial University, Series 6, Zoology* 2(1) 37-59.

+DGD < 7KH IDXQD RI $NNHVKL %D\ 9 7KH SHODJLF Ciliata. Journal of the Faculty of Science. *Hokkaido Imperial University, Series 4, Zoology* 5 143-216.

Hada Y. (1938). Studies on the Tintinnoinea from the western tropical Pacific. Journal of the Faculty of Science. *Hokkaido Imperial University, Series 6, Zoology* 6(2) 87-190.

Havens K. (2013, January). *Plankton Web*. Retrieved January 23, 2014, from KWWSZZZVIUFXIOHGXSODQNWRQZHELQH[WP

Jan S., Wang J., Chern C.S., Chao S.Y. (2002). Seasonal variation of the circulation in the Taiwan Strait. *Journal of Marine Systems* 35, 249- 268. DOI: 10.1016/S0924-7963(02)00130-6.

Kamiyama T. & Tsujino M. (1996). Seasonal variation in the species composition of tintinnid ciliates in Hiroshima Bay, the Seto Inland Sea of Japan. *Journal of Plankton Research* 18, 2313-2327.

Kofoid C.A. & Campbell A.S. (1929). A conspectus of the marine and freshwater Ciliata belonging to the suborder Tintinnoinea, with descriptions of new species principally from the Agassiz expedition to the eastern tropical Pacific 1904-1905. *University of California Publications in Zoology* 34, 1-403.

Kofoid C.A. & Campbell A.S. (1939). The Tintinnoinea of the eastern tropical Pacific. *Bulletin of the Museum of Comparative Zoology of Harvard College* 84, 1-473.

Lynn D.H. (2008). *The ciliated protozoa. Characterization, classification and guide to the literature*. 3rd ed. Springer: Berlin.

0L DJXFKL +)XMLNL 7 .LNXFKL 7 .XZDKDUD 96 7RGD 7 (2006). Relationship between the bloom of N. scintillans and environmental factors in the coastal waters of Sagami Bay, Japan. *Journal of Plankton Research*, 28, 313-324. DOI: SODQWIEL.

Nie D. (1934). Notes on Tintinnoinea from the Bay of Amoy. *Annual Report of the Marine Biology Association of China* 3, 71-80.

Pierce R.W. & Turner J.T. (1993). Global biogeography of marine tintinnids. *Marine Ecology Progress Series* 94, 11-26. DOI: 10.3354/meps094011.

3LWW .LQ VIRUG 0- 5LVVLN '.RRS . -HOOLVK PRGLI\WKH UHVSRQH RI SODQWRQF DVVHPEODJHV WR QWULHQW pulses. *Marine Ecology Progress Series* 351, 1-13. DOI: 10.3354/meps07298.

Sanders R.W. (1995). Seasonal distributions of the photosynthesizing ciliates *Laboea strobila* and *Myrionecta rubra* (= *Mesodinium rubrum*) in an estuary of the Gulf of Maine. *Aquatic Microbial Ecology* 9, 237-242. DOI: 10.3354/ame009237.

Sato N.E., Hernández D., Viñas M.D. (2010). Hábitos alimentarios de Noctiluca scintillans en aguas costeras de la Provincia de Buenos Aires, Argentina. *Latin American Journal of Aquatic Research* 38, 403-412 (In Spanish, with English summary). DOI: 10.3856/vol38-issue3-fulltext-5.

6WRHFNHU '&DSX R-03UHGDWLRQ QXUWRU RDLWV LPSRUWDQH WR RRSODQNWRQ *Journal of Plankton Research* 12, 891-908. DOI: SODQW.

WHU%UDDN&-)6PLODXHU3 *CANOCO Reference Manual and CanoDraw for Windows User's Guide: software for canonical community ordination (version 4.5) ,WKDFD 1HZ 5RUN* Microcomputer Power.

7KRPSVRQ $GHU9 %ROWRYVNR %UDQLL) Abundance and biogeography of tintinnids (Ciliophora) and DVVRFLDWHG PLFURRRSODQWRQ LQ WKH 6RXWKZHVWHUQ ODQLF Ocean. *Journal of Plankton Research* 21, 1265-1298. DOI: SODQW.

Urrutxurtu I. (2004). Seasonal succession of tintinnids in the Nervión River estuary, Basque Country, Spain. *Journal of plankton research* 26(3), 307-314. DOI: SODQWIEK.

8WHUP|KO + =XUYHUYRONRPPXQGHU TXDQWLWDWLYHQ SKWRSODQWRQ0HWKRGLN *Mitteilungen der Internationalen Vereinigung fur Theoretische und Angewandte Limnologie* 9, 1-38. (In German)

8H61DJDR17DPDNL+ Geographical and seasonal variations in abundance, biomass and estimated production UDWHVRIPLFURRRSODQWRQQWKH,QDQ6HDR *Journal of Oceanography* 52 (6), 689-703. DOI: 10.1007/BF02239460.

Vaqué D., Blough H.A., Duarte C.M. (1997). Dynamics of ciliate abundance, biomass and community composition in an oligotrophic coastal environment (NW Mediterranean). *Aquatic Microbial Ecology* 12, 71-83. DOI: 10.3354/ame012071.

Verity P.G. (1987). Abundance, community composition, size distribution, and production rates of tintinnids in Narragansett Bay, Rhode Island. *Estuarine, Coastal and Shelf Science* 24, 671-690. DOI: 10.1016/0272-7714(87)90106-5.

Verity P.G. & Lagdon C. (1984). Relationships between lorica volume, carbon, nitrogen, and ATP content of tintinnids in Narragansett Bay. *Journal of Plankton Research* 6, 859-868. DOI: SODQW .

Wang Y., Zhang W., Lin Y., Cao W., Zheng L., et al. (2014). Phosphorus, nitrogen and chlorophyll-a are significant factors controlling ciliate communities in summer in the Northern Beibu Gulf, South China Sea. *PLoS ONE* 9(7), e101121. DOI:10.1371/journal.pone.0101121

Wang Y., Zhang W., Lin Y., Zheng L., Cao W., et al. (2013). 6SDWLDO SDWWHUQ RI WKH SODQWRQF FLOLDWH FRPPXQLW\ DQ relationship with the environment in spring in the northern Beibu Gulf, South China Sea. *Oceanological and Hydrobiological Studies* 42(4), 470-479. DOI: 10.2478/s13545-013-0103-x.

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