Embracing a dynamic view of “pristine” seagrass meadows in the wake of successful green turtle conservation

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Abstract

What was “pristine” in the coastal oceans? The idea that climax vegetations represent a more natural past is increasingly being called into question. Thanks to concerted conservation efforts, recent decades have seen a remarkable recovery of multiple green turtle (*Chelonia mydas*) populations in the world's oceans. These returning populations feed on tropical seagrasses and radically transform meadows from continuous stretches dominated by climax species to patchy multi-species complexes that change in space and time. A dynamic spectrum of ecosystem states should replace climax meadows as reference states in management plans, thus acknowledging risks of meadow collapse and enabling their management.

Main Text

An idealised conception of the pristine pervades ecological and conservation thinking, and is typically influenced by a forest-centred view of nature [1]. The (mis-)conception of forests as "pristine" state and savannahs as "degraded" has a marine equivalent in seagrass meadows. Meadows composed of large, slow growing climax seagrass species are considered healthy, while meadows with fast-growing pioneer seagrass species are considered disturbed or in decline. This view inadvertently neglects the role that megaherbivore grazing played in the past [1] and reflects a much more recent functioning of seagrass meadows, long after their principal megaherbivores (turtles and sirenians) became ecologically extinct [2]. Here we document the dynamic stages meadows undergo as a result of megaherbivore-seagrass interactions and propose them as a novel baseline against which to evaluate effective management.

Recently, green turtles (*Chelonia mydas*), the large-bodied marine herbivores that feed on seagrass, have seen significant population increases following centuries of low abundance. This has resulted in locally dense aggregations of green turtles in their seagrass foraging grounds. Their dramatic impact on seagrass seascapes is evidenced at five green turtle feeding grounds in the Indian Ocean, Pacific Ocean, Atlantic Ocean and the Caribbean and is schematized in Fig.1. At low turtle densities, green turtles feed on competitively dominant, long-lived seagrass, selectively foraging on nutritious young leaf tissue. As grazing increases, turtles create specific grazed areas within the meadow that they revisit and repeatedly graze, maintaining high nutrient intake (described as ‘rotational grazing; [3]). Grazing increases plant nutrient content [4], and although productivity may initially increase [5] it declines when grazing intensifies and/or prolongs [3,5]. Upon sustained grazing, rotational grazing shifts towards random grazing while seagrass pioneer species gradually replace climax species [3,6]. Ultimately, pioneer shoot densities will decrease too, and turtles resort to digging up rhizomes, targeting nutritious below-ground tissues [5]. This eventually leads to meadow collapse, triggering turtle migrations to new foraging grounds. In some cases, meadow collapse can occur even before turtles dig up the rhizome, when consumption far outweighs productivity and pioneer species do not occupy the grazed areas [4]. These case studies show that green turtles respond to changes in seagrass composition and abundance with extraordinary flexibility in feeding strategies that allow them to exploit new meadow resources while maintaining site-fidelity [7].

The idea of large uninterrupted stands of climax ecosystems may be a much more recent characterisation of ‘the pristine’, born of the extirpation of megaherbivores on land and in the sea [2]. Our case studies paint rather a different picture of the normal functioning of tropical seagrass ecosystems. Our results suggest that ‘pristine’ seagrass meadows, with their full complement of meso and mega herbivores, consist of spatio-temporally dynamic mosaics in different states of grazing pressure and recovery. Meadows dominated by highly-grazed, short-lived, pioneer species may exist cheek-by-jowl with meadows of long-lived climax assemblages that have escaped grazing. We currently value seagrass meadows for the numerous ecosystem services they provide, such as coastal protection, provision of habitat, nutrient cycling and carbon storage. Though some of these services might be unaffected under low herbivory [8], and may be even enhanced under intermediate grazing, they are likely to be significantly compromised when seagrass meadows become functionally extinct due to intensified turtle grazing [9]. At seascape scale, in parallel with forest-savanna mosaics, a full spectrum of seagrass meadow states likely provides a higher diversity of ecosystem services than a sea fringed solely by long-lived climax meadows.

How do we reconcile this new dynamic baseline with the conservation of seagrass meadows and their functioning? For a start, it requires us to move beyond polarised conservation approaches that privilege either turtle numbers or seagrass meadow functions. It may be critical to accept that seagrass mosaics, characterised by a full spectrum of meadow states, from rich, fully developed meadows to sparse habitats, are not signs of a degraded seascape and, in fact, may reflect pre-Anthropocene ecosystems more closely. By embracing this much more nuanced understanding we move from the view of “nature in balance” that still pervades literature and environmental policy [1], towards embracing the “flux of nature”, where herbivory (and disturbances, in general) plays a central role. Increasing green turtle populations may lead to seagrass meadows that cycle through periods of decline and recovery worldwide. However, recovery of seagrass beds ‘from scratch’ is typically slow and unpredictable [10]. Borrowing from forest-savannah systems, this state would be the equivalent of a terrestrial ‘desert’. It may be necessary to intervene in grazed meadows before imminent collapse. Measures could be taken to exclude turtles, either from small remnant patches to facilitate meadow recovery once turtles have abandoned the site or to exclude grazing for example through(re-)introduction of calcareous free-living algae that protect basal leaf sections, meristems and roots [11]. These ameliorative measures take on even more urgency as seagrass habitat degradation intensifies due to human influence. In light of the degrading state of tropical seagrass meadows we may also need to revisit active green turtle conservation efforts, involving stakeholders in both seagrass and sea turtle conservation.

Conceptions of the pristine are more value-laden rather than ecologically relevant. Rather than attempting to manage for a "pristine" meadow in equilibrium state that might be largely incompatible with abundant megaherbivores, we call for embracing a much more nuanced management that include seascapes characterised by inherently non-equilibrium dynamics, even if some of these habitats provide fewer ecosystem services. While green turtles represent a rare conservation success at some locations, turtle populations continue to face a suite of pressures worldwide. The dramatic ecosystem impacts turtles have at these few locations should not compromise global conservation efforts. As conservation successes of ecosystem-modifying flagships continue, we may need to acknowledge that the dynamic mosaics they create, impoverished as some of them may seem, are paradoxically closer to pristine conditions than our Edenic conceptions of them.

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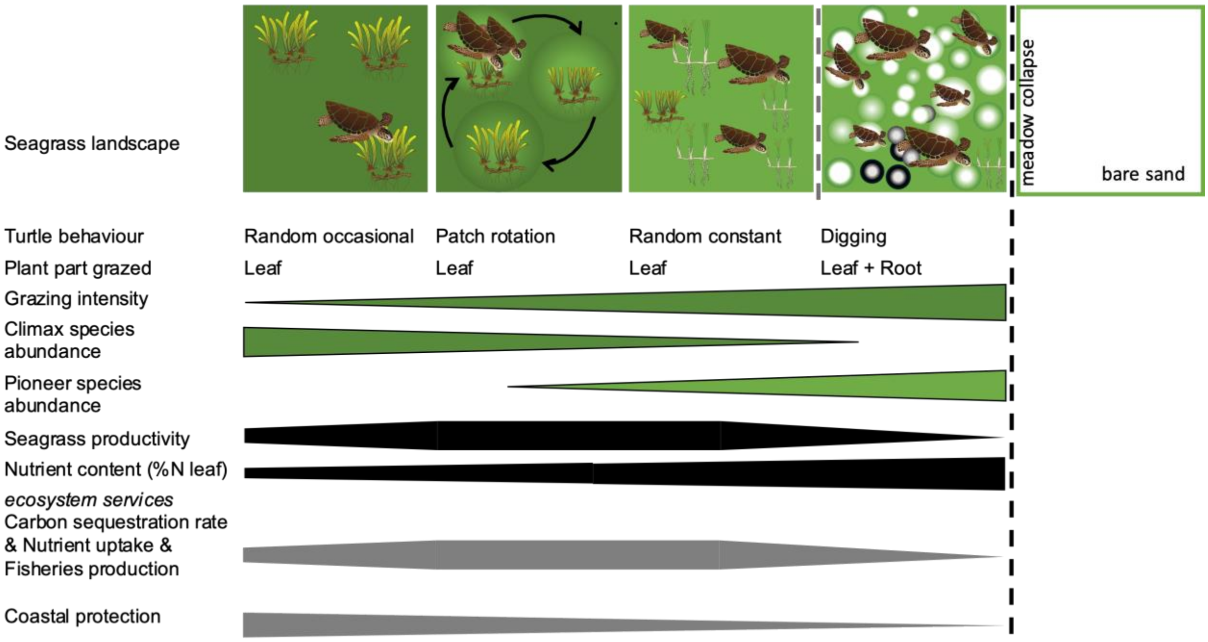

Fig. 1. Green turtle grazing impact on seagrass seascapes. Under increased turtle densities (from left to right) and sustained turtle grazing regimes, turtles change feeding strategies to exploit new meadow resources while maintaining site fidelity. Seagrass meadows experience dramatic changes in their landscape features, nutrient quality, primary production, species composition and ecosystem services. Meadow collapse can either occur after intensive random leaf grazing in meadows where pioneer species are absent, depicted by the gray dashed line, or as a result of erosion following digging, depicted by the black dashed line. Estimated ecosystem services trends adapted from [9], carbon sequestration trends adapted from[12].