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Do Planktonic Foraminifera Juveniles Bias the Paleoceanographic/Paleoclimatic History Interpretation?: Short Report of Year-long Trap Result

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부유성 유공충의 유생은 고해양/고기후의 연구에 영향을 미치는가? : 1년간의 퇴적물트랩 관찰로부터

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ABSTRACT

The effect of the relative abundances of planktonic foraminifera juveniles on the climatic and oceanographic history interpretations is documented for the first time (as far as we know) by use of the year-long time-series sediment trap samples. Statistical correlation analysis suggests that many climatic and oceanographic variables such as sinking flux (total number) of planktonic foraminifera, relative abundance of some climatic indicator species *G. bulloides* and *N. dutertrei*, temperature, and salinity do not show any significant correlations with the relative abundance of planktonic foraminifera juveniles. However, planktonic foraminifera juveniles show moderate correlations with species diversity indices (species richness, Shannon-Wiener index, and Equitability). These indicate that the juveniles do not affect the relative abundances (%) of species compositions but affect the species diversity indices. Based on this one-year trap result, special care is required when we use species diversity indices for the interpretations of paleoceanography when the juveniles are excluded from total planktonic foraminiferal countings.

요 약

부유성 유공충의 상대적인 양이 고기후 및 고해양환경의 해석에 미치는 영향을 1년 동안 관찰한 퇴적물 포집장치에 함유된 유공충의 연구로 행하여졌다. 본 연구는 저자들이 알고 있는 한 처음으로 행해진 것이다. 총 부유성 유공충의 수, 고기후의 지시자로 사용되는 부유성 유공충 *G. bulliodes*와 *N.*

*dutertrei*의 상대적인 양, 수온, 염도 등은 부유성 유공충 유생의 상대적인 양과 통계적으로 의미 있는 상관관계를 보이지 않는다. 하지만 부유성 유공충 유생의 상대적인 양은 종다양성지수(종 풍성도, 샤논-와이너 지수, 균등도)와 상관관계를 보인다. 이러한 결과는 유생의 양은 종의 상대적인 양에는 영향을 미치지 않으나 종다양성에는 영향을 미침을 의미한다. 따라서 퇴적물 포집장치에서 일년간 관찰한 결과에 의하면 부유성 유공충의 유생을 count 시 제외했을 때 종다양성 지수를 이용한 고기후/고환경해석시 주의가 요망된다.

INTRODUCTION

Climatic and oceanographic changes may affect the abundances of the juveniles of planktonic foraminifers occurring in the ocean, but the relationship has not been documented. Some authors have referred numbers (or percentages) of juveniles in the foraminifera percentage chart without further analysis. Some authors excluded the numbers (or percentages) of juveniles in the percentage chart. Relative abundance (percentage) variations are one of the most important variables in foraminiferal micropaleontologist for the study of paleoceanography. In general, foraminifera researchers assume that the relative abundance (percentage) of juveniles among the total assemblage does not affect their study of paleoceanographic history.

We have asked questions many times about the effects of the relative abundances of juveniles on the paleoceanographic history to many micropaleontologists in the various international conferences. However, we obtained no solid answers.

We have an opportunity to test the above assumption using planktonic foraminifera collected from the year-long sediment trap samples. Sediment trap samples provide an excellent opportunity to test this assumption because the intact planktonic foraminifera shells are collected compared to the core sediment. The sediment trap samples were collected at 2,780 m depth (320 m above the bottom) in the East Sea (lat 39° 40.0' N, long 132° 24.0' E) from the period of July, 1994 to July 1995 (Fig. 1). The sediment trap site is an area where the North Korean Cold Current meets with the East Sea Warm Current (Tsushima Warm Current) (Park and Shin, 1998).

In this study, sediment trap samples contain relatively abundant juveniles of planktonic foraminifera. The percentages of planktonic foraminiferal species including juveniles in each month are shown in Table 1.

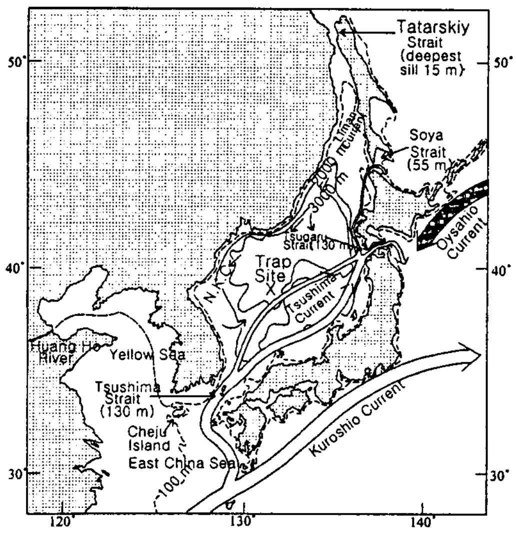

Fig. 1. Location map of the sediment trap site in the East Sea (Sea of Japan) (modified from Oba et al., 1991).

Nine species of planktonic foraminifera are identified in the >63 μm sieve fraction. Among them, the percentage of *N. pachyderma* ranges from 59.5 to 100.0%. The juveniles range from 0.0 % to 100.0 % (average 27.7 %). We used juveniles any tests less than 125 μm in diameter. It appears that all of the juveniles are *Neogloboquadrina pachyderma*. The juveniles of *N. pachyderma* called "planktonic foraminifera juveniles" hereafter due to the great dominance of *N. pachyderma* in the total planktonic foraminiferal assemblages. The purpose of this paper is to investigate whether the relative abundance of planktonic foraminifera juveniles affects some environmental variables (total planktonic foraminifera flux, relative abundance of some climatic indicator species, species diversity indices, temperature, salinity) or not.

METHODS

The percentage of planktonic foraminifera juveniles are statistically correlated with sinking flux (total number) of planktonic foraminifera, planktonic foraminifera species such as *Globigerina bulloides* and *N. dutertrei*, species richness (S), Shannon-Wiener Index [H(S)], equitability (E), temperature, and salinity values in each month. The raw data of these variables are shown in 〈Table 1〉. The statistical correlations are shown in 〈Fig. 2〉.

Species richness (S) S is a number of species present in each month. The Shannon-Wiener index [H(S)], derived from information theory, is defined as $H(S) = -\Sigma Pi \ln Pi$, where S is the number of species in the sample and Pi is the proportion of the ith species in the sample. One advantage of this information function is the minimization of problems related to sample size (Gibson and Buzas, 1973). This information is little affected by rare and extremely abundant species, but more affected by species with common abundances (Gibson and Buzas, 1973). The maximum value of H(S) occurs when all species are equally distributed.

For Equitability (E), the Buzas-Gibson's equation (1969) is used here. It is defined as $E = e^{H(S)}/S$. E values are always less than one and measure how far the sample departs from complete equitability. When all species are equally distributed, E=1.0. A low value for E indicates greater deviation from a sample of equally proportioned species.

Temperature and salinity in the surface waters were not measured concurrently at the trap site. Monthly averages of surface water temperature and salinity (Levitus, 1982) were used in this study. The detailed method of sediment trap is in Park and Shin (1998).

RESULTS AND DISCUSSION

Several previous workers have used the total number of planktonic foraminifera for deciphering paleoceanographic history. For example, the total number of planktonic foraminifera affects the sedimentation rates, (Finger and Lipps, 1981) and also is affected by primary productivity (Tolderlund and Be, 1971; Finger and Lipps, 1981; Arikawa, 1983). Tolderlund and Be (1971) found that high phytoplankton productivity in spring is reflected in an increased standing stock of planktonic foraminifera in the North Atlantic

Table 1. Percentage chart of planktonic foraminifera and several environmental variables (modified from Park and Shin, 1998).

Month \ Species	*Globigerina bulloides* (%)	*G. falconensis* (%)	*G. incompta* (%)	*G. quinqueloba* (%)	*Globigerinita uvula* (%)	*Globigerinoides ruber* (%)	*Neogloboquadrina dutertrei* (%)	*N. pachyderma* (total) (%)	*N. pachyderma* (right-coiled) (%)	*N. pachyderma* (left-coiled) (%)	*N. pachyderma* (*juvenile*) (%)	*Pulleniatina obliquiloculata* (%)	Total planktonic foram (picked number)	Species richness (S)	Shannon-Wiener Diversity [H(S)]	Equitability (E)	Total foram flux (m^2/day)	Monthly average temperature (Celsius)	Monthly average salinity (‰)
January	1.34	0.33	4.01	0.00	0.33	1.00	1.34	91.31	79.60	8.03	3.68	0.33	299	8	0.43	0.19	1,929	7.07	33.91
February	13.04	4.35	0.00	0.00	0.00	0.00	0.00	82.61	26.09	4.35	52.17	0.00	23	3	0.56	0.58	74	5.82	34.10
March	35.38	0.00	5.13	0.00	0.00	0.00	0.00	59.49	29.23	24.62	5.64	0.00	195	3	0.83	0.76	1,393	5.68	34.11
April	5.81	0.00	10.47	0.00	1.16	0.00	0.00	82.55	39.53	22.09	20.93	0.00	86	4	0.61	0.46	555	7.18	34.16
May	4.55	0.00	1.95	0.00	0.00	0.00	0.00	93.51	21.43	42.21	29.87	0.00	154	3	0.28	0.44	1,027	11.08	34.12
June	1.64	0.00	0.00	0.00	0.00	0.00	1.64	96.73	83.61	11.48	1.64	0.00	61	3	0.17	0.39	197	15.27	34.06
July	3.57	0.51	2.04	0.00	0.00	0.00	1.02	92.85	83.67	2.55	6.63	0.00	196	5	0.34	0.28	1,307	20.15	33.84
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	1	1	0.00	1.00	3	23.47	33.55
September	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	12.50	0.00	87.50	0.00	56	1	0.00	1.00	361	21.75	33.37
October	33.33	0.00	0.00	0.00	0.00	0.00	0.00	66.67	66.67	0.00	0.00	0.00	3	2	0.64	0.94	20	17.88	33.39
November	0.79	0.00	2.76	0.00	0.39	0.00	8.66	87.41	79.53	0.79	7.09	0.00	254	5	0.47	0.32	8,194	13.82	33.60
December	0.00	0.00	7.37	1.05	0.00	0.00	3.16	87.37	68.42	2.11	16.84	1.05	95	5	0.47	0.32	3,167	9.72	33.86

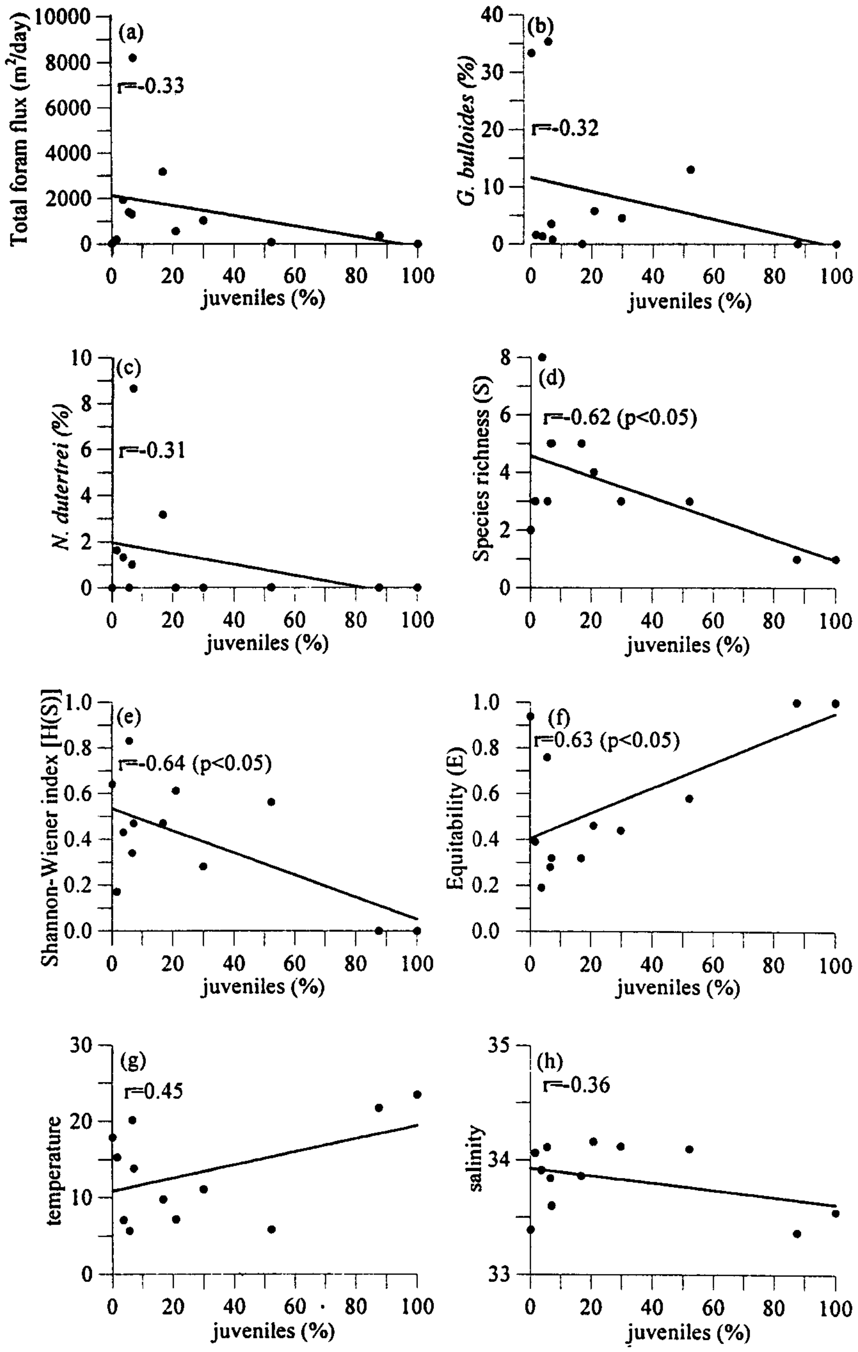

Fig. 2. Correlation between planktonic foraminifera juveniles and several environmental variables.

and the planktonic foraminifera are less abundant during the summer when water temperature peaks. High phytoplankton productivity also has a close relationship with the organic carbon content in the sediment. Ortiz and Mix (1992) reported that the offshore decrease in organic carbon flux is paralleled by an offshore decrease in the total planktonic foraminiferal shell flux in the East Pacific off Oregon. They also showed that the fluxes of cold water species were relatively high during the winter when Subarctic Water entered the area. The total planktonic foraminiferal flux is significantly elevated in the upwelling areas in the North Pacific (Thunell and Sautter, 1992). The subarctic region (north of 45°N Lat.) is characterized by large total populations of planktonic foraminifera even though the number of species is small (Bradshaw, 1959).

The transitional region of the subarctic front contains a greater number of species and somewhat smaller populations than the subarctic. At several stations near the mixing zone of the Kuroshio and Oyashio Currents, relatively small populations of planktonic foraminifera were recorded (Bradshaw, 1959). Bradshaw also found the highest numbers of planktonic foraminifera from the zone of convergence and associated sinking of the surface waters. Total number of planktonic foraminifera is also a good index to monitor calcium carbonate dissolution and sedimentation (Balsam, 1982). However, as we mentioned in the previous section, many researchers do not even mention about juveniles in their foraminifera abundance chart when they interpret the paleoceanography. It is important to test the effects of the relative abundances of juveniles on some oceanographic variables (total number of planktonic foraminifera, some climatic indicator species, species diversity indices, temperature, salinity) to use them as paleoceanographic tracers.

The percentage of planktonic foraminifera juveniles does not show any correlation with the sinking flux (total number) of planktonic foraminifera (Fig. 2a; $r=-0.33$). This observation indicates that the sinking flux (total number) of planktonic foraminifera does not have any significant relationship with the relative abundances of juveniles.

More importantly, relative abundance of planktonic foraminifera juveniles does not correlate with the relative abundance of temperature indicator species such as ***Globigerina bulloides*** (Fig. 2b; $r=-0.32$) and ***Neogloboquadrina dutertrei*** (Fig. 2c; $r=-0.31$). ***Globigerina bulloides*** is a cold water species (Bradshaw, 1959) and ***N. dutertrei*** is a warm water species (Tolderlund and Be, 1971). Most importantly, planktonic foraminifera juveniles do not correlate with surface water temperatures (Fig. 2g; $r=0.45$) and salinities (Fig. 2h; $r=-0.36$). These results suggest that the relative abundance of juveniles does not give a bias for paleotemperature interpretations even though juveniles are excluded in the foraminiferal counting procedure.

However, relative abundances of planktonic foraminifera juveniles show moderate negative correlations with species richness S (Fig. 2d; $r=-0.62$) and Shannon-Wiener Index, H(S) (Fig. 2e; $r=-0.64$), and moderate positive correlation with Equitability, E (Fig. 2f; $r=0.63$). These indicate that the relative abundance of juveniles affects the species diversity indices. As we may expect, there show decreasing species richness and Shannon-Wiener index and increasing equitability as increasing juveniles. It is well-known that the greater species diversity [S, H(S)] occurs in warm surface water temperatures even though it is not known the controlling factor(s) for the E values. However, special care is needed when we interpret the paleoclimatic history based on species diversity indices when we exclude juveniles from the total planktonic foraminifera countings.

All of the above results are only based on one-year long sediment trap result in the Sea of Korea (Japan Sea). There may need more result based on several years of sediment-trap data in a various areas. However, we only have one year-long sediment trap samples.

CONCLUSIONS

The relative abundances of the planktonic foraminifera juveniles do not show correlation with some climatic indicator species, temperature, salinity, and foraminifera number, but show moderate correlations with species diversity indices. Therefore, when the foraminifera researchers pick foraminifers excluding juveniles, it is more accurate to use species compositions rather than species diversity indices for the paleoceanographic / paleoclimatic interpretations.

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