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LIFE SPANS OF PLANKTONIC FORAMINIFERS: NEW INSIGHT THROUGH SEDIMENT TRAPS

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ABSTRACT

Determining life spans of planktonic foraminifera is vital in view of their increasing use for palaeoclimatic studies. Till date all the estimates about life spans of planktonic foraminifers are based on the extrapolations of growth rates obtained in culture experiments and range from a few days to a few weeks, varying widely. Here we propose the use of sediment trap technique to get much better estimates of life spans of planktonic foraminifers. On the basis of sediment trap results, we hypothesize that in general the life spans of planktonic foraminiferal species are of the order of few months instead of few days to few weeks, as reported earlier.

Key words: Planktonic foraminifers, life span, sediment traps, quiescent period.

INTRODUCTION

The morphology along with oxygen isotopic ratio of calcareous test secreted by foraminifera, unicellular marine protists with a hard covering called test, is a function of physico-chemical characteristics of ambient seawater. These characteristics of foraminifers, especially the capacity of equilibrium fractionation of oxygen, are widely used in palaeoceanographic studies, specifically palaeosea surface temperature and palaeosalinity estimations based on whole test ICP-MS oxygen isotope analysis of planktonic foraminifers. The life spans of foraminifers are crucial for the effective use of foraminiferal proxies for palaeoclimatic reconstruction, as it will give an idea about the duration for which the tests incorporate and represent the physico-chemical conditions of ambient seawater. Because of inability to maintain live specimens in lab culture, through their complete life cycle (Murray, 1991), estimates of the life spans of planktonic foraminifers have been based on the extrapolations of growth rates obtained by maintaining juvenile specimens collected from the sea, in lab culture till they attain maturity by quickly adding last few chambers and undergo gametogenesis. These culture studies based extrapolated life span estimates range from few days to few weeks (Bé, Caron and Anderson, 1981; Caron Bé, and Anderson, 1981; Caron and Swanberg, 1990). Due to the limitations of the culture experiments, wide variations have been observed in these extrapolated life span estimates. Lunar or semi-lunar periodicity in reproduction has also been observed, suggesting life span of two to four weeks for few species like *Hestigerina pelagica* (Spindler, Hembleben, Bayer, Bé and Anderson, 1979). But discrepancies were noted in laboratory and field observations (Hemleben, Spindler and Anderson, 1989), raising doubts about the validity of culture-based extrapolated life span estimates.

Here, we propose the use of sediment trap technique to solve the chaos prevailing about the life spans of planktonic foraminifera.

MATERIALS AND METHOD

In the present study, foraminiferal flux results of three sediment traps, viz. Western Arabian Sea Trap (WAST, at 4016 m water depth), Central Arabian Sea Trap (CAST, at 3901 m) and Eastern Arabian Sea Trap (EAST, at 3770 m water depth), (fig. 1) have been utilized. These traps were deployed during May 1986 in the Arabian Sea, to collect samples for eighteen months. Each mooring had one trap at 1000 m below the sea surface and another at 1000 m above the sea floor, capable of collecting 13 samples, each of 12/13 day duration. The mooring with arrangement of different components is shown with the help of schematic diagram (fig. 2). The detailed results of total particle flux (Nair, Ittekkot, Manganini,

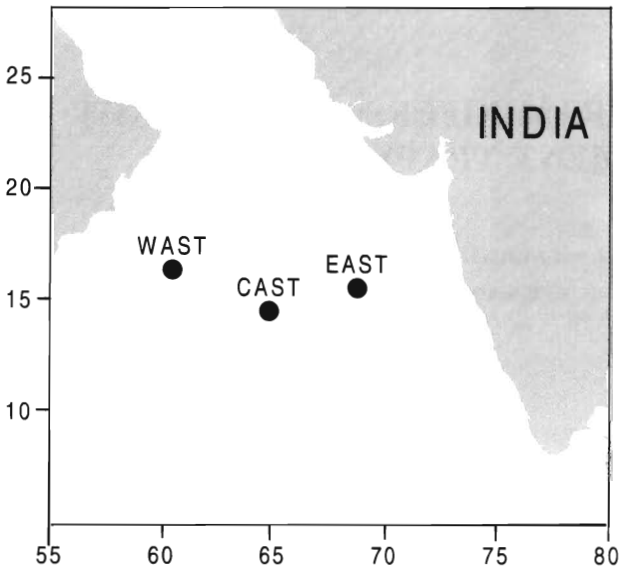

Fig. 1. Location of sediment traps.

Ramaswamy, Haake, Degens, Desai and Honjo, 1989), foraminiferal distribution and isotopic composition (Curry, Ostermann, Guptha and Ittekkot, 1992) have already been published. These publications also describe the detailed methodology for sample collection.

RESULTS

The foraminiferal distribution in the sediment trap moorings deployed at about 1000 m above seafloor for a duration of eighteen months in the Arabian Sea reveal that there are periods (onwards referred to as quiescent period or QP), as long as 34 to >100 days during which the number of specimens of one or other species, as well as total number of specimens, getting trapped, while sinking down after death, becomes almost zero, with biannual periodicity [fig. 3 (A), (B), (C)]. The sediment trap results further reveal that in most of the cases QP precedes monsoon season. Such flux patterns have been observed for almost all the species (Curry *et al.*, 1992).

DISCUSSION

If the life spans are of the order of few days to few weeks, each trap should have received considerable number of specimens throughout the year, as in this case there would have been consistent existence of planktonic foraminifers in the water column throughout the year. Then what should be the viable explanation for QP? It is unlikely that the traps malfunctioned because, (i) such periods of nil or near nil flux have not been observed for only one trap or for one location, but from almost all parts of the world oceans (Thunnel and Honjo, 1987; Guptha, Curry, Ittekkot and Murlinath, 1997; King and Howard, 2001; Kawahata, Nishimura and Gagan,

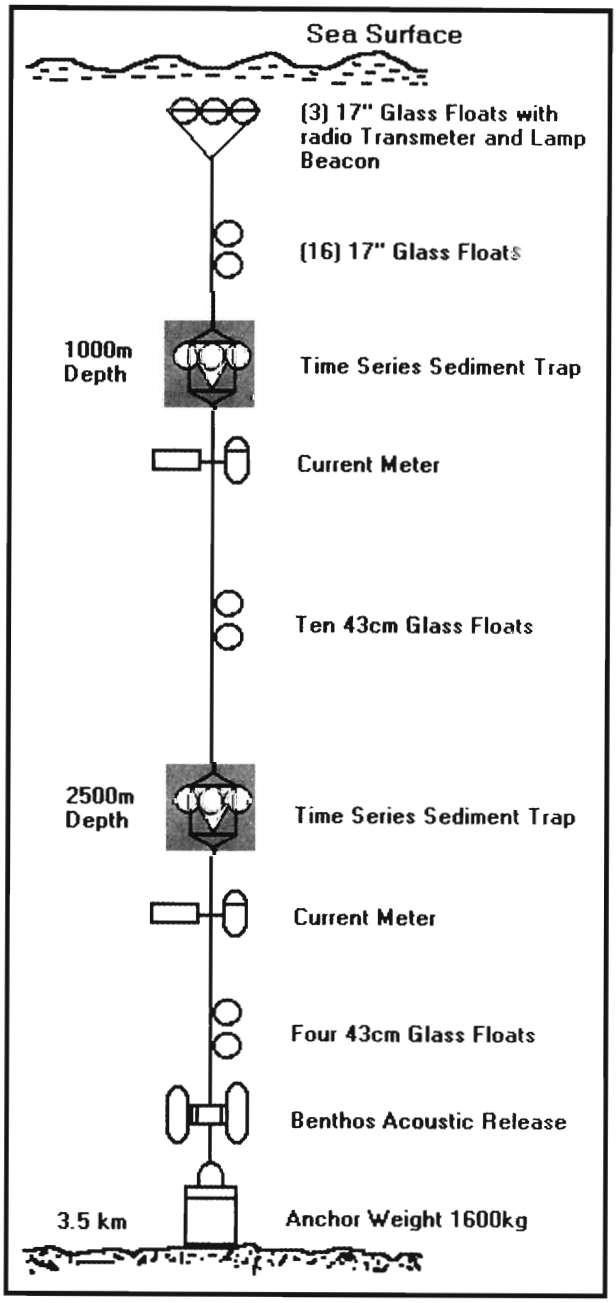

Fig. 2. Schematic diagram of sediment trap mooring.

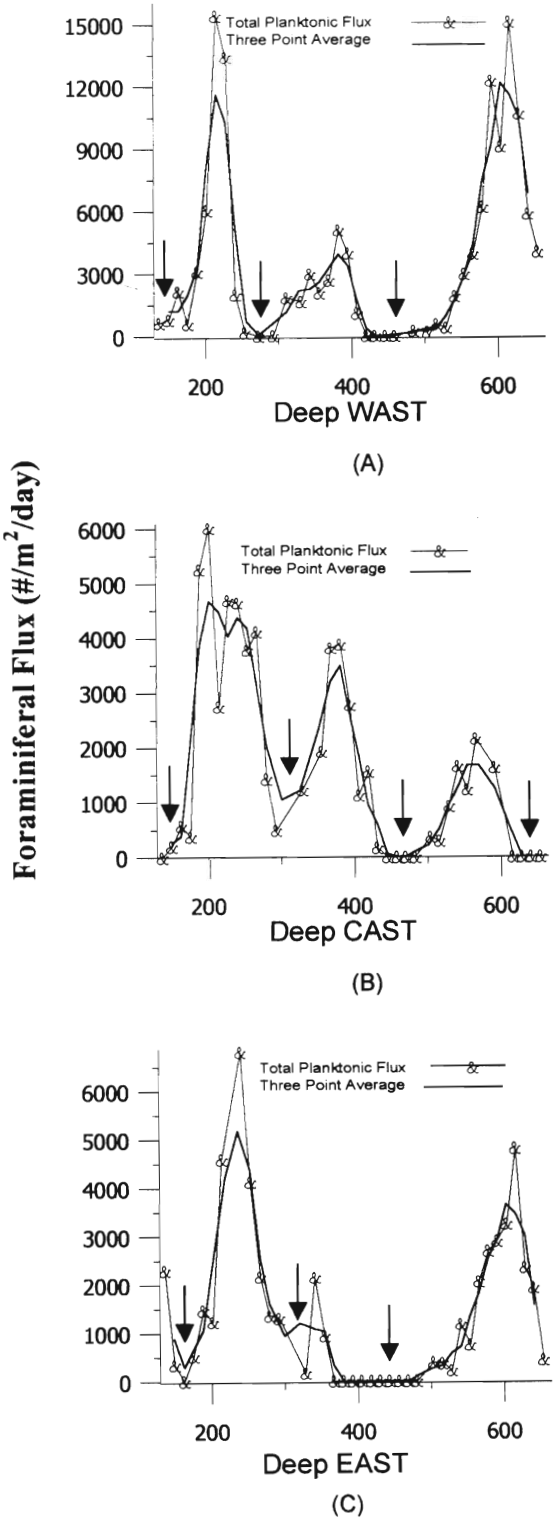

Fig. 3. Variation of total planktonic foraminiferal flux for deep Western Arabian sea Trap (Deep WAST), Central Arabian Sea Trap (Deep CAST) and Eastern Arabian Sea Trap (Deep EAST). The nil flux periods (Quiescent Period, QP), indicated by black arrows are remarkably present for all three trap locations. (Modified after Curry *et al.*, 1992).

2002; Eguchi, Ujiie, Kawahata and Taira 2003), (ii) all the traps can not stop functioning simultaneously and that for the same time of the year for consecutive years. Estimates about the settling velocities of planktonic foraminiferal tests under laboratory conditions (Takahashi and Bé, 1984) (>300 m/day), rule out the possibility of nil flux as a result of horizontal transport of foraminiferal tests away from the trap locations. The chances of dissolution of tests during the QP, because of changed physico-chemical conditions of ambient seawater are remote as per the observations, that there is none or very little dissolution of tests during settlement through water column (Thunnel and Honjo, 1981; Berger and Piper, 1972).

These observations about long nil flux period can be reconciled if the life spans of planktonic foraminifers are assumed to be several months instead of several days to few weeks as has been widely reported (Bé *et al.*, 1981; Caron *et al.*, 1981; Caron and Swanberg, 1990). One plausible explanation for QP, then, may be that during this period there was none or negligible production of planktonic foraminiferal tests, because of absence of gametogenesis, as they were in very slow growth phase, because of unfavourable conditions [decreased availability of food during non-monsoon months (Nair *et al.*, 1989)]. With the seawater upwelling commencing just before the monsoon period, abundant food becomes available, leading to rapid growth and addition of last few chambers in quick succession. This relatively faster rate of addition of last few chambers under favourable conditions is responsible for the decreased estimates of the life spans of planktonic foraminifera based on extrapolation of lab culture observations. According to Bé *et al.* (1981), an inverse relationship exists between feeding frequency and survival time, and that planktonic foraminifers under favourable conditions mature quite early and undergo gametogenesis. This is in accordance with the views of Curry *et al.* (1992) and Nair *et al.* (1989) who held the productivity and food availability to be responsible for the observed foraminiferal flux pattern. This view of reproduction during a particular period of the year is also supported by Hemleben *et al.* (1989), who concluded that, "...reproduction

appears to occur only during the early spring months as this is the time of year when abundant juvenile stages are found in the water column". Monsoon starts receding by the time almost all of the larger foraminifera had undergone gametogenesis, and left behind are mostly the smaller juveniles. Because of inability to cope with the increasingly unfavourable conditions, the premature death of some of the juveniles contributes to the smaller fraction flux during non-monsoon period. The surviving smaller ones remain in a very slow growth phase because of decreased availability of food resulting from closure of upwelling till the onset of the next monsoon. Hemleben *et al.* (1989) also observed that "food deprivation in the natural environment may result in slower growth of the organisms and prolonged existence, thus perhaps favouring survival until more favourable conditions arise for reproduction and survival of the young".

Our views about the longer life spans of planktonic foraminifera will have a bearing on intriguing intraspecific variation in δO^{18} values of different size fractions, as reported from Arabian Sea (Naidu, personal communication), and other areas (Houstan, Huber and Spero, 1999). It has been observed that the specimens from the same horizon, when sorted according to size, give different $\delta^{18}O$ values indicating that the last few chambers have a different isotopic values than initial chambers because of addition of chambers in different temperature conditions. As few weeks' life spans could not explain these differences, researchers invoked either ontogenetic effects or vertical migration of the specimens during different phases of their life cycle (Peeters, Brummer and Ganssen, 2002; Bemis and Spero, 1998) to explain such results. The addition of different chambers of individual during different times of the year, with marked change in hydrographical conditions, explains the intraspecific size fraction related $\delta^{18}O$ values.

CONCLUSION

Therefore, on the basis of the above discussion we hypothesize that the life spans of planktonic foraminifera are of the order of a few months, approximately six months, instead of few days to few weeks as conceived by earlier researchers. This hypothesis can be tested by analysing sediment trap data of several consecutive years, along with attempts to culture planktonic foraminifera through entire life cycle, with new experimental strategies.

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