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Research paper

Vertical distribution of polycystine radiolarians in the northern East China Sea

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ABSTRACT

The East China Sea (ECS) is a marginal sea influenced by the Kuroshio Current (KC) and by freshwater discharged by the Changjiang River. In this study, the vertical distribution of polycystine radiolarians in the northern ECS was investigated. We collected plankton-tow samples from the water column at five stations in the northern ECS. Stations 11 and 11′ were on the ECS continental shelf, and stations 1, 8, and 12 were in the northeastern ECS, which is influenced by the KC. We identified six distinct depth intervals by a Q-mode cluster analysis. At stations 1, 8, and 12, radiolarians were abundant and species diversity was high. In the surface waters, standing stocks of subtropical species such as *Didymocyrtis tetrathalamus*, *Phorticium pylonium*, *Pterocanium praetextum*, *Spongaster tetras tetras*, and the *Tetrapyle octacantha* groups were high, reflecting the influence of the warm KC. In contrast, at intermediate water depths, standing stocks of subarctic radiolarians such as *Actinomma leptodermum*, *Cycladophora bicronis*, *Haliommetta miocenica*, *Pseudodyctiophimus gracilipes*, and *Lithelius minor* were relatively high, which may reflect the influence of a subarctic water mass that probably originated in the North Pacific. At stations 11 and 11′ on the shelf, the influence of freshwater from the Changjiang River is high and radiolarians were absent in the upper 20 m of the water column and scarce at depths of 20–100 m; where three species dominated: *Archipera triclavigera*, *Pseudocubus obeliscus*, and *Cryptogyrus calvatus*.

1. Introduction

The East China Sea (ECS) is a marginal sea bounded by the Eurasian continent, Taiwan, the Ryukyu Islands, the Korean Peninsula, and Kyushu Island. The ECS is influenced by the Kuroshio Current (KC), a warm current that originates from the North Equatorial Current (Nitani, 1972; Tomczak and Godfrey, 1994), and by freshwater discharged by the Changjiang River, the so-called Changjiang Diluted Water (CDW) (Fig. 1). These two water masses produce unusual oceanographic conditions in the ECS, and numerous studies have used foraminifera as a paleoenvironmental proxy to reconstruct past ECS hydrography (Xu and Oda, 1999; Ijiri et al., 2005; Kubota et al., 2010).

Polycystine radiolarians are microorganisms with siliceous skeletons that are widely distributed in the world's oceans, and their distributions in the water column have been investigated in many regions: tropical and equatorial regions of the Atlantic Ocean, including the Caribbean Sea and the Gulf of Mexico (e.g., McMillen and Casey, 1978; Casey et al., 1979; Dworetzky and Morley, 1987; Boltovskoy et al., 1996); the North Pacific (e.g., Lombari and Boden, 1985; Boltovskoy et al., 2010; Itaki, 2003; Motoyama and Nishimura, 2005; Kamikuri et al., 2008); the seas surrounding Japan (Ishitani and Takahashi, 2007; Ishitani et al., 2008), including the Tsushima Strait (Itaki et al., 2010), the northern Japan Sea (Itaki, 2003), the Sea of Okhotsk (Nimmergut and Abelmann, 2002; Okazaki et al., 2004), and the Oyashio region of the northwestern Pacific (Okazaki et al., 2004); the subarctic North Pacific near the Bering Sea (Tanaka and Takahashi, 2008); the central North Pacific (Renz, 1976; Kling, 1979); the southern California margin (Casey et al., 1979; Kling and Boltovskoy, 1995; Molina-Cruz et al., 1999); and the western and eastern Equatorial Pacific (Boltovskoy and Jankilevich, 1985; Yamashita et al., 2002). This rich knowledge of modern radiolarian ecology in the North Pacific has been applied by numerous studies to paleoceanographic reconstructions (e.g., Kamikuri et al., 2007; Itaki et al., 2007, 2012; Matsuzaki et al., 2014a, 2015a).

Despite this extensive literature, the vertical distribution and ecology of radiolarians in the ECS remain unknown, because only a few radiolarian assemblages from surface sediments have been reported (Tan and Chen, 1999; Chang et al., 2003). Therefore, the aim of this study was to elucidate the vertical distributions of radiolarians in the northern ECS and relate them to the regional hydrography. We collected plankton samples from depths of up to 700 m at five stations and used the radiolarian distributions at these stations and hydrographic data collected simultaneously to investigate the ecology of the radiolarians in this area. We focused in particular on how seawater temperature, salinity, and the chlorophyll α content influenced the vertical and horizontal spatial distributions of radiolarian species in the northern ECS. We expect this

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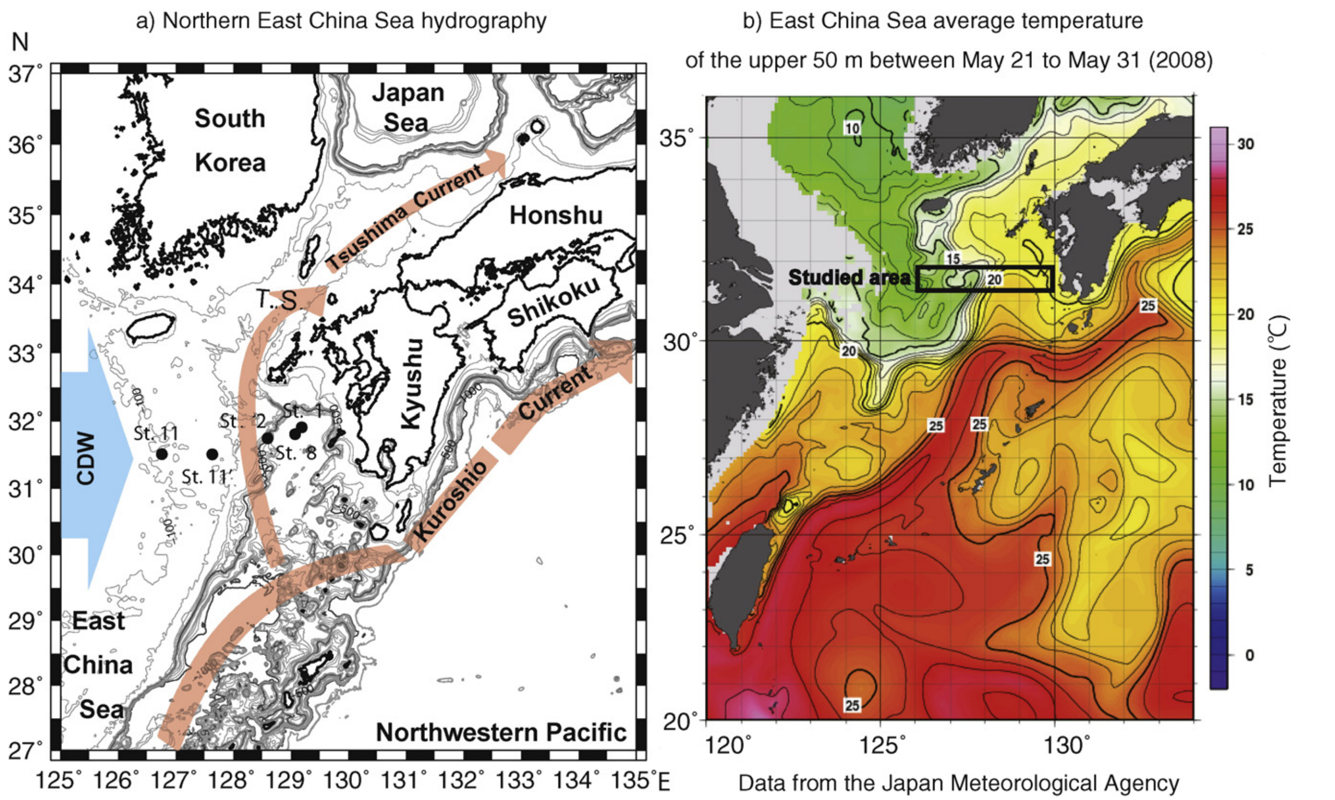

Fig. 1. Map showing the location of the studied stations and Northeast China Sea oceanographic setting (Map from ETOPO 1 grid data base generated by Generic Mapping Tools 5 software). The mean temperatures for 21–31 May 2008 are presented for the upper 50 m (data from the Japan Meteorological Agency at http://www.data.jma.go.jp/kaiyou/data/db/kaikyo/jun/t100_HQ.html?areano=3&stryy=2008&strmm=05&strdd=3). TS: Tsushima Strait.

information to be useful for future radiolarian-based paleoceanographic studies of the ECS.

2. Oceanographic setting

The ECS is relatively shallow; 70% of it lies above a continental shelf, and over the western shelf, the water column is shallower than 200 m (Fig. 1). Surface waters of the ECS are strongly influenced by warm, saline water from the KC and Taiwan Warm Current (TWC) (Tomczak and Godfrey, 1994) (Fig. 1) as well as by the cooler, less saline CDW (Fig. 1). Under the influence of the East Asian Monsoon, the shallow-water hydrography of the ECS exhibits drastic seasonal changes (Kagimoto and Yamagata, 1997). The highest volumetric flow rate of the KC, which brings warm, saline, oligotrophic water from the Equatorial North Pacific northward, occurs during the summer (Lee et al., 2001). During the summer in the southern ECS, sea surface temperature (SST) and sea surface salinity (SSS) reach maxima of 28 and 34, respectively (Sun et al., 2005), but in the northern ECS, between mainland China and Kyushu Island, where the samples were collected for this study, summertime SST and SSS are relatively low, 26 °C and 32 , respectively, owing to the discharge of the Changjiang River into the northwestern ECS (Fig. 1; Ichikawa and Beardsley, 2002). The CDW accounts for 80% of the total freshwater discharge into the ECS (Ichikawa and Beardsley, 2002) and dominates the waters above the shallow continental shelf in the northern ECS before they mix with the warmer and more saline KC-influenced waters in the northeastern ECS (Fig. 1).

3. Materials and methods

We collected plankton-tow samples from the northern ECS during cruise KT08-10 of R/V *Tansei-maru* of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). Samples were collected from multiple depths at five stations in late May 2008 by using a closing net with a 63 μm mesh and a mouth diameter of 45 cm. Station (St.) 1, St. 8, and St. 12 were on an area influenced by KC water, and St. 11 and St. 11′ were above the continental shelf (Fig. 1, Table 1). The volume of seawater filtered by the net was calculated from the net mouth area and readings from a flow-meter attached to the net. All collected materials were preserved in 100% ethanol and stained with Rose Bengal solution for later identification of living and dead specimens. Hydrographic data were obtained with a conductivity-temperature-depth profiler (CTD).The CTD was also equipped with a fluorescence sensor for collect chlorophyll α data.

The material in the net was passed through a 1-mm-mesh sieve to exclude large zooplankton, and then the filtrate was passed through a 45-μm-mesh sieve to collect radiolarians for analysis. The residual materials (45–1000 μm) were divided into equal parts using a plankton splitter, and the obtained aliquots were transferred onto a 24 × 36 mm cover glass and dried on a hot plate; once the aliquot had dried, it was mounted with Canada balsam. All radiolarians on the slides were identified under a light microscope at magnifications of 200×. Only well-preserved specimens with more than 50% of their skeletons present were counted as entire specimens. Both empty (unstained) specimens and those with stained protoplasm were counted, and the counts were converted to standing stocks (number of radiolarians per cubic meter of filtered seawater) and relative abundances (%). Only specimens with protoplasm clearly stained with Rose Bengal were considered to have been alive at the time of sampling, and only stained radiolarians were used in our analyses. However, some studies of benthic foraminifers have reported that cells can be stained with rose Bengal up to four weeks after the death of the foraminifer (e.g., Bernhard, 1988). In addition, Takahashi and Honjo (1981) reported that the sinking speed of dead radiolarians in the water column is between 13 and 416 m/day at constant seawater temperature, which suggests that