Supplementary Material

For

Reviews and syntheses: Bioturbation impacts on sediment accretion and erosion in tidal marshes, with implications for carbon burial and sequestration

Leigh-Ann Smit[1,2*], Janine B. Adams[2,3], Gavin M. Rishworth[1,2]

[1]Department of Zoology, Nelson Mandela University, Gqeberha, South Africa

[2]SARChI: Shallow Water Ecosystems, Institute for Coastal and Marine Research (CMR), Nelson Mandela University, Gqeberha, South Africa

[3]Department of Botany, Nelson Mandela University, Gqeberha, South Africa

*corresponding author: s217268250@mandela.ac.za

Supplementary Material

Table S1: Synthesis of literature on bioturbation studies as they relate to sediment accretion and carbon sequestration in tidal marshes

Bioturbator Assemblage	Habitat/Region	Species	Aim of study	Methodology	Main finding	Directional effect	Reference
Process: Sediment erosion and/or accretion							
Infauna	Intertidal mudflat	*Nereis diversicolor,* Oligochaete & Meiofauna	Investigate how the activities of infauna destabilize intertidal sediment	Experimentally reduced the density of infauna by spraying insecticide on the sediment	A decrease in macrofaunal densities resulted in an increase in sediment stability	Negative	De Deckere et al., 2001
Nematode (lugworm)	Sandflats in intertidal zone	*Arenicola marina*	Investigate how the ecological role of lungworms is influenced by increased mud sedimentation	Lungworm and siltation regimes were manipulated in a field experiment	The main ecosystem effect of the lungworm is hydraulic destabilization of the sediment	Negative	Montserrat et al., 2011
Crustacean (crab)	Salt marsh	*Sesarma reticulatum*	Analyse the ecophysical feedbacks from crab burrowing on geotechnical and geochemical properties of soil	Measured biogeochemical properties of soil (redox potential, pH, belowground biomass, shear strength)	Bioturbation significantly changes biogeochemical properties of soil	Negative	Wilson et al., 2012

Bioturbator Assemblage	Habitat/Region	Species	Aim of study	Methodology	Main finding	Directional effect	Reference
Bivalve mollusc (cockle)	Mesocosm set up in a laboratory	*Cerastoderma edule*	Assess the influence of bioturbators on sediment stability	Canal flume experiment	Cockles promote the erosion of surface sediment. The destabilizing effect increases with increased density	Negative	Dairain et al., 2020
Crustacean (crab)	Flume tank in a laboratory	*Sesarma reticulatum* & *Uca pugnax*	Examine the effects of burrowing on sediment surface roughness and erodibility	Laboratory flume experiment	Burrowing and feeding activities increase surface roughness and decrease the shear stress needed for sediment erosion	Negative	Farron et al., 2020
Bivalve mollusc (clam) & Polychaete worm	Intertidal mudflat	*Scrobicularia plana* & *Hediste diversicolor*	Investigate the effect of bioturbators on sediment properties, microbial dynamics and biogeochemical variables	Field manipulation experiments were run where bioturbator abundances were altered	*S. plana* enhanced erosion processes while *H. diversicolor* favoured sediment accretion	Positive and negative depending on species	Morelle et al., 2024
Crustacean (crab)	Intertidal marsh, tidal creeks and open mudflat	*Neohelice granulata*	Investigate how burrowing influences sediment dynamics in different	Field surveys & burrow mimics	*N. granulata* promoting the trapping of sediment in open mudflats and internal	Positive & Negative depending on the salt marsh region	Escapa et al., 2008

Bioturbator Assemblage	Habitat/Region	Species	Aim of study	Methodology	Main finding	Directional effect	Reference
			intertidal habitats		saltmarsh, whereas in the saltmarsh edge, they were increasing sediment removal		
Bivalve mollusc (mussel)	Salt marsh	*Geukensia demissa*	Quantify the effect of mussels on salt marsh accretion	Field surveys and field experiments	*G. demissa* contributes to vertical accretion in salt marshes, thus contributing to the sediment budget	Positive	Crotty et al., 2023
Crustacean (crab)	Mangrove and salt marsh	/	Analyse variation in surface elevation, accretion and mangrove growth over time	Structural equation models	Gains in surface elevation are dependent on biological factors related to frequency of bioturbation, plant cover, and species composition	Neutral to positive	Bennion et al., 2024
Process: Carbon sequestration							
Crustacean (crab)	Salt marsh	/	Measure the effect of burrowing on the production and decomposition	Field experiment	Burrows enhance sediment oxygenation, which stimulates microbial activity and accelerates	Negative	Montague, 1982

Bioturbator Assemblage	Habitat/Region	Species	Aim of study	Methodology	Main finding	Directional effect	Reference
			of organic carbon		metabolic processes		
Crustacean (crab)	Mudflat	*Chasmagnathus granulatus*	Examine how burrowing activities contribute to the cycling and storing of organic matter	Sampled crab densities and used satellite images	Burrows of *C. granulatus* act as organic matter sinks, influencing the nutrient cycling and increasing carbon sequestration	Positive	Botto et al., 2006
Crustacean (crab)	Salt marsh	*Chasmagnathus granulatus*	Evaluate how crab burrowing activities influence carbon availability in surface sediments of salt marshes	Field experiment using burrow mimics	Ecosystem engineering by crabs that burrow cause a net loss of carbon concentration in surface sediment resulting in a decrease in the amount of carbon	Negative	Gutiérrez et al., 2006
Crustacean (crab)	Salt marsh and mudflat	*Helice tridens tientsinensis, Sesarma dehaani, Sesarma plicata & Uca arcuata*	Assesses the combined effects of crab excavation burrow mimic trapping on the turnover of sediment and	Field surveys	Burrowing crabs enhance sediment turnover and promote the movement of carbon and nitrogen, while	Negative	Wang et al., 2010

Bioturbator Assemblage	Habitat/Region	Species	Aim of study	Methodology	Main finding	Directional effect	Reference
			distribution of carbon		decreasing soil bulk density.		
Crustacean (crab)	Creek bank habitats in marsh	/	Examine the impact of trophic shifts on substrate stability, habitat loss, and carbon loss	Field surveys, manipulative experiments and GIS analysis	Burrowing by crabs weakens the peat base of marshes and hinders marsh accretion, and leads to a loss of sequestered carbon	Negative	Coverdale et al., 2014
Crustacean (crab)	Mangrove	/	Investigate the effects of macrobenthos on sediment organic carbon storage	Field surveys & radiocarbon dating	Burrowing crabs enhance sediment carbon storage by facilitating the burial of organic matter	Positive	Andreetta et al., 2014
Crustacean (crab)	Salt marsh	/	Assess whether benthic metabolism, and the amount, distribution and bioavailability of organic matter in the sediment is affected by crab bioturbation	In situ experiments manipulating crab and burrow densities	The quality, distribution and bioavailability of sedimentary organic matter is changed by bioturbation. Overall benthic metabolism and flux of dissolved organic matter is enhanced and carbon storage capacity is reduced	Negative	Fanjul et al., 2015

Bioturbator Assemblage	Habitat/Region	Species	Aim of study	Methodology	Main finding	Directional effect	Reference
Crustacean (crab) & Polychaete worm	Estuary	*Macrophthalmus japonicas* & *Perinereis aibuhitensis*	Quantify the effects of the mud crab and clamworm on the migration of organic carbon	Indoor experiment using a microcosm system	These macrobenthos accelerated the mineralization of organic matter in the sediment and promoted the release of organic carbon	Negative	Nie et al., 2021
Livestock	Salt marsh	/	Quantify carbon stocks and sequestration rates in grazed versus nongrazed plots	Field surveys	Grazing by livestock has a neutral to positive effect on carbon sequestration	Neutral to Positive	Graversen et al., 2022
Crustacean (crab)	Salt marsh, mangrove and mudflat	/	Evaluate the effect of burrowing crabs on nutrient stocks, ecosystem functions and sediment properties	Systematic meta-analysis	Burrowing crabs accelerate the rate of nutrient cycling, but the magnitude and direction of the effects of burrowing crabs depends on the crab superfamily, the presence of vegetation and the interaction	Positive	Rinehart et al., 2024

Bioturbator Assemblage	**Habitat/Region**	**Species**	**Aim of study**	**Methodology**	**Main finding**	**Directional effect**	**Reference**
Crustacean (crab)	Salt marsh	*Sesarma reticulatum*	Quantify how *S. reticulatum* influences carbon fluxes, stocks and recovery	Field surveys and remote sensing	*S. reticulatum* caused a loss in carbon stocks	Negative	Wittyngham et al., 2024