Zooplankton fecal pellets as the primary driver of settling particles in reef systems

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Abstract

Zooplankton fecal pellets are a potentially vital source of nutrients for coral reefs. While zooplankton fecal pellets are recycled relatively quickly in pelagic systems, the shallow nature of reefs means more organic matter from the surface can reach the benthos. Fecal pellets can aggregate together and entrain additional organic matter, aiding in the transference of organic material to reefs. These settling particles can be ingested by coral to supplement their diet and nutrients obtained by their symbiotic algae (zooxanthellae) as coral are known to ingest sediment. Settling particles can provide essential fatty acids to coral reefs such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) which are produced by phytoplankton and repackaged by zooplankton. Through lipid and stable isotope analysis, zooplankton were determined to be primary driver of settling particles in the Upper Florida Keys. Zooplankton fecal pellets most likely help to create a homogenous composition of organic material. As the primary drivers of settling particle composition, zooplankton abundance and composition play a vital role in determining the availability of organic matter and settling particles on coral reefs.

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Background

Settling particles and their associated organic matter are a potentially vital source of nutrients for corals. While settling particles can block out light and reduce the ability of zooxanthellae (the symbiotic algae that live inside coral tissues) to photosynthesize, this primarily occurs in highly turbid environments (Jones et al. 2019; Nugroho et al. 2018; Risk 2014). In areas with low turbidity, settling particles can be ingested by several species of Scleractinia (reef building coral) (e.g. Anthony, 1999; Krueger et al., 2018). Corals must acquire essential fatty acids (EFAs) from their zooxanthellae (Papina et al., 2003) or through their diet (Ferrier-Pagès & Gattuso, 1998). Through both their daily vertical migration and fecal pellets, zooplankton help to deliver organic matter from the upper water column to coral reefs (Heidelberg et al., 2010). The presence of both phytoplankton and zooplankton are vital to the organic matter input to coral reefs as the average daily mass of phytoplankton alone in the Florida Keys can reach 21.4 mg C m^{-3} (Heidelberg et al., 2010). Since Scleractinia have been shown to ingest settling particles, it could be an important source of nutrients, such as essential lipids, fatty acids, and nitrogen, to supplement their diet.

The primary objective of our study was to evaluate the role of zooplankton as a conduit of organic matter to benthic corals through settling particles. We measured the $\delta^{13}C$ and $\delta^{15}N$ of values of settling particles collected from reefs of the Florida Reef Tract. Additionally, fatty acid and lipid biomarkers were measured to determine the origin of organic matter. Through their diurnal vertical migration, zooplankton and their production of fecal pellets are vital to the transferal of organic matter from the water column to the benthos and coral reefs. Our study provides crucial information on the origin of nutrients on coral reefs.

Methods

Figure 1. Location of the Florida Keys within the US

Figure 2. Sampling Locations in the Upper Florida Keys

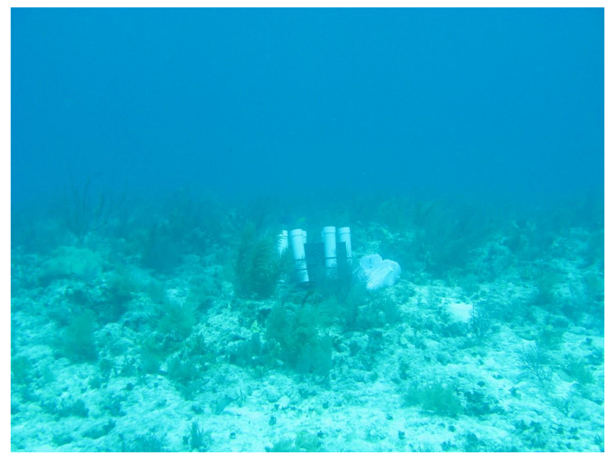


Figure 3. Sediment trap at Offshore South

Sample Collection
- Sediment traps made of PVC pipe following Storlazzi et al., 2011
- 5 traps at each site

Bulk Characteristics
- Filtered through 0.7 µm glass fiber filter
- Half of each filter was used to measure total organic matter (OM) and total inorganic matter (IC)
- $\delta^{13}C$, $\delta^{15}N$, weight percentages of organic carbon and nitrogen measured using an elemental analyzer and stable isotope mass spectrometry

Compound Specific Stable Isotope Analysis
- Stable isotope composition of derivatized individual fatty acids measured using gas chromatography-combustion-isotope ratio mass spectrometry (GC-C-IRMS)

Lipid Analysis
- Extracted using methods described in Teece et al., 2011
- Derivatized lipids measured using gas chromatography – mass spectrometry (GC-MS)

Results

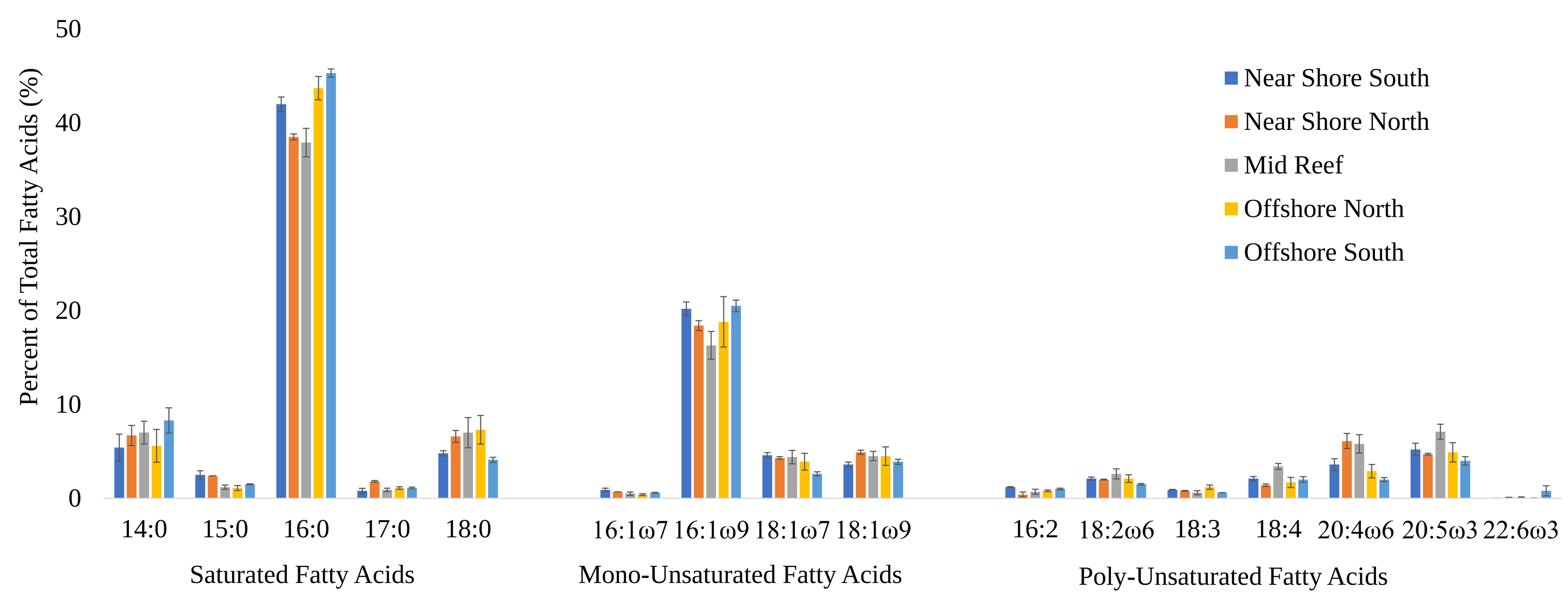


Figure 4. Composition of fatty acids in settling particles (mean of n=5 bars represent standard error)

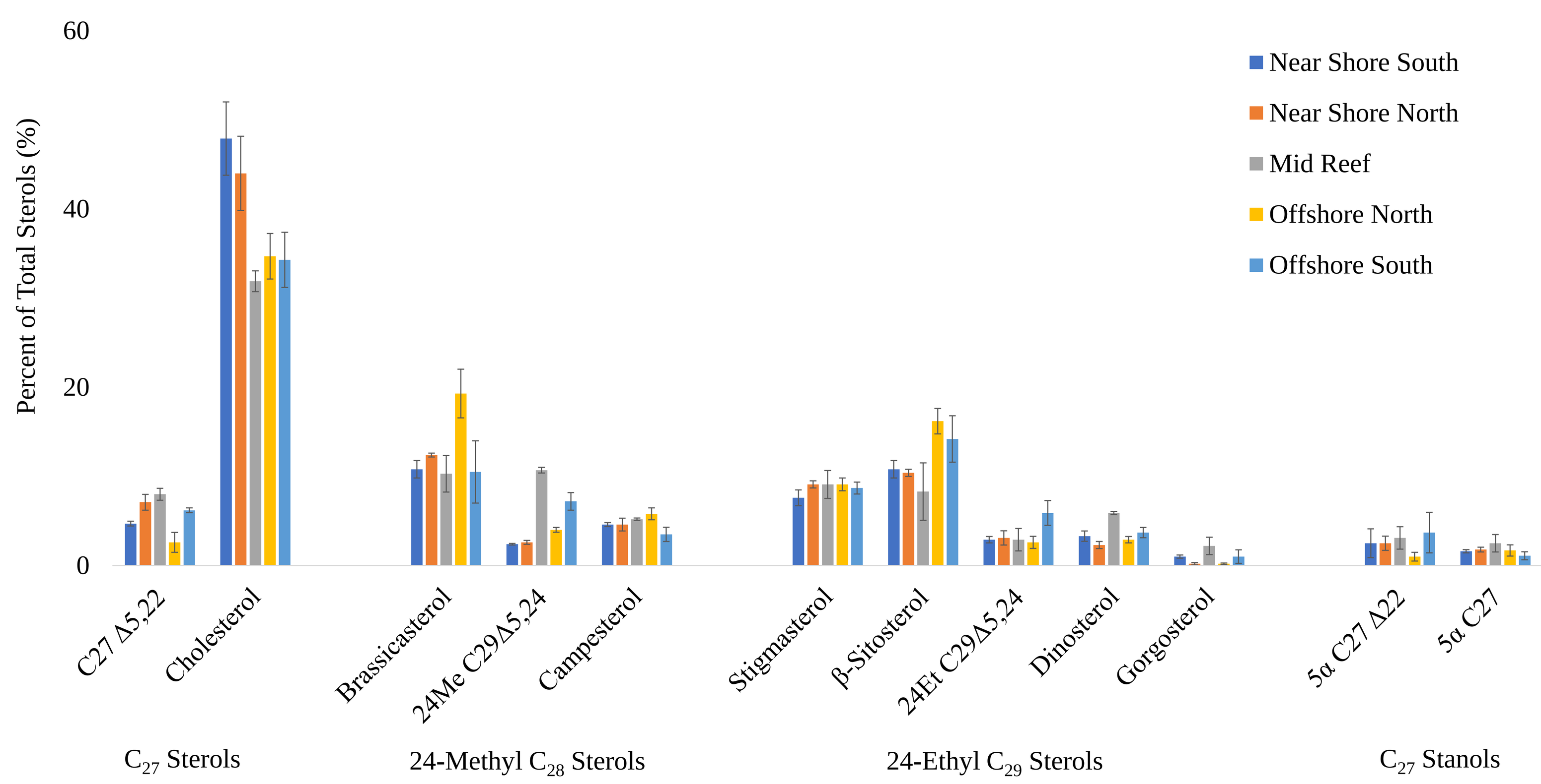


Figure 5. Composition of sterols in settling particles (mean of n=5, bars represent standard error)

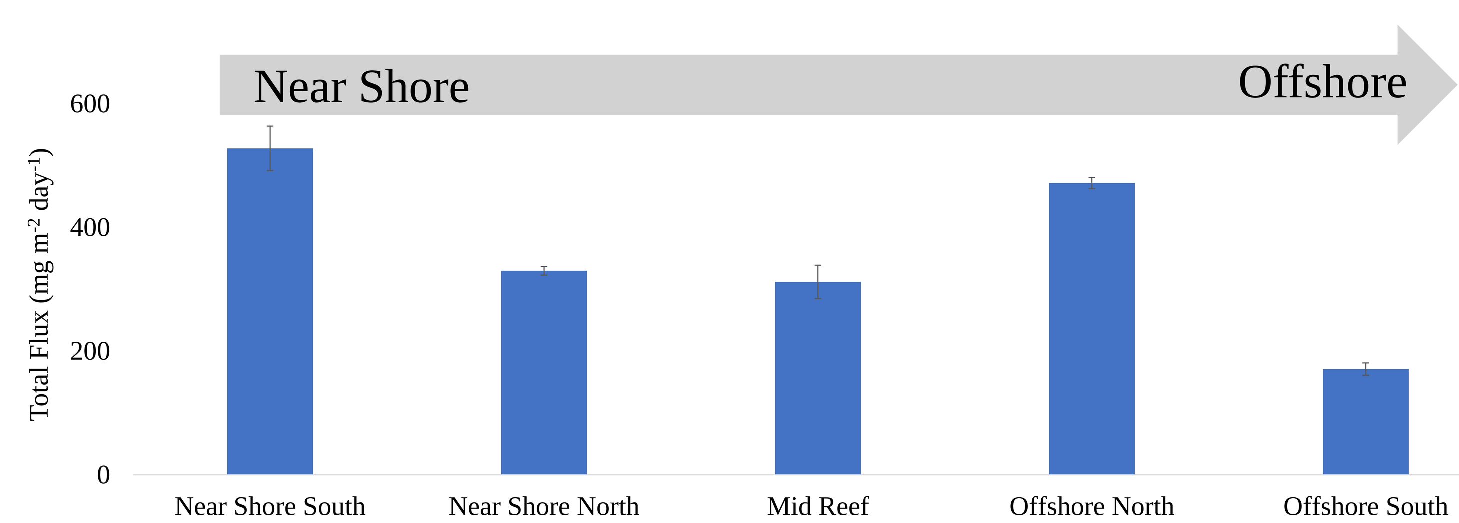


Figure 6. Total sedimenting flux of settling particles (mean of n=5, bars represent standard error)

- Saturated fatty acids (SAFA; 52-58%) were the dominant compounds in all samples with lower amounts of monounsaturated (MUFA; 25-29%) and polyunsaturated (PUFA; 11-20%) fatty acids.
- $\delta^{13}C$ values of individual fatty acids in settling particles spanned a considerable range from -18.8 to -27‰.
- Cholesterol accounted for up to 48% of all sterols.
- All stanols were present in low concentrations (< 3%).
- $\delta^{13}C$ values of all sterols and stanols were lower at the most offshore sites (Mid Reef and Offshore North) compared with the nearshore sites.
- Organic matter and organic nitrogen flux mirrored total flux.
- No significant difference in organic matter and inorganic carbon between sites.

Discussion

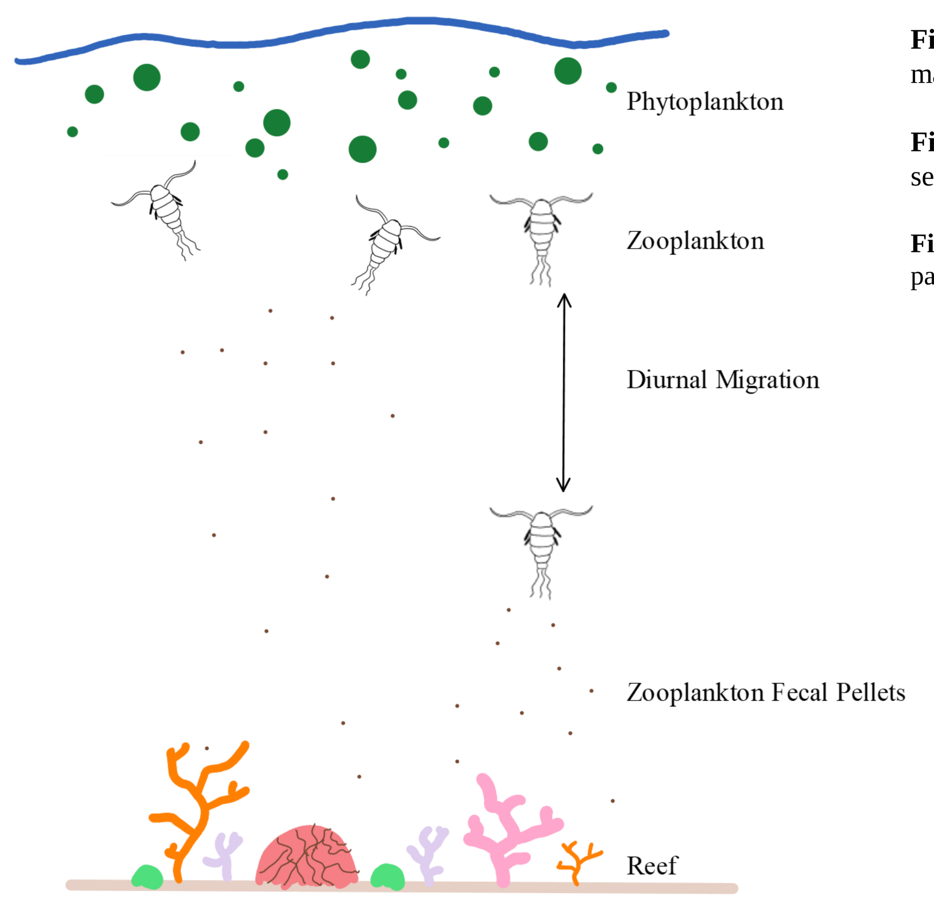
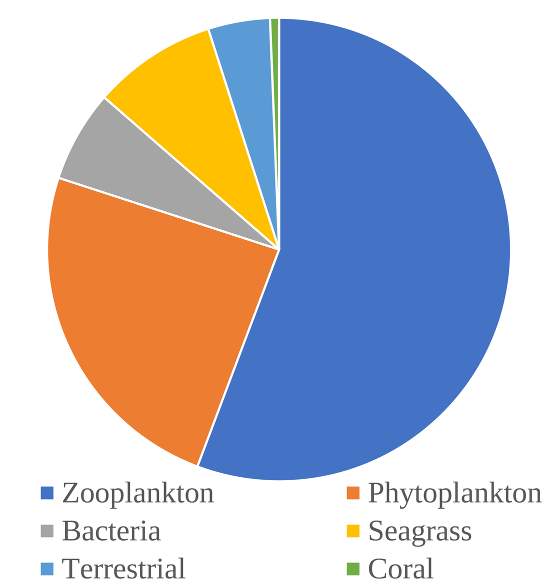
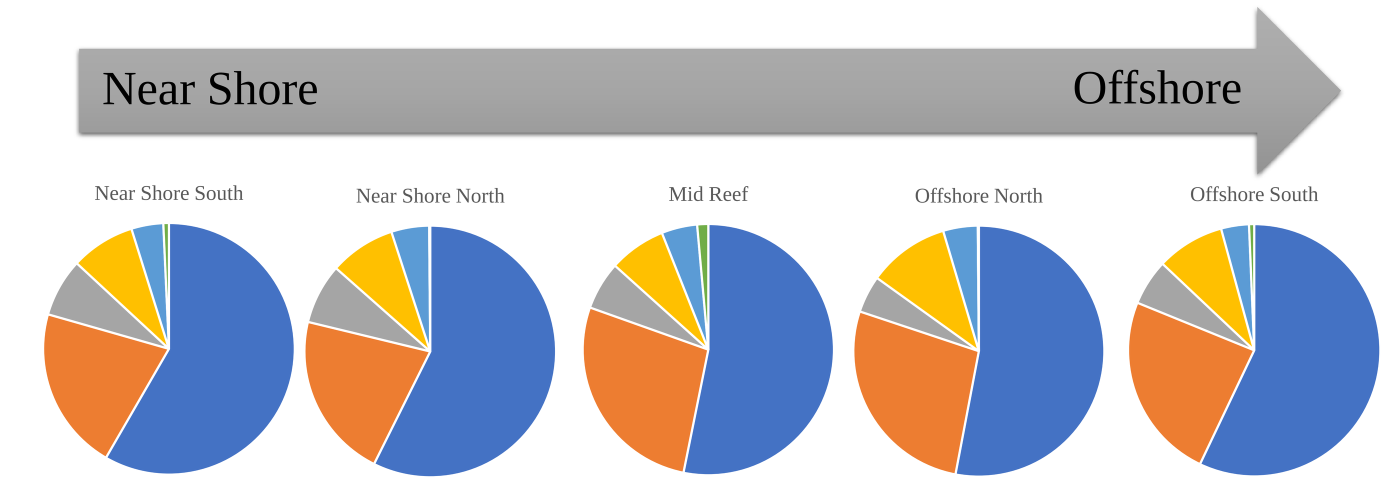


Figure 7 (left). Diagram of the transfer from organic matter from the surface to coral reefs

Figure 8 (right). Average biomarker components of settling particles

Figure 9 (bottom). Biomarker components of settling particles by site





- Zooplankton are the primary component of settling particles
- Compound specific isotope analysis indicates zooplankton as $\delta^{13}C$ values were similar to zooplankton, not phytoplankton.
- Little to no presence of bacteria as there were small concentrations of odd-chain fatty acids and stanols.
- Sterols representing diatoms were constituted 13-23% of total sterols.
- Biomarkers related to vascular plants and macroalage were more common near shore and constituted up to 18% of the total lipids.
- Gorgosterol, the primary indicator of coral and zooxanthellae constituted 0.2-2.2% of the total sterols, demonstrating little contribution to settling particles.
- Of the phytoplankton, known biomarkers of diatoms and dinoflagellates were the most common.
- As the climate continues to change organic matter will be remineralized at shallower depths, reducing the quantity of fecal pellets reaching the benthos.

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