



# Morphodynamic Thresholds for Seagrass Restoration

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**Abstract.** This work addresses a critical challenge in the restoration of seagrasses along the Adelaide metropolitan coastline's nearshore areas. While improved nutrient management has created conditions favorable for seagrass growth in previously depleted zones, bed sediment movement and mobility remain a barrier to natural seagrass recovery. Consequently, determining the hydrodynamic tolerance thresholds of seagrasses is crucial to effectively guide restoration efforts.

Hydrodynamic (1 year of wave height and period from pressure sensor measurements) and morphological data (24 years of annual beach and nearshore profiles), as well as 40 years of wave hindcast modelled data were obtained at Grange Beach (South Australia) where seagrass recruitment (mostly *Posidonia angustifolia*) is naturally occurring, from which near-bottom orbital velocities and Depth of Closure (DoC) were calculated. Results indicate that wave-driven orbital velocities varied between 9.5 cm/s during modal conditions and 87.05 cm/s during the 99.5% exceedance conditions. The blue line (zmin, or the upper limit of seagrass presence) corresponds with the outer DoC<sub>out</sub> position. At Grange, seagrasses withstand storm conditions that produce higher orbital velocities than those suggested by the literature in the Mediterranean Sea. However, for seedlings, this threshold is substantially lower than that observed during storm events. This difference suggests that successful recruitment would have required a window of one or more years of low wave energy- conditions that coincidentally occurred in the region during a decade of drought that began in the early 2000s.

**Keywords:** Seagrass recruitment · Sediment dynamics · DoC · orbital velocity

## 1 Introduction

Identifying and describing the hydrodynamic tolerance thresholds of seagrasses is essential for informing restoration efforts [1]. For instance, wave-driven orbital velocities have been identified as a key factor determining the upper limit “zmin” (or the shallowest, most landward boundary) for the distribution of seagrass species such as *Posidonia oceanica* [2]. The Depth of Closure (DoC) is the depth where wave action and nearshore profile changes becomes negligible, and it is suggested to be related to zmin as the

limit where sediment erosion and burial becomes tolerable for seagrass communities [2]. This study addresses a critical issue in managing seagrass restoration projects, using the Adelaide metropolitan coastline, in South Australia, as a case study. Here we test the prediction that (i) the seagrass meadow line coincides with the DoC and (ii) where seagrasses are naturally recruiting, wave-induced orbital velocities that drive sediment transport/movement and seabed instability are below a threshold and seagrass, once established, can therefore persist.

## 2 Methods

The selected study site is Grange Beach, on the Adelaide Metropolitan Coast in Gulf Saint Vincent, South Australia (Fig. 1), where seagrass recruitment is naturally occurring [3]. In order to measure wave conditions impacting the sparse emergent seagrass meadow, a RBRsolo3 D/wave logger was installed at approximately 4 meters water depth (Fig. 1) with a sampling rate of 2048 pressure readings every 10 minutes at 16Hz.

The near-bottom orbital velocity  $u_b$  was determined following linear wave theory and applied for calculations of  $u_{b_{\text{modal}}}$  and  $u_{b_{99.5}}$ , using modal and 99.5% exceedance wave parameters, respectively.

Depth of Closure (DoC) was calculated [4] for ‘inner’  $\text{DoC}_{\text{in}}$  and ‘outer’  $\text{DoC}_{\text{out}}$  based on wave parameters that were extracted from a 40 years hindcast wave model [5]. DoC approximations were compared with coastal profiles measured annually by the Department of Environment and Water (DEW) since 1970 (shown from 2000 here, see Figure 1).

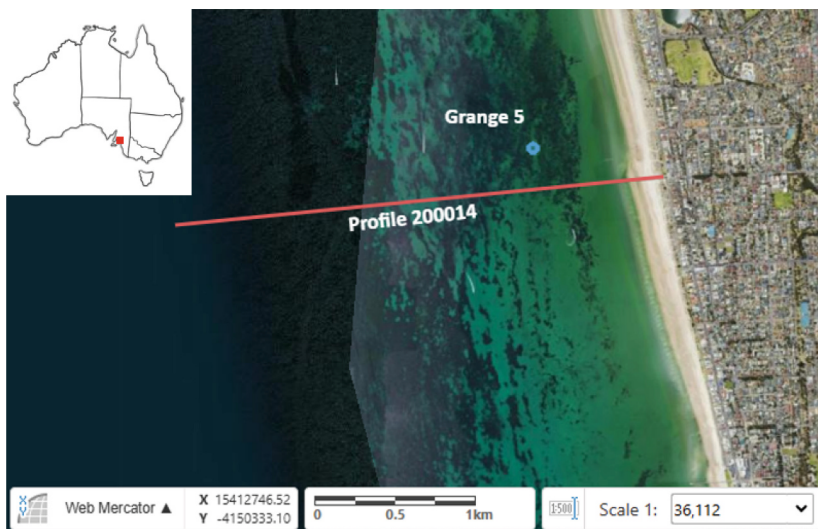


**Fig. 1.** Study site (Grange Beach) in Gulf Saint Vincent, South Australia, and location of RBR pressure sensor (Grange 5) and the beach/nearshore profile monitored by DEW annually since 1970.

### 3 Results and Discussion

Our results show that wave-driven orbital velocities varied between 9.5 cm/s during modal conditions and 87.05 cm/s during the 99.5% exceedance conditions. The position of the inner and outer DoC are validated by the long-term coastal profiles, and  $z_{min}$  corresponds with the  $DoC_{out}$  position (Fig. 2).

At Grange, seagrasses (mostly *Posidonia angustifolia*) can withstand storm conditions that produce higher orbital velocities than the storm generated threshold  $u_b$  of 80 cm/s for *P. oceanica* meadows in the Mediterranean [6].  $DoC_{out}$  is a good predictor of the blue line position ( $z_{min}$ ), suggesting that in Grange, seagrass growth is limited by hydrodynamics only.

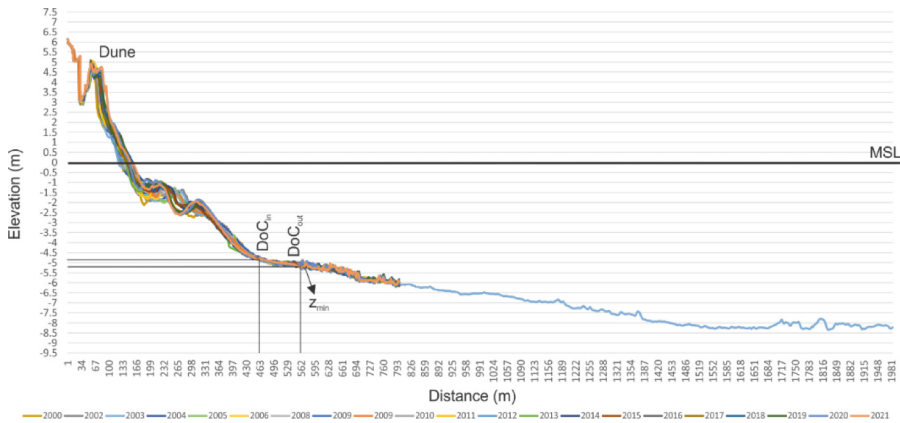


**Fig. 2.**  $DoC_{in}$  and  $DoC_{out}$ , and blue line ( $z_{min}$ ) along annual beach and nearshore profiles in Grange.

Seagrass seedlings have a much lower hydrodynamic threshold and would not recruit in  $u_b > 18$  cm/s [7]. In our study site at Grange, storm  $u_b$  are more than four times this threshold, suggesting that recruitment would have required a window of opportunity of low wave energy, which occurred in the region during a decade of drought that started in the early 2000s (Fig. 3). The combination of sustained (~10 years) low wave energy and reduced input of wastewater, stormwater and fluvial discharge into Gulf Saint Vincent could have supported natural recruitment of seagrasses.

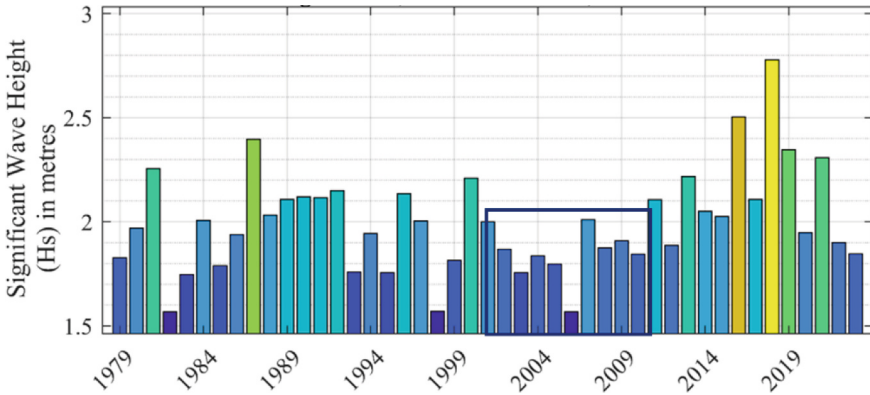


**Fig. 3.** Annual maximum Hs (m) offshore Grange Beach, indicating a sustained period of relatively low wave energy (navy box) [8].

## 4 Conclusion

Our study improves an understanding of the critical hydrodynamic tolerance thresholds for seagrasses. Our findings indicate that the inshore seagrass meadow-bare sand line (the so-called ‘blue line’) coincides with the Depth of Closure (DoC). In areas where seagrasses are naturally recruiting, the storm wave-induced orbital velocities are above the threshold for seedling recruitment, suggesting that recruitment would have required a few years of low wave energy, which occurred in the region during a decade between 2000 to 2010. These findings provide essential insights for seagrass restoration efforts, especially along the Adelaide metropolitan coastline in South Australia.

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