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Metazooplankton communities in the Ahe atoll lagoon (Tuamotu Archipelago, French Polynesia): Spatiotemporal variations and trophic relationships

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ABSTRACT

Metazooplankton abundance, biomass (<80 μm, 200–500 μm and >500 μm) and community structure in the Ahe atoll were studied together with their relationships with environmental factors (temperature, salinity, wind) and trophic factors (phytoplankton, bacteria, heterotrophic nanoflagellates (HNF) and ciliates) during three periods in 2008–2009. Meroplankton, mainly bivalve and gastropod larvae, was dominant. Holoplankton was dominated by copepods, the main species being *Oithona* spp., *Paracalanus parvus*, *Clausocalanus* spp., *Corycaeus* spp., *Acartia fossae* and *Undinula vulgaris*. The results suggest a clear wind influence on the structure and horizontal distribution of the zooplankton communities. The metazooplankton appeared to be controlled mainly by food resources, suggesting a bottom-up control. The low nanophytoplankton biomass in contrast to the high abundance of picophytoplankton, HNF and nano-particle grazers (mainly *Oithona* spp., *Paracalanus* and bivalve larvae) highlighted the importance of the microbial loop in the food web.

1. Introduction

Metazooplankton plays a major role in the functioning and productivity of aquatic ecosystems through its impact on nutrient dynamics and its key position in food webs. Most mesozooplanktonic organisms exert a strong grazing impact on the phytoplankon and on the microzooplankton (Pont, 1995; Calbet, 2008). They are also a food source for organisms of the upper trophic levels such as planktivorous fish and carnivorous invertebrates (Pinel-Alloul, 1995). In coral reef and atoll lagoon environments, they are important contributors to the benthic and pelagic food webs (Bozec et al., 2004; Alldredge and King, 2009). Zooplankton organisms can also be used as biological indicators for pollution, water quality and eutrophication (Attayde and Bozelli, 1998; Webber et al., 2005). Their generation times may be short enough to respond quickly to acute stress but long enough to integrate the effects of chronic problems. These attributes can be useful to design a community ecosystem health indicator (Cairns et al., 1993). However, very few studies have dealt with zooplankton in atoll lagoons (Gerber, 1981) and only a few have concerned the Tuamotu Archipelago (Michel et al., 1971; Ricard et al., 1979; Le Borgne et al., 1989; Carleton and Doherty, 1998).

Coral reef and atoll lagoons are productive ecosystems, compared to surrounding ocean (Hatcher, 1997). They have been frequently exploited for aquaculture, as in the Tuamotu Archipelago (French Polynesia) where pearl oyster farming is a major driver of the local economy (Andrefouët et al., 2012). The planktonic pearl-oyster larvae mainly feed on nanophytoplankton with high ingestion rates (Doroudi et al., 2003). The adults, cultivated in sub-surface pelagic nets, are also important passive consumers of nanoparticles (Yukuhira et al., 1998; Fournier et al. 2012). Farmed pearl-oyster populations can be considered as components of the pelagic ecosystem in pearl farming lagoons. In these ecosystems, they share (and may compete for) food resources with several pelagic components (including zooplankton) and may serve as food for other ones. Studying the different communities of the pelagic ecosystem and evaluating their stocks and their inter-relationships are required to define the optimal conditions for the recruitment and development of oysters. This information is also necessary to determine the load capacity for cultivation (Niquil et al., 1998).

A multidisciplinary research program was funded by the European Development Fund (EDF) in 2007 to describe, among

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other goals, the ecological environment of the pearl-oyster *Pinctada margaritifera* (Linnaeus, 1758) and its relationship with the pelagic trophic network.

Our study is part of this multidisciplinary study on the trophic environment of *P. margaritifera*. It aimed at analyzing within a farmed lagoon the spatiotemporal variations of metazooplankton standing stock and community composition according to the main environmental and trophic parameters.

2. Methods

2.1. Study site and sampling strategy

The Ahe atoll (14°29′S; 146°18′S) to the north west of the Tuamotu Archipelago in the Pacific Ocean is 23.5 km long and a maximum of 12.2 km wide (Fig. 1). The lagoon is 142 km^2 in area with maximum depth of 70 m in the central zone. The atoll rim which surrounds the lagoon is not completely closed: there is a passage (300 m long and about 20 m deep) to the northwest between the lagoon and the ocean, and several spillways mostly in the southern part of the rim. The climate is wet tropical with one rainy season from November to April with the maximum precipitation being in January and December. The annual air temperature variation is low (25–29 °C) with a regular seasonal trend. The dominant winds (NE trade-winds) are strongest in October–November.

Meteorological data (monthly averages of air temperature, rainfalls, and wind speed) were available from the meteorological station of Takaroa (Tuamotu; 14°28′S–146°2′W) for a period bracketing our surveys, in 2007–2009 (Fig. 2). The station is only 130 km from Ahe (see Fig. 1) and given the lack of any orographic effects on these low lying islands, Takaroa data were deemed representative of the conditions in Ahe atoll.

Three sampling surveys were carried out in May 2008, October 2008 and February 2009. During each period, four lagoon stations (Station 1, 23 m depth, Station 3, 50 m depth, Station 9, 50 m depth and Station 11, 45 m depth) were sampled on 2 (October 16 and 20, 2008) and 3 (May 14, 20 and 23, 2008; February 17, 20 and 24, 2009) occasions.

2.2. Environmental and trophic variables

Vertical profiles of salinity and temperature were recorded using a YSI 600 probe, from surface to bottom. Water samples were collected at two (0.5, 10 m; stations 1 and 11) and three (0.5, 10 and 20 m; stations 3 and 9) depths using a 5 L Niskin bottle. Chlorophyll *a* (Chl *a*) concentrations of particles retained on Whatman GF/F filters (0.7 μm of porosity) were measured on 400 ml water samples using a Turner Designs TD 700 fluorometer after methanol extraction (Welschmeyer, 1994). Particle fractionation using 2 μm pore size Nuclepore membranes gave an estimate of Chl *a* concentration for 0.7–2, and >2 μm size classes. The fraction of Chl *a* not retained by a 2-μm membrane was assigned to picophytoplankton biomass.

Bacteria and picoautotrophic cells were fixed with 0.2 μm filtered formaldehyde (final concentration 2%) and frozen in liquid nitrogen. Bacterial cells were enumerated by flow cytometry using the method described by Marie et al. (1999). A 1 ml formaldehyde-fixed subsample was incubated with DAPI at a final concentration of 1/10,000 for 15 min at room temperature in the dark. Each subsample was counted using a MoFlo cytometer (DAKO). Stained bacterial cells, excited at 488 nm, were enumerated according to their right-angle light scatter (RALS) and green fluorescence (FL1) measured using a 530/30 nm filter. These cell parameters were plotted onto 1024 channels and recorded on a 4-decade logarithmic scale. Fluorescent beads (0.94 μm, Polysciences Inc., Warrington, PA, USA) were added to each sample. Standardized RALS and FL1 values (RALS and FL1 for the cells divided by the RALS and FL1 for 0.94 μm beads,) were used to estimate the relative size and nucleic acid content of the bacterial cells (Troussellier et al., 1999). The list mode files were analyzed using SUMMIT software (Dako Colorado Incorporation).

Picophytoplankton (*Prochlorococcus* sp. and *Synechococcus* sp. cells) and autotrophic picoeukaryotes counts were performed using the same flow cytometer. Cells excited at 488 nm were detected and directly enumerated according to their FALS and RALS properties and their orange (585/42 nm) and red fluorescence (>650 nm) from phycoerythrin and chlorophyll pigments, respectively. Fluorescent beads (0.94 μm) were also added to each sample. The list mode files were analyzed using SUMMIT software (Dako Colorado Incorporation).

For microzooplankton enumeration (ciliates), water samples (1 L) were fixed with alkaline lugol iodine (2% final concentration). A first sedimentation was conducted for 24 h and the top 900 ml of the samples was slowly siphoned off using small-bore tubing. The remaining 100 ml was then stored at 4 °C in the dark before enumeration. After sedimentation in a Utermöhl settling chamber (Hydro-Bios combined plate chamber), cells were enumerated at a magnification of ×200 using a Zeiss axiovert inverted microscope with interference contrast.

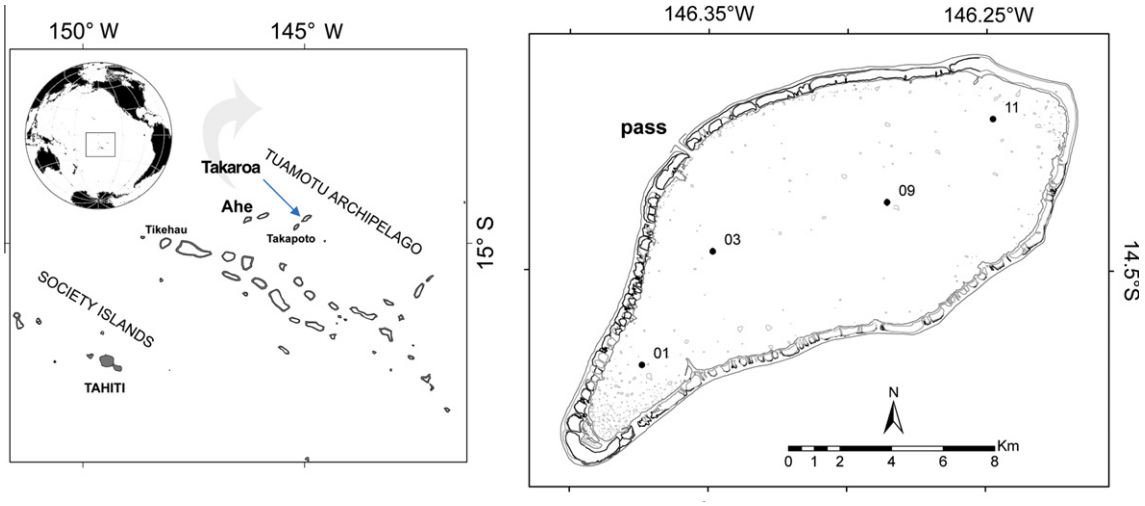

Fig. 1. Left: Location of Ahe (sampling sites) and Takaroa (meteo station) atolls. Right: Positions of the sampling stations in the Ahe lagoon.