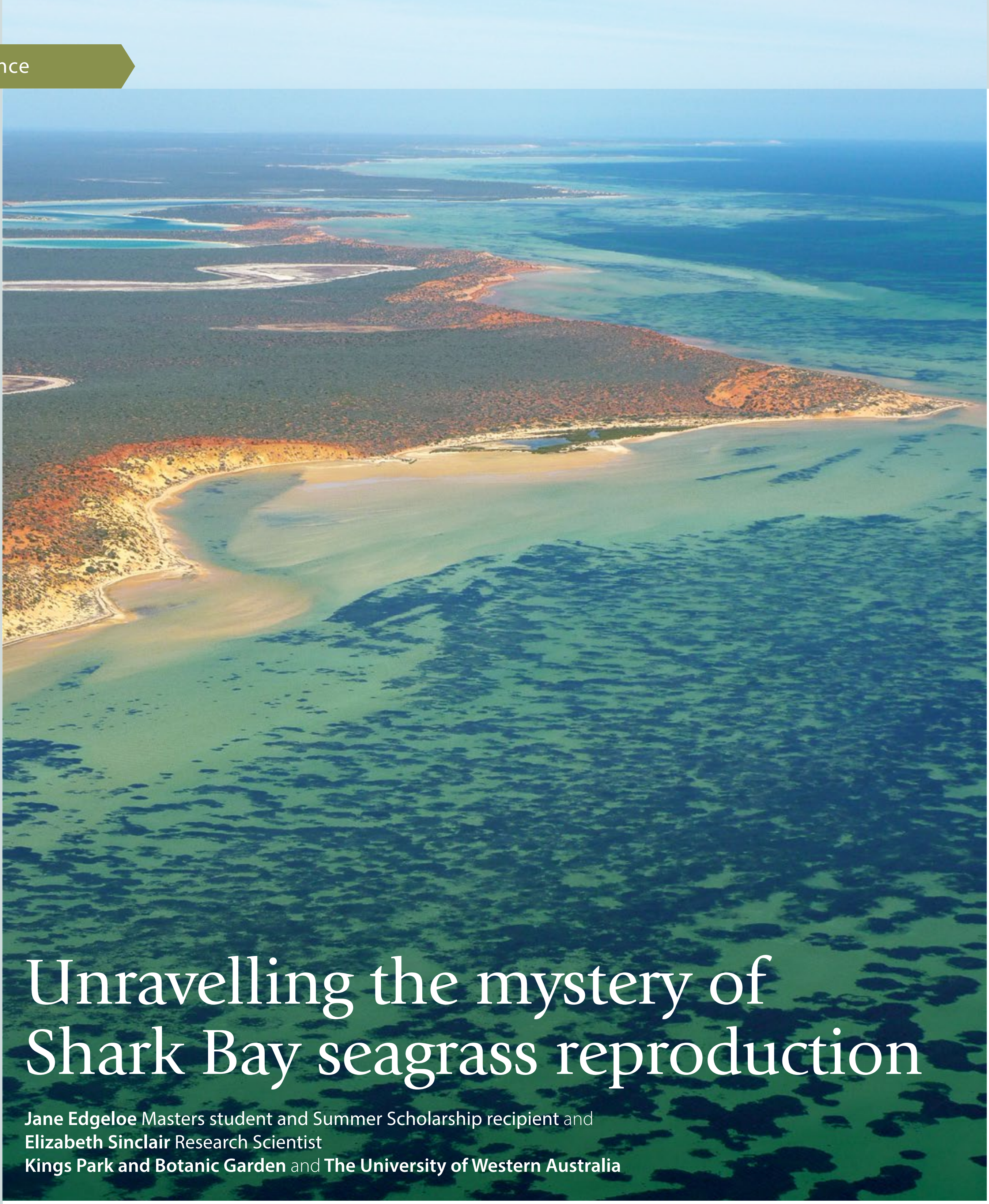

Unravelling the mystery of Shark Bay seagrass reproduction

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Red earth, sandy beaches and turquoise water contrast with the dark patches of seagrass in Shark Bay. Photo: Angela Rossen

Shark Bay, also known as Gatharragudu (two-waters) by the Malgana Traditional Owners, is a pristine ecosystem of global significance. The largest temperate seagrass meadows on the planet create a unique environment within the bay which supports the oldest living organisms – stromatolites.

The bay's 13 species of temperate and tropical seagrasses provide food and habitat for dugongs, turtles and sharks, as well as many fish species. The seagrass meadows also store large amounts of carbon in their rhizomes below the sandy seafloor and maintain the stunning, crystal-clear waters by trapping free-floating sediment in their leaves.

Ironically, human activities including the burning of ancient plant material (fossil fuels) are heating the planet, including the world's oceans. An extreme heatwave during the summer of 2010/2011 impacted both the terrestrial and marine ecosystems, with over a third of the estimated 4000 km^2 of seagrass meadows dying or damaged. The loss of this marine habitat continues to impact some species.

Shark Bay was formed 7000 to 8000 years ago with rising sea levels. It is an expansive, shallow estuary with a permanent salinity gradient, with salinity increasing towards the southern end.

Seagrasses are responsible for the creation of the Wooramel Banks, which greatly reduce water flow into Hamelin Pool. This creates a hypersaline environment which ironically becomes unsuitable for seagrasses, but one in which stromatolites thrive.

The *Posidonia* meadows within Shark Bay are at the northern most edge of their distribution. Populations that live at the edge of their species range are typically small, fragmented with low genetic diversity and limited connection to other populations.

Edge populations are often living at the limit of their thermal tolerance, so are also most at risk of extinction from changing climate. However, they are also more likely to be better adapted to warming environments.

An extreme marine heatwave in 2010/2011 caused extensive die-off of the large temperate seagrasses. Valuable scallop and blue swimmer crab fisheries were closed and sea snakes, dolphins and culturally significant species, such as green turtles, dugongs and cormorants, experienced large declines in populations (Kendrick *et al*. 2019).

Some of the *Posidonia* meadows subsequently flowered and produced fruit, but none of the seeds developed to maturity. It has taken six years to observe natural recovery of *Posidonia* shoots, but this recovery is likely driven through vegetative growth, rather than from new seedlings. (Kendrick *et al*. 2019).

Flowering and fruiting are naturally very patchy across Shark Bay. We assessed flowering and fruiting in three meadows (Guischenault Point, Red Hill Bay, Fowlers Camp) and collected approximately 30 adult (maternal) shoots and flowering stems with mature fruit.

Posidonia **seagrass meadow. Photo: Angela Rossen**

Maturing *Posidonia australis* inflorescences emerge above the leaf canopy. Male (red anthers) and female (stigma) parts are present on the same flower. Photo: Angela Rossen

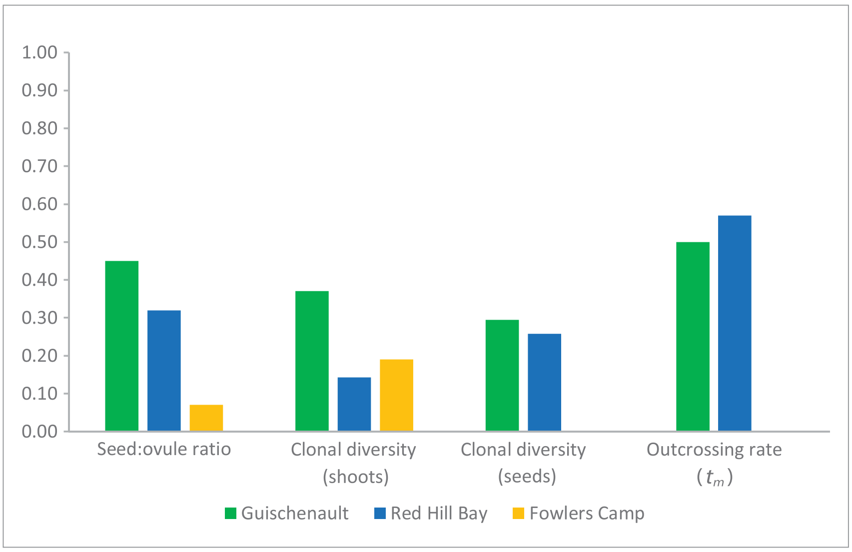
Each fruit contained a single continuously growing seed. DNA was extracted from the maternal shoots and seeds. We generated genetic 'fingerprints' using seven DNA markers. This enabled us to determine how many different plants were flowering and whether the seeds were the result of pollination between different plants (outcrossed pollination).

Guischenault Point had the highest proportion of successful pollination events (seed:ovule ratio). It also had the greatest number of plants flowering (clonal diversity in maternal shoots) resulting in a higher proportion of genetically different seeds (clonal diversity in seeds).

Genetic estimates of the outcrossing rates (t_m) showed that about half of all seeds were due to pollen from different plants. The fruit from Red Hill Bay were small, some of the seeds were misshapen and there was an unusually high abortion rate (~14%). Fowlers Camp meadow had lots of flowering stems from different plants, but no fruit was collected.

The *Posidonia australis* from Shark Bay therefore had a mixed mating system (seeds resulting from outcrossed pollination and self-pollination) which shows a shift from complete outcrossing which was reported in genetically diverse meadows across Perth metropolitan waters (Sinclair *et al.* 2014).

Flowers in Guischenault Point and Red Hill Bay may be exposed to a large amount of local pollen through strong tidal flows. However, overall genetic diversity was low and outcrossing rates were lower because pollen was produced by fewer plants, leading to more self-pollination (or apomixis, the asexual formation of a seed from the maternal tissues of the ovule).



Seed:ovule ratio and estimates for genetic diversity in three flowering *Posidonia australis* meadows in Shark Bay.

The mixed mating system is likely driven by a combination of pollen limitation and local environmental conditions.

So, what does this mean for restoration of damaged meadows in Shark Bay?

Tackling restoration in warming range edge populations presents challenges including low seed numbers. Our collaboration with the Malgana Traditional Owners involves trialling transplanting and seeding methods, which will assist nature-based solutions to climate-change related seagrass loss.

Seeding methods include the collection of floating fruit and re-dispersal of seeds into targeted areas. Transplanting methods are similar to land-based gardening, planting seagrass cuttings into exposed sandy areas. Our genetic data guides where the transplants and seeds should be collected from.

We suggest that collecting transplants or seeds from multiple flowering meadows may increase outcrossed pollination and seed production in restored areas, which in turn may assist recovery through natural recruitment in the future. ■

Transverse section through mature *Posidonia* fruit showing (left to right) viable, misshapen and aborted embryos. Scale: one square = 1 cm. Photo: Elizabeth Sinclair

Additional reading

Kendrick GA, Nowicki RJ, Olsen YS, Strydom S, et al. (2019) A systematic review of how multiple stressors from an extreme event drove ecosystem-wide loss of resilience in an iconic seagrass community. Frontiers in Marine Science 6:455

Sinclair EA, Gecan I, Krauss SL, Kendrick GA (2014) Against the odds: complete outcrossing in a monoecious clonal seagrass. Annals of Botany 113:1185-1196

Lost in a cloud of sandy sediment, scuba diver Rachel Austin with a *Posidonia australis* transplant highlights just how much sediment can be disturbed when seagrass cover is lost. Photo: Martin Breed