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Review

# Sediment impacts on marine sponges

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ABSTRACT

Changes in sediment input to marine systems can influence benthic environments in many ways. Sponges are important components of benthic ecosystems world-wide and as sessile suspension feeders are likely to be impacted by changes in sediment levels. Despite this, little is known about how sponges respond to changes in settled and suspended sediment. Here we review the known impacts of sedimentation on sponges and their adaptive capabilities, whilst highlighting gaps in our understanding of sediment impacts on sponges. Although the literature clearly shows that sponges are influenced by sediment in a variety of ways, most studies confer that sponges are able to tolerate, and in some cases thrive, in sedimented environments. Critical gaps exist in our understanding of the physiological responses of sponges to sediment, adaptive mechanisms, tolerance limits, and the particularly the effect of sediment on early life history stages.



**Contents**



## 1. Introduction

Although marine organisms naturally experience settling and suspended sediment, there is increasing evidence from across the world that the amount of sediment moving from land-based sources to coastal waters is increasing (e.g. Lohrer et al., 2006; Bannister et al., 2012; Stender et al., 2014; Capuzzo et al., 2015). There are many causes for these increases, but most relate to changes in land use, particularly agricultural intensification and deforestation (Syvitski et al., 2005). These alterations have led to increased sediment loading in riverine systems, which

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subsequently gets transported to the coast. In addition to these terrestrially derived sediment inputs, human activities in the ocean, such as dredging, trawling and seabed mining can also increase the amount of sediment in the water column (Fettweis et al., 2010). Typically this sediment is then deposited back on the seabed, although the finest particles may remain in the water column for weeks (Pineda et al., 2015). Contrastingly, there may be locations where sediment inflows into the marine environment are decreasing, for example where rivers have been dammed (Syvitski et al., 2005). Changes in sediment availability have the potential to exert a strong influence on marine biodiversity and productivity, particularly for benthic organisms, which are strongly influenced by sediment in a number of ways.

Sponges are a major component of sessile benthic communities in temperate, polar and tropical habitats (Lilly et al., 1953; Dayton et al., 1974; Barthel et al., 1991; Bell and Barnes, 2000a; Diaz and Rützler, 2001; Bell, 2007) and have a number of important functional roles in marine ecosystems (Bell, 2008). These roles range from bioeroding calcium carbonate substrate, to filtering large quantities of water and acting as a major link between benthic and pelagic environments (Diaz and Rutzler, 2001; Wulff, 2001, 2006; Bell, 2008). Sponges are suspension feeders and obtain the majority of their food and nutrients from filtering the water column, although many tropical species also rely on photosynthetic symbionts. Sponges predominately feed on particles less than 5 μm, particularly cyanobacteria and heterotrophic bacteria (Pile et al., 1996), which are similar in size to small sediment particles (Bakus, 1968; Bannister et al., 2012). While there is increased interest globally in how changes in suspended and settled sediment influences marine organisms, little is known about how sponges respond to sediment changes. It has been shown that some soft bottom specialist sponge species are highly resilient to sedimentation (Ilan and Abelson, 1995), and in some cases sedimentation has actually been shown to correlate with increased sponge diversity (Bell and Barnes, 2000a). Despite this, sedimentation is thought to have a generally negative impact on sponges (e.g. Gerrodette and Flechsig, 1979; Wilkinson and Vacelet, 1979; Roberts et al., 2006; Tjensvoll et al., 2013). Sediments can adversely affect sponges in a number of ways: (1) through direct ingestion of fine particles, which can block or clog delicate filtering apparatus and impact physiological processes (Bakus, 1968); (2) through scouring of external surfaces by larger sediment particles (Rogers, 1990; Ilan and Abelson, 1995); (3) by increasing turbidity and reducing light penetration, which will impact phototrophic species (Rogers, 1990; Telesnicki and Goldberg, 1995; Lemloh et al., 2009); and (4) by preventing settling larvae from reaching suitable substrate if covered in settled sediment (Maldonado and Uriz, 1999; Maldonado et al., 2008). Given the heightened interest in sedimentation globally, and the increasing recognition of the importance of sponge conservation (see Bell et al., 2015), it is critical to understand the direct and indirect impacts of sediment and the adaptations shown by sponges to tolerate high levels of sedimentation. Here we review the current information on how sediment impacts sponges and the adaptations they show. We also identify the current gaps in our knowledge of the impact sediment may have on these important organisms.

**Table 1**
Summary of the impacts of settled and suspended on different aspects of sponge ecology and physiology.

| Impact | Settled Sediment | Suspended Sediment |
|---|---|---|
| Filtering apparatus & pumping | – Clogging<br>– Reduction or complete arrests in pumping activity | – Clogging<br>– Reduction or complete arrests in pumping activity<br>– Some sponges exhibit ability to recover when sediment is gone |
| Respiration | – Not known | – Reduction due to decrease in pumping to reduce ingestion of sediment<br>– Elevation possibly due to initiation of sediment clearing mechanisms, causing increased metabolic demand |
| Feeding | – Reduction in feeding efficiency following burial by sediment | – Reduction in feeding efficiency |
| Reproduction | – Reduction in spermatocytes and oocytes | – Reduction in proportion of reproducing individuals<br>– Reduction in female to male ratio<br>– Oocyte size and reproductive index reduced.<br>– Reduction in spermatocytes and oocytes |
| Growth | – Growth reduction due to energy expenditure on sediment removal mechanisms | – Weight loss due to reduction in symbiont derived nutrients<br>– Less pronounced negative effects in species with heterotrophic feeding strategies |
| Sponge symbionts | – Cyanobacterial loss in buried tissues<br>– Chlorophyll α concentration reduction | – Higher phototrophic sponge abundance at less turbid offshore sites |
| Larvae | – Not known | – Not known |
| Juveniles | – Increased mortality | – Increased mortality |
| Abundance & diversity | – Variation between studies; reports of increases and decreases in abundance and diversity | – Variation between studies; reports of increases and decreases in abundance and diversity |

## 2. Direct and indirect impacts of sediment

Sediment, through either deposition or suspension, is able to affect sponges through a number of mechanisms (Table 1). The nature and degree to which sediment can have a harmful effect on sponges is not just dependent on the quantity of sediment but also the particle size and mineralogy (e.g. Bannister et al., 2012). Grain sizes range from sand (>63 μm), to fine silt (4-16 μm) and clay (<4 μm) (Leeder, 1982); mineralogy is dependent upon the sediments origin, which is either biogenic, hydrogenic or lithogenic (Biscaye, 1965). Impacts can be loosely divided into those effects that are a direct result of higher suspended sediment concentrations or settled sediment, and those which are indirect.

The clogging of inhalant canals and the aquiferous system by suspended sediments is likely the most important direct impact (Gerrodette and Flechsig, 1979; Tompkins-MacDonald and Leys, 2008). Sponges are obligate filter feeders with little selective control over their filtering intake (Reiswig, 1971a), and are therefore particularly vulnerable to clogging, especially by fine sediments (Bannister et al., 2012). Suspension feeding is the primary source of nutrients for most sponges, therefore clogging can have serious consequences for other biological processes and result in reductions in feeding efficiency (Reiswig, 1971a; Gerrodette and Flechsig, 1979). Smothering by large deposits of sediment can also clog the filtration apparatus of sponges (Ilan and Abelson, 1995). Smothering can be lethal for some small marine infauna (e.g. Peterson, 1985) and has been shown to inflict at least partial mortality on some sponge species (Wulff, 1997). Abrasion is another direct impact; sediment in combination with high water movement can act in an abrasive manner, removing tissue or entire