The Organization of Plankton within Matapouri Estuary, northern New Zealand

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Abstract

There is an undeniable need for more data assessing the ecological significance of mangrove dominated estuaries. The ecological significance of a mangrove dominated estuary can be better understood by analyzing the nutrient dynamics of the system. Planktonic organisms are studied at three locations within Matapuori Estuary, northern New Zealand and considered partially representative of the nutrient structure within the system. The data is broken up by tidal conditions – low or high tide - as well as whether the data was collected in their inner or outer estuary. Copepods, salp, and barnacle exoskeletons were more abundant during high tide. Amphipods were more common during low tide. The outer estuary offered more diatoms and amphipods; however, it also contained fewer salp. The results of the analysis point to the further need to study the complexities of mangrove dominated estuarine environments.

Introduction

Historically, the mangroves that have dominated northern New Zealand estuaries have been considered ecologically rich ecosystems with high functional and structural importance (Alfaro et al. 2006). In fact, the Maori of Northern New Zealand have considered mangroves as taonga – a prized possession (Park 2004). Today, however, the issue of mangrove colonization and expansion is highly polarized with some groups advocating mangrove preservation and others believing that by overtaking pristine beaches they are damaging to the ecological and aesthetic value of their community (Morrisey et al. 2007). It is not clear whether or not these mangroves deserve the degree of loathing they are receiving from certain groups or if they are in fact ecologically rich and important habitats. It is therefore imperative to obtain as much information on nutrient dynamics and consequentially the biological importance of mangrove habitats.

Matapouri Estuary, located about 35 kilometers northeast of Whangarei provides an ideal location to understand nutrient structure within a mangrove dominated estuarine environment (Figure 1). The numerous habitats and relatively high species diversity make this estuary biologically interesting and significant (Alfaro 2006; Pohe 2008). Of primary importance to the nutrient distribution within the estuary are its freshwater and marine influences. Although the foremost contributions to the estuary are through tidal influences, the northerly Te Wairoa and the southerly Parangarau streams provide a substantial freshwater supply. During low tidal conditions these freshwater streams make up a substantial part of the total water supply within the estuary whereas during high tidal conditions marine water dominates the estuarine system.

Figure 1. Matapouri Estuary, the location of the study site. It is located approximately 35 km northeast of Whangarei, northern New Zealand

For the purpose of this study, nutrient dynamics within Matapouri Estuary are considered in terms of planktonic organisms – by definition organisms whose movements are entirely determined by the water current (Little 2000). Previous work has demonstrated that planktonic organisms play a pivotal role as a food source for higher organisms within Matapouri Estuary and as a result have an undeniably important part in molding the trophic structure of the estuary (Alfaro et al. 2006). This study, overall, aims to better quantify and understand the organizational structure of plankton within the estuary. It was reasoned that the distribution of plankton would be heavily determined by the tidal condition – low or high tide - and the location with respect to the mouth of the estuary.

Background on Studied Organisms

In order to fully understand the significance of the planktonic distribution within the estuary, it is imperative to have a solid understanding of the general ecology and trophic interactions of the studied organisms. Generally the ecology of planktonic organisms within an estuary is heavily determined by the physiochemical conditions of the estuary. For instance, along any estuary there is usually a sequence of salinity moderated planktonic assemblages from the estuarine mouth to the riverine freshwater environment. The species types beginning from the more marine environment typically progress from euryhaline marine to estuarine to euryhaline freshwater (Little 2000). Euryhaline creatures are able to adapt to a wide range of salinity conditions although the range for euryhaline freshwater and euryhaline marine should be of lower and higher salinities respectively. The inner estuary is closer to the mouth and consequentially should have more euryhaline marine species whereas the outer estuary is more subject to freshwater influences and should have a greater degree of euryahline freshwater species. Organisms that were seen to display notable trends throughout the estuary are discussed.

Diatoms are unicellular microscopic algae that are known to vary, among other factors, in terms of their habitat and salinity preference (Stoermer and Smol 2001). Both benthic and pelagic diatoms constitute important primary producers that may at times dominate estuarine primary production (Haese et al. 2007, Kasim and

Mukai 2006). Within Matapouri Estuary specifically, diatoms have been demonstrated to be a food source to filter feeders, zooplankton, and especially grazers (Alfaro et al. 2006).

Zooplanktons are heterotrophic or detrivorous small animals drifting in the water column. It is common for zooplankton to act as trophic intermediates between productive phytoplankton, such as diatoms, and the higher trophic levels of an estuary (Park and Marshall 2000). Copepods are an example of zooplankton that contribute heavily to estuarine productivity and are major components of the secondary trophic level (Dalal and Goswami 2001). Additionally, different copepod species are known to be selected for at different locations within an estuary due to salinity tolerances (Little 2000). Amphipods similarly consume diatoms and are consumed by higher trophic levels including fish (Hecht et al. 2004). Moreover, their distribution within an estuary has been shown to be determined by salinity concentrations (Little 2000). In Matapouri Estuary, zooplankton including copepods and amphipods were reasoned to act as a food source to scavengers such as crabs as well as predators including fish and shrimp. They were also understood to feed upon diatoms (Alfaro et al. 2006). Salps are gelatinous, marine zooplankton known to filter feed on phytoplankton and other smaller organisms. Vargas and Madin (2004) pointed out that these creatures hold the potential to drastically modify and control regional food webs.

Other Organisms

Macroalgae and seagrass are both found commonly in the benthic zone of estuaries. Their organic matter, however, can become suspsended into the water column by water currents or by direct consumption from heterotrophs. Seagrass is rather unpalatable for direct grazing due to its relatively low nitrogen content and secondary metabolites (Larkum et al. 2006). After decomposition by bacteria they are much more palatable and within Matapouri estuary can be potentially consumed by grazers, filter feeders, and scavengers (Alfaro et al. 2006). Macroalgae is much more palatable and contributes to the nutrition of grazers and scavengers in Matapouri estuary (Alfaro et al. 2006).

Also of note within Matapouri Estuary is the presence of barnacle exoskeletons. Barnacles are entirely marine species and their exoskeletons are known to be high in protein (Ruppert et al. 2004). As a result of this high protein content, it is entirely possible that they contribute a significant amount of energy to larger organisms within the estuary.

Methods

The study was conducted at Matapouri Estuary, located about 35 km northeast of Whangarei in northern New Zealand. Data was obtained in April of 2009. Plankton content was measured at three different locations within the estuary (Figure 1). At each of the three locations fifty meter transects were conducted in which a plankton net was towed through the channel. The plankton net effectively filtered any existing matter within the water column into a plastic bottle. In order to preserve the collected organic material, formaldehyde was added to the solution. At each of the locations the plankton net was towed once going upstream and another time downstream. The aforementioned process was carried out during both high and low tide conditions giving a total of four samples per location.

Figure 2. Locations of three plankton tows within Matapouri Estuary of northern New Zealand. The red lines correspond to the fifty meters the plankton tows occurred over. Picture courtesy of Google Maps.

Plankton distribution was assessed by examining each sample and quantifying the distribution of organisms. Two ten milliliter replicates were randomly drawn from each sample and considered representative of the bottle they were drawn from. Each location therefore had four replicates per tidal condition. Within each replicate the number of planktonic organisms was counted and recorded. Ultimately ten types of plankton were found throughout the samples: diatom cells, macroalgae fragments, seagrass fragments, amphipods, copepods, other arthropods, salp, barnacle exoskeletons, larval barnacles, and polychaete worms. Furthermore, three families of copepods were distinguished and recorded: calanoids, cyclopoids, and harpacticoids.

Results

The average number of planktonic organisms per replicate was organized by location and tidal condition. The averages are summarized in Figure 2. Larval barnacles and polychaete worms were ultimately not considered in the study due to their extremely infrequent occurrence. The summary of average organism counts suggests that a majority of the organisms had a varied distribution across the locations and tidal conditions. In order to better understand the influence of tidal condition and estuarine location the data was broken down into additional categories.

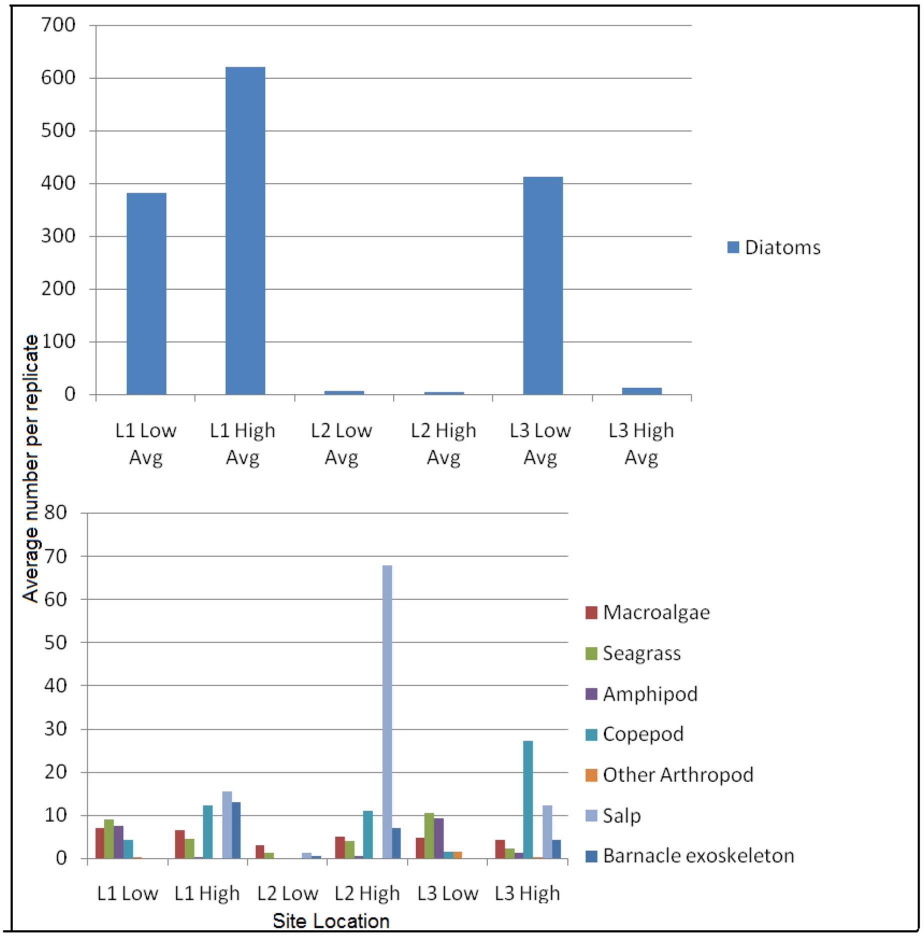

Figure 3. Summary figure of average numbers per replicate. Results suggest a variation in organism distribution by location and tidal condition

Tidal Conditions

The average number of planktonic organisms per replicate was grouped according to their occurrence at high or low tide (Figure 3). Diatoms were slightly higher during low tide. Amphipods were substantially more frequent during low tide. High tide seemed to drastically increase the presence of copepods, salp, and barnacle exoskeletons.

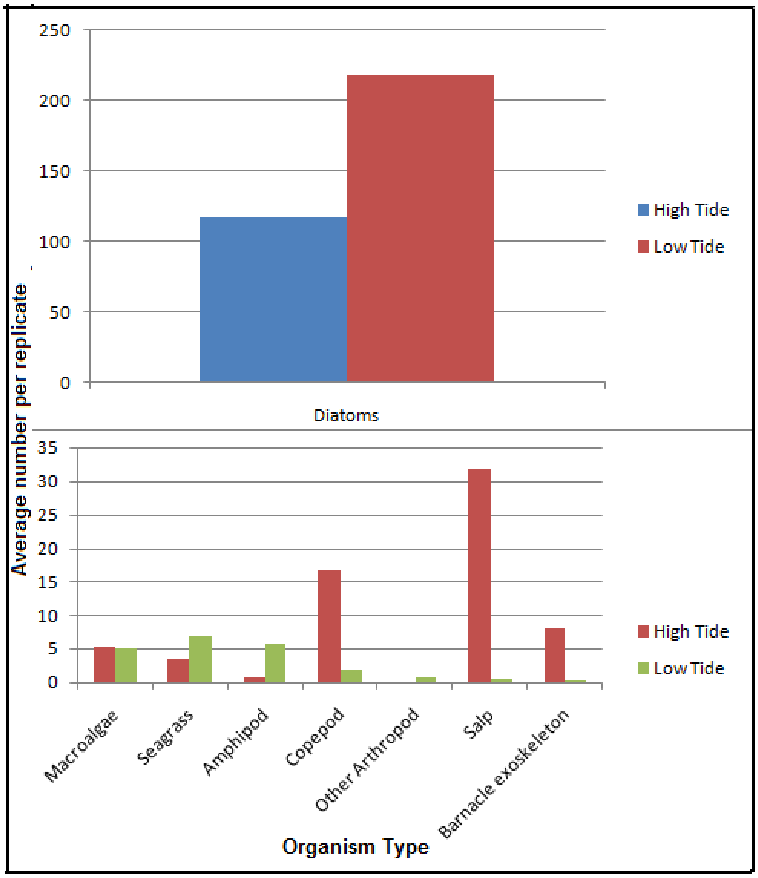

Figure 4. Average number per replicate grouped by tidal condition. Results indicate an increase in Salp, Copepods, and Barnacle exoskeletons during high tide. Amphipods increased during low tide.

Estuarine Location

The three locations were grouped as either part of the inner or outer estuary. Location two was considered as part of the inner estuary due to its proximity to the estuarine mouth. Locations one and three were both categorized as part of the outer estuary because they were relatively further away from the mouth. The average number of planktonic organisms per replicate were grouped by the outer and inner estuary (Figure 4). Diatoms and amphipods were both substantially higher in the outer estuary. Salp presence increased in the inner estuary.

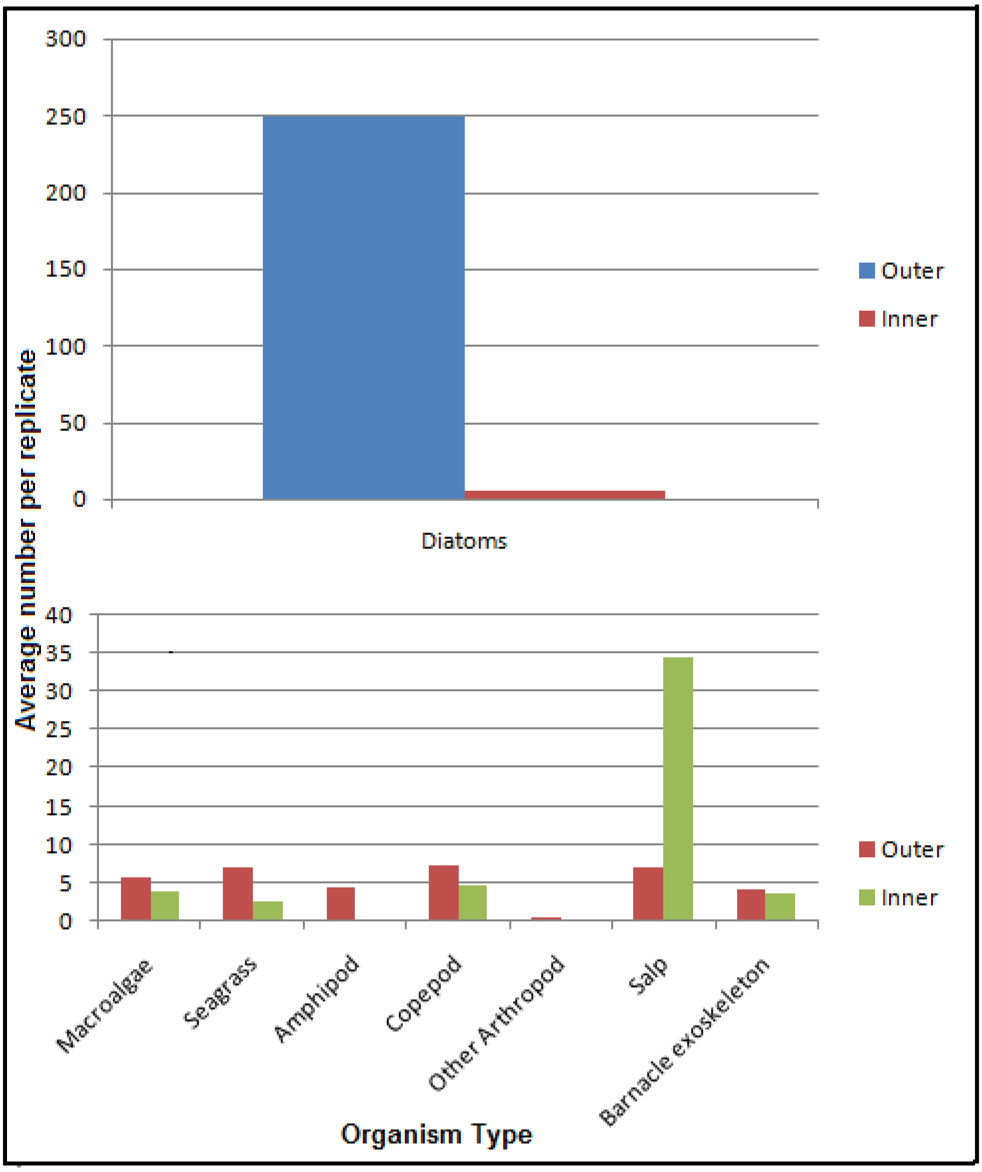

Figure 5. Average number per replicate grouped by estuarine location. Diatoms and amphipods were more abundant in the outer estuary. Salp was more common in the inner estuary.

Copepod Families

The three families of copepods found – calanoid, cylopoid, and harpacticoid – showed no clear preference in habitat location relative to each other. There is, however, a clear abundance of cyclopoids and calanoids compared to the number of harpacticoids (Figure 5).

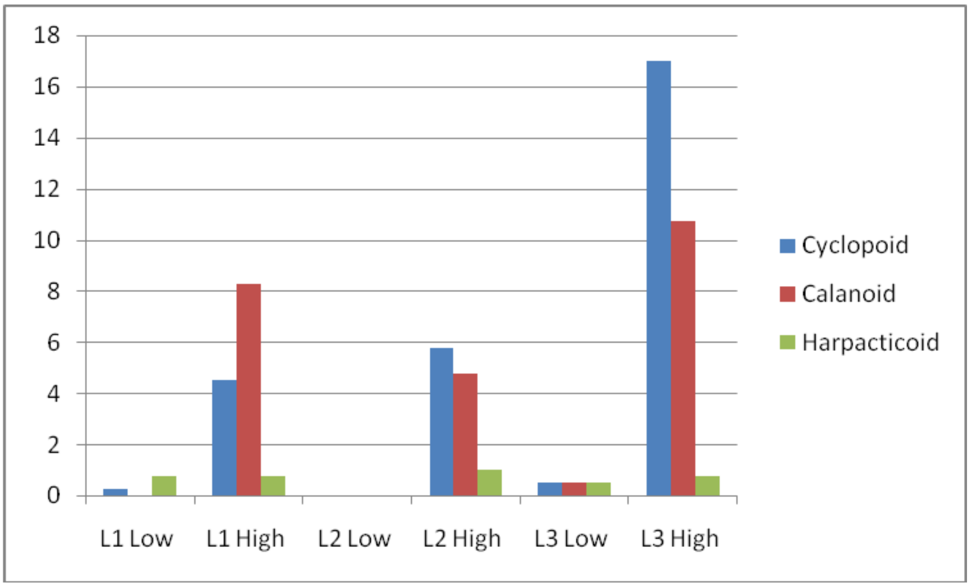

Figure 6. Copepod families organized by location and tidal condition. Harpacticoids are less abundant than the other two families.

Discussion

The results of this study hold some rather interesting implications for nutrient dynamics within Matapouri Estuary. The distributions of many organisms were found to vary by site and tidal condition and thus demonstrate how vast differences in planktonic structure can occur over a relatively short geographical span within an estuary.

Diatoms

The organizational structure of diatoms within the estuary was rather curious especially with respect to their abundance at the outer estuary relative to the inner estuary. It was initially reasoned that the diatom presence in the inner estuary would be higher due to the influx of water from the sea. Tidal currents have been known to frequently resuspend benthic diatoms into the water column (Haese et al. 2007, Stoermer and Smol 2001). As a result of this, the density of diatoms within the inner estuary – where tidal currents play a more prominent role – should have been higher as a result of the presence of both pelagic and benthic diatoms. There are a few possible explanations for this discrepancy between expected and actual results. One possibility is that there is a greater degree of euryhaline freshwater species and so the diatoms choose to dominate the areas where freshwater influence is greater. Another explanation is that one or more type of heterotrophic creature is consuming diatoms in large quantities within the inner estuary and keeping their levels down. Also, the confluence of freshwater and seawater could be causing an increase in turbidity within this region. The increase in turbidity would cause the finer sediments to get stirred up and cloud the water. The clouded water limits light available for the diatoms to utilize and therefore hinders their ability to grow and survive in the area.

Zooplankton

The different types of zooplankton found within the samples each offered their own distribution patterns and implications. The variety in results across organism type demonstrates the versatility in behavioral patterns and tolerances that different zooplankton may exhibit within an estuary.

Copepods, for instance, were found to be drastically more abundant during high tidal conditions. This suggests that many of the copepods found in the estuary were flushed in from the sea. In terms of their physiology many of the copepods found were thus likely adapted to the high salinity conditions of coastal waters. The amphipods found, on the other hand, were generally found to be more abundant during low tidal conditions and in the outer estuary. The low tidal conditions and outer estuary both offer less salinity than their counterparts. They therefore point to the possibility that most of the amphipods in the estuary are euryhaline freshwater.

A higher resolution examination of copepods within the study site reveals the presence of calanoids, cyclopoids, and harpacticoids. Although there is no clear preference of site by any of the copepod families, it is clear that harpacticoids were less prevalent in the water column compared to the other groups. This biologically makes sense considering that harpacticoids are primarily benthic organisms (Troch et al. 2008). In order to better understand the harpacticoid distribution within Matapouri a benthic analysis of the site is necessary.

The organization of salp within the estuary was additionally noteworthy. Salp occurred at rather high quantities during high tidal conditions and within the outer estuary. This result is logical considering that salps are marine organisms (Vargas and Madin 2004). The high tide is in this case bringing in the salps from the ocean and concentrating them into the inner estuary where marine conditions are more prevalent. Because salps are known to consume phytoplankton such as diatoms, it is entirely possible that they are helping keep the level of diatoms down to the currently low quantities of the inner estuary. In order to substantiate this conclusion, however, it is necessary to conduct a stable isotope or gut content analysis on salp and determine exactly to what degree they are consuming diatoms within the estuary.

Other Organisms

The barnacle exoskeletons were drastically higher during high tidal conditions. This result biologically makes sense considering that barnacles are marine species. The exoskeletons they shed in coastal waters are brought in by the tide to the estuary. The water currents brought in by the high tide may also be resuspending any exoskeletons deposited within the sediment. It is important to determine what contributions these high protein exoskeletons are making to the estuarine food web. This could be done by performing a gut content analysis on higher trophic organisms and looking for the signatures of the exoskeleton.

Although macroalgae and seagrass displayed no distinguishable trend throughout the estuary, it is important to note that they were found at all locations within the study. This suggests that they make substantial contributions to the entire estuarine food web whether through direct consumption or through the detrital pathway.

Implications and Future Studies

Overall, the results of the study indicate that the planktonic community of Matapouri Estuary is highly dynamic and heterogeneous over a relatively short geographical span and time period. This points to the further need to understand the ecological significance of Matapouri estuary and other mangrove fringed habitats. A few possible future studies to better comprehend the biological structure of Matapouri estuary include stable isotope and gut content analyses to determine the trophic interactions of plankton such as salp and barnacle exoskeletons. Additionally, in order to better quantify diatom and other species composition at different locations within an estuary a sediment rather than water column analysis should be conducted. A sediment sample would contain all of the species that have deposited over the years in a particular location. The plankton tow, on the other hand, is subject to reflect the seasonality of the species and may not be completely representative of the true species composition (Little 2000). Moreover, future studies should be conducted that take into account other factors such as sediment type and water current strength in their analysis. It is important to keep in mind during future studies that a medley of factors, each with its own distinctive role, come together to mold the current estuarine nutrient dynamics.

Conclusion

- The results generally suggest that the habitat preference of many of the planktonic organisms found within the study is partly determined by location with relation to the mouth of the estuary. Moreover, the physiological tolerances of the organisms are highlighted by their relative abundances during the high versus low tide conditions.

- The results point out that further work needs to be done to better understand the ecological importance of mangrove dominated estuaries. Future studies should involve a broader look that examines not only biological diversity within a mangrove fringed habitat, but also the contribution that the ecosystem may make in terms of factors such as pollutant and sediment control.

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