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Seagrass Meadows Provide 3D Habitat for Reef Fish

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For large fishes, seagrass canopies typically provide a relatively flat habitat on seabeds, but seagrasses in the genus *Posidonia* can provide additional habitat complexity by forming organic-rich deposits known as mats. Erosional processes can scour channels through the mats, resulting in the formation of escarpments with caves. Here we report that reef fishes, such as groupers, inhabit the caves found within mat escarpments. The characteristics of the cavities are highly variable, ranging from small-elongated holes to deep caves with large entrances. The origin of these caves (biological and/or geological) is unknown, but it is possible that fish behavior enhance their formation. *Posidonia* seagrass escarpments provide a complex 3D habitat for reef fish that is not provided by typical canopy structure of seagrass. Further studies are required to gain insights into the natural history of seagrass escarpments and their ecological importance.

Keywords: *Posidonia*, biodiversity, fish ecology, behavior, Mediterranean Sea, Indian Ocean

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Seagrass canopies typically provide a relatively uniform habitat on the seabed, which is not suitable for large reef fishes. However, seagrasses in the genus *Posidonia* can modify bottom bathymetry through vertical plant growth and sediment accumulation, resulting in organic-rich deposits known as mats (Pérès and Picard, 1964; Mateo et al., 1997). Erosional processes can scour channels through the mats, resulting in the formation of 1–3 m high and up to 500 m long escarpments (Serrano et al., 2016; **Figure 1**). Previous studies also reported the presence of blowouts in *Thalassia testudinum* meadows, consisting of bare areas with an eroding edge that forms a vertical wall with overhanging seagrass roots and rhizomes (Patriquin, 1975; Wanless, 1981; Maciá and Robinson, 2005).

The mechanisms behind escarpment formation can be related to natural processes (e.g., wave action, tidal flow, and hurricanes) or to anthropogenic activities, such as dredging, vessel groundings, and propeller scars (Whitfield et al., 2002). Mat escarpments have been described in shallow and highly productive *P. oceanica* meadows from the Mediterranean Sea, *P. australis* meadows from the Indian Ocean (Serrano et al., 2016), and in *T. testudinum* meadows from the Caribbean exposed to strong wave action (Patriquin, 1975; Wanless, 1981). In *Posidonia* meadows, the inter-twined remains of seagrass tissues consolidate the sandy substrate, holding together the exposed face of the seagrass escarpment and maintaining a semi-rigid, 3D structure, in which caves are found. This phenomenon is unusual but of ecological importance due to its role as habitat for exclusively reef fish species (**Figure 2**).

During a routine field trip to monitor seagrass meadows at Shark Bay (Western Australia), we discovered that escarpments supported abundant reef fish assemblages. Caves (up to ~1 m³) found throughout mat escarpments were occupied primarily by groupers (*Epinephelus coioides*, Serranidae), with up to 10 individuals (30–100 cm in length) observed in a single

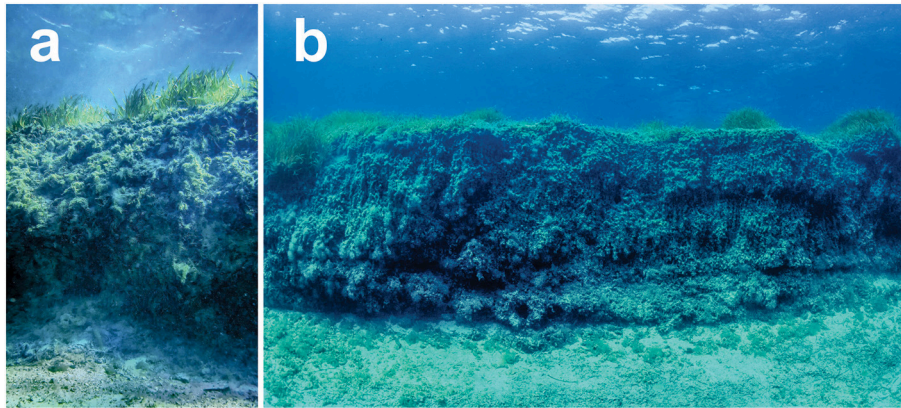


FIGURE 1 | Erosional mat escarpments in seagrass *Posidonia* meadows. (a) *Posidonia australis* mat escarpment in Shark Bay, Western Australia (-25.796563° , 113.460218° ; Indian Ocean). (b) *Posidonia oceanica* mat escarpment in Es Pujols Cove, Balearic Islands (38.727964° , 1.456189° ; Mediterranean Sea).

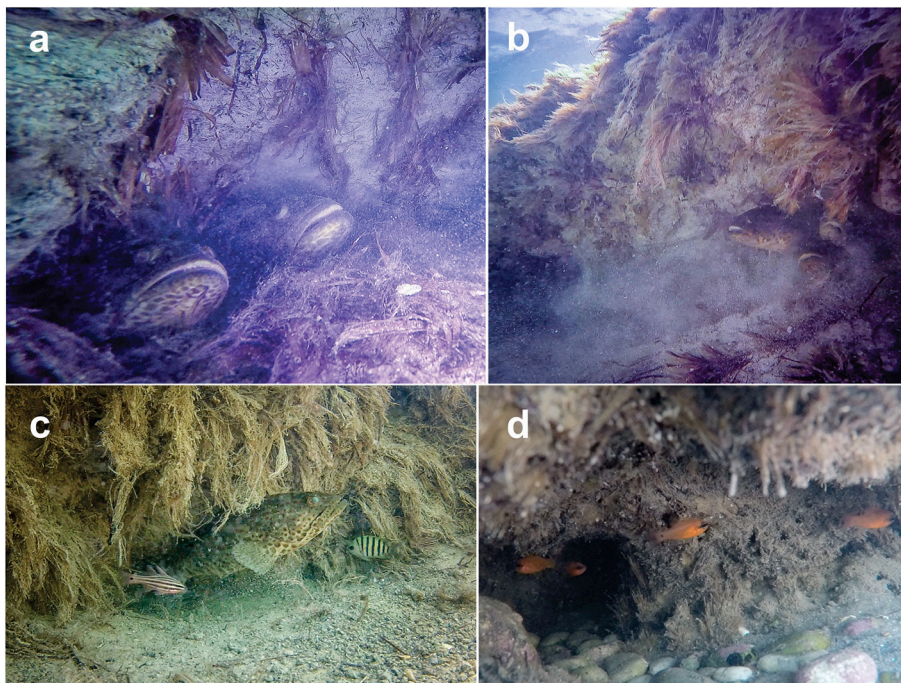


FIGURE 2 | Reef-associated fish inhabiting caves within seagrass mat escarpments. (a–c) *Epinephelus coioides*, *Apogon angustatus*, and *Abudedefduf bengalensis* inhabiting caves within *Posidonia australis* mat escarpment in the Indian Ocean (Shark Bay, Western Australia). (d) *Apogon imberbis* inhabiting caves within *Posidonia oceanica* mat escarpment in the Mediterranean Sea (Balearic Islands).

cave (Figure 2 and Supplementary Video 1). Other reef-associated fish found within the escarpment included sea perches (*Psammoperca waigiensis*, Latidae), cardinalfishes (*Apogon angustatus* and *A. cavitensis*, Apogonidae), bengal sergeants (*Abudedefduf bengalensis*, Pomacentridae), and sea chubs (*Microcanthus strigatus*, Kyphosidae) (Figure 2 and Supplementary Video 1). A similar fish assemblage was observed in reef habitat but not in seagrass canopies nor in unvegetated sand at Shark Bay. Life-time observations made

by the authors revealed that mat escarpments in *P. oceanica* meadows are also occupied by reef-associated fish such as scorpionfishes (*Scorpaena porcus* and *S. scrofa*, Scorpaenidae), groupers (*Epinephelus marginatus* and *E. costae*, Serranidae), cardinalfishes (*Apogon imberbis*, Apogonidae), brown meagres (*Sciaena umbra*, Sciaenidae), seabreams (*Diplodus sargus*, Sparidae), and wrasses (*Labrus viridis*, *L. merula*, *Symphodus tinca*, Labridae) (Figure 2 and Supplementary Video 1).

In both *P. oceanica* and *P. australis* mat escarpments we found several burrows in the form of cavities inhabited by reef fish. The form, shape, and dimension of the cavities were highly variable, ranging from small-elongated holes to deep caves with large entrances. The process(es) forming these caves (biological and/or geological origin) is unknown, but it is possible that displacement of sediment by fish (i.e., swimming action and/or deliberate digging or burrowing) leads to, or enhances, their formation, as described in other unconsolidated sandy substrates (Mueller, 2015).

Seagrass meadows provide valuable ecosystem services (Green and Short, 2003) and are ecologically important as they provide habitat and shelter for juvenile fish and larval recruitment (Hemminga and Duarte, 2000; Borg et al., 2006; Prado et al., 2009), maintaining high biodiversity, while providing shoreline protection against erosion (Green and Short, 2003), and sequestering carbon (Fourqurean et al., 2012), among others. The ecosystem services provided by seagrass meadows greatly vary among habitats due to biotic and abiotic factors, and in this study we provide evidence of a novel function of *Posidonia* escarpments, through provision of complex 3D habitat for reef fish that is not provided by typical canopy structure of seagrass.

Further studies are required to gain insights into the natural history of seagrass escarpments and their ecological importance. Firstly, there is need to report and map additional seagrass escarpments within *Posidonia* meadows (Serrano et al., 2016) and other seagrass ecosystems worldwide, including *T. testudinum* meadows in the Caribbean region. Secondly, further research is required to understand the mechanisms of escarpment and

cave formation, including testing the hypothesis of cavities within the escarpment originated by fish behavior, and describe their size and dimension. Finally, there is a need to demonstrate the ecological importance of seagrass escarpments as reef fish habitat, enhancing fish biodiversity and biomass, and their importance for reproduction, predator avoidance and feeding areas, among others.

ETHICS STATEMENT

The Ethics Committee of Edith Cowan University has approved this study – Project 17297.

AUTHOR CONTRIBUTIONS

OS: Conceived the manuscript. All authors critically revised and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <http://journal.frontiersin.org/article/10.3389/fmars.2017.00054/full#supplementary-material>

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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