THE DISTRIBUTION AND ABUNDANCE OF DECAPOD AND FISH COMMUNITIES IN CLEVELAND BAY, AUSTRALIA

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Abstract

Spatial and temporal variations in the fish and decapod communities were investigated at three stations in Cleveland Bay along with other zooplankton and phytoplankton communities. The linkage between biological assemblages and physical properties of the ocean was explained to develop better understanding of population dynamic of planktonic communities. Biological and physical properties data were gathered in 3 stations by 6 different trips. The results show that there is a significant association between daytime and tidal period to the abundance of planktonic communities ($P < 0.05$). Spatial distribution of fish and decapod communities are likely explained by "predator pit" and "match/mismatch" concepts to increase the survival probability along with physical properties of the ocean.

Keywords: Biological oceanography; decapod and fish communities; Cleveland bay

INTRODUCTION

Small pelagic fish are essential elements of marine ecosystems (30% of global fisheries) due to their significant biomass at intermediate levels of the food web that play important role in connecting the lower and upper trophic levels (Cury et al., 2000; Smith et al., 2011). Moreover, the decapod species are also found in high diversity in the aquatic environments (90% of total species) that mostly live in the sea or in adjacent brackish waters (Anger, 2001). Both groups are commercially exploited by coastal and offshore fisheries (Anger, 2001; Smith *et al.*, 2011).

Spatial and temporal distributions of both groups are related to their life-cycle movement, such as eggs and larvae movement, settlement range movement, ontogenetic shift, relocation and migrations (non-spawning and spawning) (Pittman & McAlpine, 2003). The influences of large-scale physical oceanography also have impact to their population dynamics, due to their relatively long period of planktonic phase (Lalli & Parsons, 1997). Moreover, the mechanism of spawning period for mostly marine creatures during the larval stages synchronized with the annual plankton production cycle to increase survival rate

(Anger, 2001; Blaxter & Hunter, 1982). These hypothesis (match/mismatch) are broadly accepted to determine the linkage between recruitment and plankton production (Cushing, 1990).

Cleveland Bay, Townsville-Queensland is located in the centre of Great Barrier Reef (GBR). A wind in the GBR was generated by near shore current with northward flow generated inhibited cross-shelf mixing. Additional thermocline in deep waters is driven by surface water convergence and larger turbulent eddies (Steinberg & Great Barrier Reef Marine Park, 2007). As a result of strong southeast trades during most of the year, the GBR shelf is likely to be well mixed (Church & Craig, 1998). The South Equatorial Current also plays crucial role and different amplitude in water transport which defined by reef density (Brinkman *et al.*, 2001). Those conditions, create high variety of trophic status and productivity which reflected by zooplankton communities (McKinnon *et al.*, 2005). Recent studies showed that the El Niño-Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO) reported has influenced characteristic of the GBR, especially planktonic and benthic assemblages (Kingsford *et al.*, 2007; Steinberg & Great Barrier Reef Marine Park, 2007).

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The recent studies in the GBR mostly covered oceanography (Eric Wolanski, 1994), primary production and energy scheme (Furnas *et al.*, 2005), habitats and biological assemblages (Fabricius *et al.*, 2005; Hurrey *et al.*, 2013; Kramer *et al.*, 2014), coral reef matters (Graham *et al.*, 2014; Uthicke *et al.*, 2014) and climate change impact (Fidelman *et al.*, 2013; Sutton & Tobin, 2011; Zeppel, 2011). However, the impact of climate change to biological assemblages is limited on the multiple effects on food web due to highly uncertainty on the response of individual marine creatures. The research's hypothesis stated that the structure of planktonic communities would follow the variability of ocean properties to maximize carrying capacity of the environment. This research examines the linkages between physical properties of the ocean on the population dynamic of planktonic assemblages, especially fish and decapod larvae in Cleveland Bay.

MATERIALS AND METHODS

Time and Location

Field survey was conducted in Cleveland Bay, Townsville-Queensland during 28 February-1 March 2015 using RV James Kirby that consist of 6 different surveys (different time). Every measurement campaign sampled same location of 3 stations (inner, mid and outer of the bay). The taxonomy and identification of zoo- and phyto-plankton based on references from (Hartwick & McKinnon, 2008; Slotwinski *et al.*, 2014).

Physical Sampling

A Seabird SBE19plus conductivity-temperature-depth (CTD) profiler fitted was used to measure salinity, temperature and density at each station with samples taken from sea surface to approximately 4-10 m based on the bottom depth at most stations. The information of tidal chart gathered from (DTMRQ, 2014).

Biological Sampling

Large-zooplankton samples were collected by using plankton-net (200 ìm) which towed for 5 minute (2 replications). This plankton-net was equipped by flowmeter (to estimate filtered volume) and setup on the starboard side of vessel. Sample was preserved using 10% of formaldehyde. Two replicate sub-samples were collected in 5 ml of container and place it in a "Bogorov" tray to examine taxonomic diversity after refiltered using 200 ìm sieve. Total individual of large-zooplankton was calculated by multiplying number of individual, which counted in sub-sample with total volume of sample, and dividing by total

volume of sub-sample. Volume sample for macro-plankton-net was multiplied swept area of plankton-net (0.75 x 0.65 = 0.49 m²) and transect distance (difference in counts of flowmeter x 26,873)/999,999).

Moreover, water samples for phytoplankton and micro-zooplankton were collected at the surface by using plankton-net (63 ìm) that towed for 10 m (2 replications). Both samples were preserved using 10% of formaldehyde. In the laboratory, samples were refiltered using 60 ìm sieve. Two replicate sub-samples of phytoplankton were collected in 1 ml of container and place it in a "Sedgewick-Rafter" tray to examine taxonomic diversity. Total cells of phytoplankton were calculated by multiplying number of cells (direct observation under microscope) that counted in sub-sample or number of grid (1,000 grids) with total volume of sample and dividing by total volume of sub-sample. In addition, 1-5 ml sub-sample of micro-zooplankton were taken (two replicates) and examined in a small "Bogorov" tray. Total individual of micro-zooplankton followed the same calculation for large-zooplankton. Total number of zooplankton was aggregated from macro- and pico- plankton-net. As this report focus on the distribution of fish and decapod, number of zooplankton is the actual number that excluded number fish and decapod (here after called as unselected zooplankton/UZooplankton).

Furthermore, surface and bottom water were sampled to determine the difference of chlorophyll concentration in different depth by taken 5 L of water using Niskin Bottle. After that, 1 L of sample was filtered onto e"0.45 ìm Whatman GF/C glass fibre with a mild vacuum (½ atm, 50 kPa). Pigments were extracted in 90% acetone following acidification techniques by ASTM (D3731-87, 2012). Spectrophotometry analysis was conducted over the range of 600 to 750 nm by determining light sensitivity of different pigments (Chl a – 664 nm; chl b – 647 nm; chls c1 and c2 – 630nm). However, nutrients and underwater light was not measured due to limited time.

Statistics Analysis

The data analyses used the software Microsoft Excel 2007, SPlus 8.0, Ocean data View (ODV) 4.0. This analysis was based on non-parametric test by considering few assumptions required, such as did non-normally distributed and unequal variance data. The association between abundance of fish and decapod larvae on different stations and tidal phase (assumed as proxy of physical influence) was tested using Kruskal-Wallis rank sum test. Spearman's Rank test was also used to examine the correlation between

abundance of copepod and number of fish and decapods larvae (Whitlock & Schluter, 2009).

RESULTS AND DISCUSSION
Results

Phytoplankton communities are dominated by group of diatoms (69%) and followed by cyanobacteria, diatoms and dino-flagellates (12%, 10 % and 9% respectively). The abundance of phytoplankton during period of survey (daytime) showed **significant** association (An Kruskal-Wallis rank sum test; $X^2 = 7.72$, df = 2, p = 0.021). The highest phytoplankton abundance occurred during 14:00-15:00 (1,158 ± 701 cells/l) compared to other period (Figure 1e). A number of phytoplankton is higher in inner station (965 ± 492 cells/l) that has higher average of salinity and temperature (35.8 ± 0.1 psu and 31.8 ± 0.3 °C). An abundance of phytoplankton was high during ebb-low in-group 3 (1,179 ± 357 cells/l), and low in-group 1 during full-flood (368 ± 226 cells/l). A Kruskal-Wallis rank sum test showed that there is **insignificant** association phytoplankton in different stations ($X^2 = 4.533$, df = 2, p = 0.104). However, there is **significant** association phytoplankton in different phase tidal (X^2

= 10.93, df = 3, p = 0.012). A Wilcoxon rank-sum test showed that there are **insignificant** differences between chlorophyll-a concentrations at different depths (Z = 0.33, df = 2, p = 0.738) (Figure 1b). Correlation test using Spearman Rank test shows that there is no significant correlation between the average of temperature and the abundance of phytoplankton (Z=0.29, p = 0.768).

The composition of zooplankton is dominated by copepod (84%) and other zooplankton (14%). The number of fish, decapod, other crustacean and other chordates are less than 5% (Figure 1b and Figure 1c). The number of fishes in outer station is higher (69 ± 164 ind./l) than other stations. In contrast, number of decapod and UZooplankton (exclude number of fish and decapod) phytoplankton are higher in inner station (77 ± 144 ind./l and 60,776 ± 45,964 ind./l, respectively) that has higher average of salinity and temperature (35.8 ± 0.1 psu and 31.8 ± 0.3 °C) (Figure 1d). A Kruskal-Wallis rank sum test showed that there are **insignificant** association between number of fish, decapod and UZooplankton in different stations. However, number of UZooplakton that
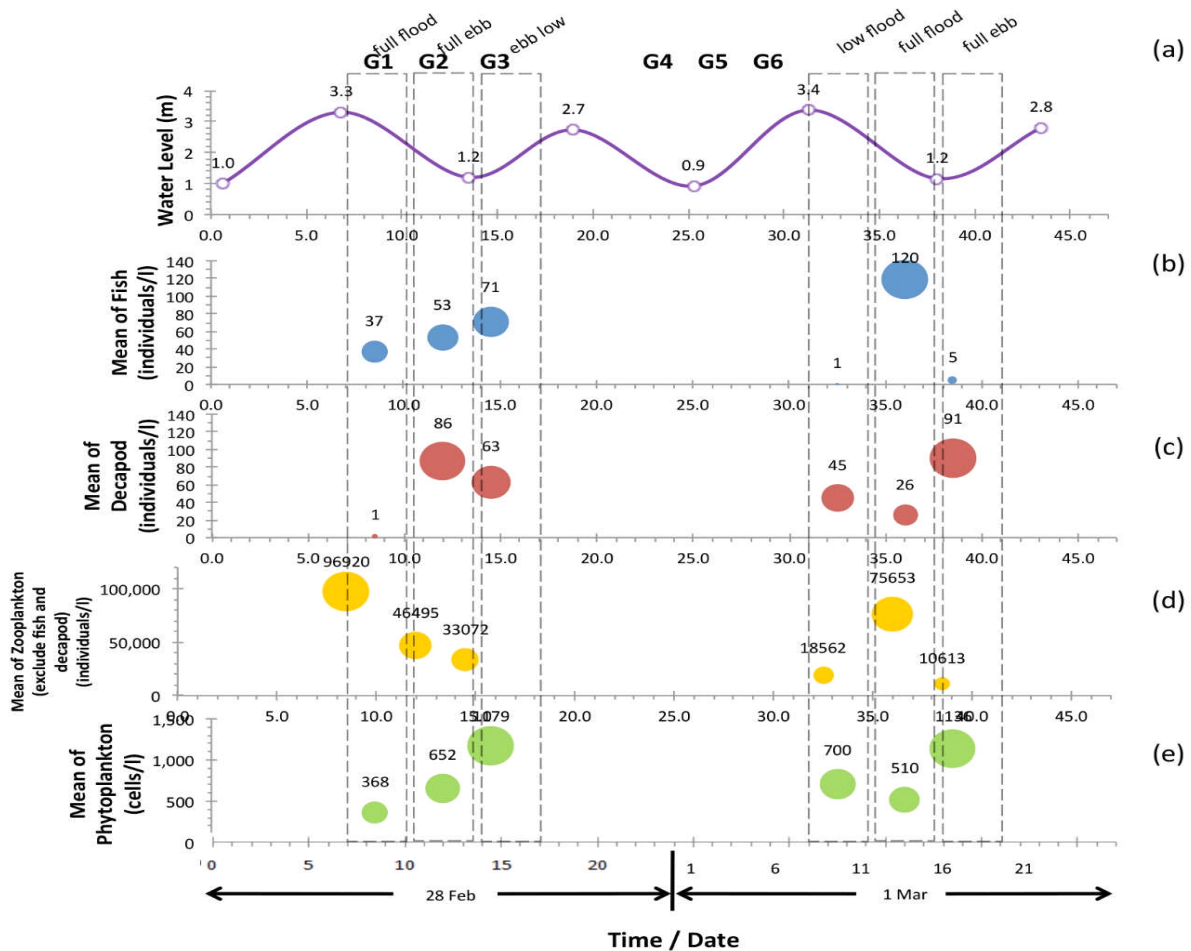

Figure 1.   The influence of tide (a) to fishes (b), decapod (c), UZooplankton (d) and and phytoplankton (e) communities.

dominated by copepod likely has **less significant** association with stations ($X^2 = 5.64$, df = 2, p = 0.059).

The distribution of fish depends on the group, which reflected influence of tidal proxy of time. A number of fishes were high during trip of group 5 when full-flood happened (120 ± 197 ind./l) and low during low-flood in-group 4 (1 ± 1 ind./l) (Figure 1b). In addition, during full-ebb in group 6 number of decapod were high (91 ± 142 ind./l), but UZooplankton was low (10,614 ± 2,781 ind./l). Similar pattern also showed in group 1 when the tide in full-flood phase, number of decapod were low (2 ± 2 ind./l), however, number of Uzooplankton were high (96,920 ± 68,656 ind./l) (Figure 1c-d). A Kruskal-Wallis rank sum test showed that there are

significant association between number of fish, decapod and UZooplankton in different phase of tidal.

Longitudinal section showed that temperature near the coastal was higher than in the open ocean. Moreover, profile indicates the subduction process of cool water from open waters to coastal water that probably signal of upwelling (Figure 2a). Moreover, generally high salinity waters moved to deeper water and filled by low saline water from the ocean (Figure 2b). Low-density waters distributed near the coastal and mixed with high dense of waters mass from the bottom of the open ocean (Figure 2a). Correlation test using Spearman Rank test showed that there is **insignificant** correlation between the average of temperature and number of fishes and decapod. However, there was **significant** correlation (positive)

(a) Temperature (°C)   (b) Salinity (psu)   (c) Density (Kg/m^3)
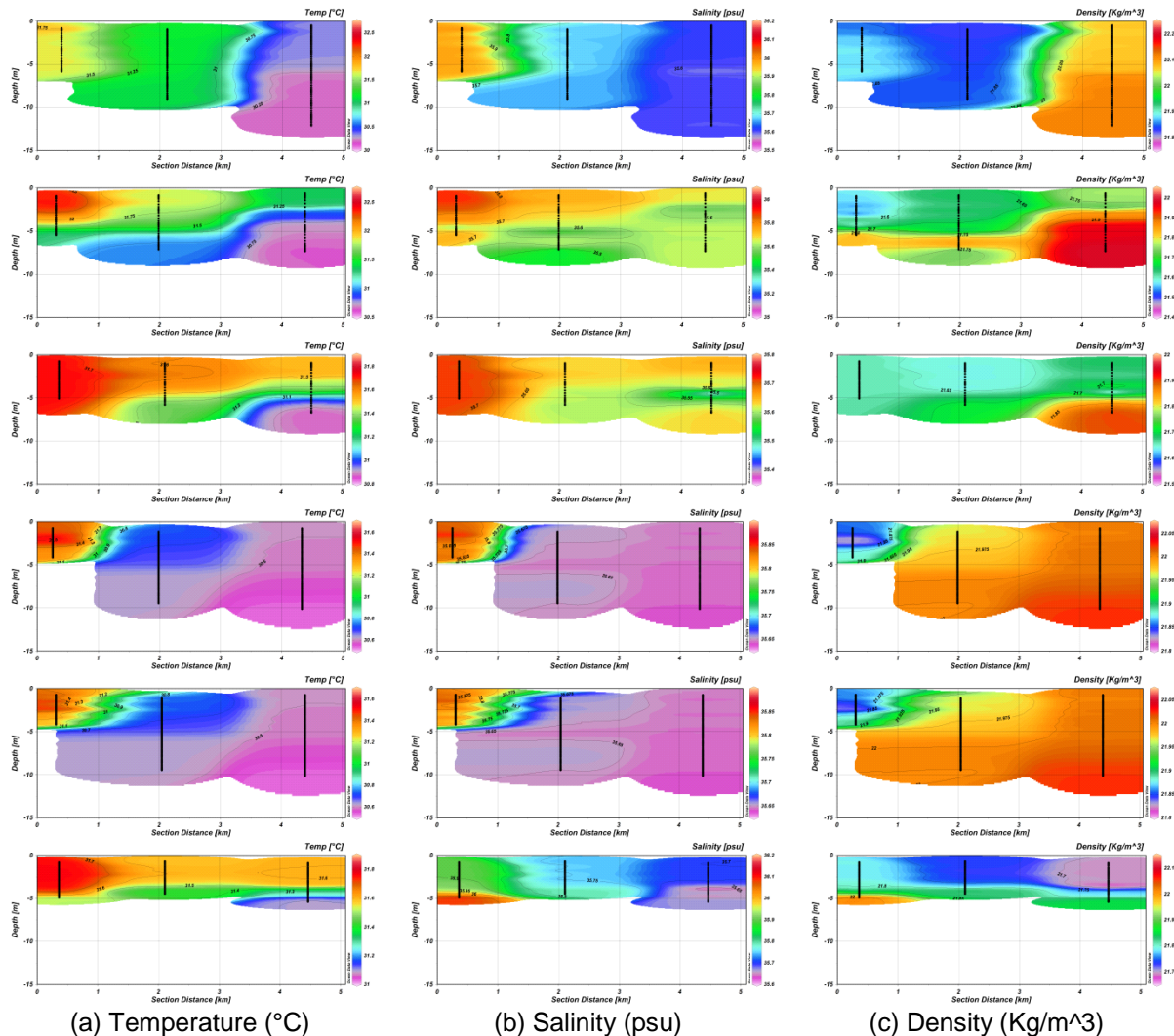
Figure 2. Section profile of temperature (a), salinity (b) and density (c) in different station (inner station: left to outer station: right).

between the mean of temperature and zooplankton abundance (Z=2.09, p = 0.036, r = 0.354).

Discussion

Planktonic assemblages are crucial as a basis of food web in the ocean ecosystem (Smith *et al.*, 2011). This assemblage was considerably influenced by the dynamic of physical properties in the ocean, such as solar radiation, salinity, temperature and nutrient (Lalli & Parsons, 1997). Phytoplankton as primary producer in the ocean is mainly driven by solar intensity. Due to the lack of underwater light data, we assume that the solar intensity gradually decrease as the depth increase (Strickland, 1958). This study showed the significant signature of temporal variety of phytoplankton abundance during survey (an Kruskal-Wallis rank sum test; X2 = 7.72, df = 2, p = 0.021). The visible spectrum (about 400-700 nm) of solar radiation has been penetrated to sea surface (around 50%) which used for photosynthesis (Miller & Wheeler, 2012). Spatial variation showed that high nutrient supply commes from mainland through run-off led to high abundance of phytoplankton in the inner station (high salinity and temperature). Nutrient availability influenced the growth rate of phytoplankton, however, mostly nutrient was high deeper layer (Lalli & Parsons, 1997). The information on nutrient distribution was substituted by concentration of chlorophyll-a. Since, in the tropical waters chlorophyll-a was used to examine the nutrient richness of the ocean (Takeda, 1998). The upwelling generated surface fertilization through mass transport. The upwelling in the GBR mostly influenced by East Australian Current flowing south (McKinnon & Thorrold, 1993). During ebb-low period of tidal, number of phytoplankton increased due to an increase in shoal-channel exchange (Kimmerer *et al.*, 1998).

The result showed that there was no significant different in the vertical distribution of chlorophyll-a. It could be argued that the waters mass during survey has been well mixed, therefore nutrient supply in the surface and bottom are similar (deeper nutricline). Similar argument was stated by E. Wolanski & Ridd (1990) that Inner shelf waters are considerable well mixed. Moreover, bottom water sample was taken from relatively swallow waters (4-7 m) and the light able to penetrate up to 150 m (Kramer *et al.*, 2014; Lalli & Parsons, 1997) by considering low turbidity during survey. However, generally the chlorophyll-a concentration was high in the outer station. It suggests the grazing process by zooplankton, is due to high abundance of zooplankton in inner station.

In addition, zooplankton (exclude fish and decapod) that mostly represented by copepod (84%) reported that high abundance occurs in inner station during full-flood phase (Figure 1d). The pattern is followed by an increase of phytoplankton in the same station. Food availability estimated as trigger of high abundance (Hurrey *et al.*, 2013) and indirect effect of terrestrial run-off (McKinnon & Thorrold, 1993). Zooplankton plays important role in aquatic ecosystem, such as grazers on the primary production and energy flux to higher tropic level (fish, birds and whale populations) (Levinsen & Nielsen, 2002).

Population dynamic of zooplankton is also influenced by temperature (significant correlation; Figure 2b). The signal of upwelling probably appeared by considering the subduction process of cool water from open waters to coastal water (Figure 2a). Temperature likely effected metabolic rate of organism (Ikeda *et al.*, 2001). High temperature water likely increased a number of zooplankton, especially copepod (Southward *et al.*, 1995). Some species of zooplankton did diel vertical migration which aimed for adaptation, grazing and communicating (Lalli & Parsons, 1997). An increase in salinity led to an increase in number of zooplankton (Vuorinen *et al.*, 1998) and also generated stress level (Gaudy *et al.*, 2000). As the longitudinal profile showed the movement of the high salinity waters to deeper water and filled by low saline water from the ocean (Figure 2b). The studies stated that the differences of consumption rate of copepod as herbivores and carnivores by 65% and 310% of their body weight (Ikeda *et al.*, 2001; McKinnon *et al.*, 2005).

Fish and decapod groups are commonly called as nekton that is important as commercial commodities, such as herring, shrimp and crab. Decapod referred to crustaceans that carapace along the back and covering the gills (Miller & Wheeler, 2012). Decapod has two life stages, i.e. benthic juvenile and pelagic larvae which is determined different morphology feature and habits (Anger, 2001). This study found that decapod mostly occured in the high abundance in inner station during full-ebb tidal phase. It is likely due to habitat fragmentation (Anger, 2001) and food availability (Cushing, 1990). Decapod larvae have high variety of food sources, such organic solutes, detrital matter, bacteria, protozoans and an enormous diversity of metazoan zooplankton (Anger, 2001). It will drive by larvae stages and food selectivity. Decapod consumed planktonic algae (20-200 µm), such as diatoms and also zooplankton (copepods, cirripedes, mollusc and echinoderm larva) (Anger, 2001). However, during the early phyllosoma larvae of decapod consumed chaetognaths, fish larvae and

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hydromedusae (Anger, 2001). The main influence of temperature and salinity to distribution of decapod is on the energy partitioning. The high salinity would lead to high stress on energy assimilation. By following pattern, it showed that high abundance of decapod followed by low density of copepod. It was argued as "predator pit" concept that to avoid predator by moving into less appropriate feeding area (Bakun, 2006).

As planktonic stages, fish was highly vulnerable as prey of other zooplankton, such decapod and copepod (Waite *et al.*, 2014). Therefore, "predator pit" concept also could explain it due to high density of fish found in the station that have low abundance of decapod and copepod. In addition, high density of fish occurred during full-flood when waters mass started to flushed and indicated by low temperature. During low-flood tidal phase when temperature was high, the abundance of fish was low as well as density of UZooplankton. It was likely follow "match / mismatch" concept (Cushing, 1990) to ensure high survival probability.

CONCLUSION

There was a significant association between the abundance of planktonic communities to time and tidal period (P < 0.05). The concept of "predator pit" and "match/mismatch"possibly explained the spatial distribution of fish and decapod communities. That phenomenon seems be related to the likelihood of survival probability and physical properties of the ocean. The further investigation is needed to examine the seasonal trend and the impact of climate change to the variation of planktonic communities.

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