



A Review of Seagrass Cover, Status and Trends in Africa

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Abstract

The recognition of the benefits that seagrasses contribute has enhanced the research interest in these marine ecosystems. Seagrasses provide critical goods and services and support the livelihoods of millions of people. Despite this, they are declining around the globe. To conserve these ecosystems, it is necessary to understand their extent and the drivers leading to their loss. However, global seagrass cover estimates are highly uncertain and there are large regional data gaps, especially in the African continent. This work reviewed all available data on the extent of seagrass cover, evidence of changes in cover and drivers of this change in Africa, to inform management and conservation approaches across the continent and identify gaps in knowledge. Using a systematic review and expert consultation, 43 relevant articles were identified. Of the 41 African countries with a coastline, 27% had no data on seagrass cover. For 44%, data were available for some parts of their coastline, while 29% had data for their entire coastline. Quantitative information on trends in seagrass cover change was only available from three countries. The study identified 32 suggested drivers of seagrass cover loss, with impacts from fishing mentioned most frequently. Direct anthropogenic drivers accounted for 66.7% of the mentions, while climate and biologically induced drivers accounted for 22.7% and 10.6%, respectively. This study demonstrates the need for better estimates of seagrass extent, in at least 70% of relevant African nations, and major gaps in our understanding of the drivers of seagrass decline in Africa.

Keywords Coastal ecosystems · Seagrass cover extent · Drivers of change · Fishing · Africa

Introduction

Seagrasses are an important component of near-shore marine ecosystems and support diverse assemblages of flora and fauna across the globe. They are foundation-stone species, providing structural complexity and primary production in many coastal food webs (Boutahar et al. 2020; Green and Short 2003). They provide critical

habitat and nursery grounds for about 20% of the world's largest fisheries (Unsworth et al. 2019) and support the livelihoods of millions of people in coastal communities (Macreadie et al. 2018; Short et al. 2011). Additionally, they provide food and shelter for many other marine species, including endangered dugongs, manatees and sea turtles (Green and Short 2003; Short et al. 2011; Sievers et al. 2019). They help maintain and improve water quality and reduce turbidity by filtering, cycling, and storing nutrients and pollutants (Short et al. 2011) and can reduce the abundance of disease-causing pathogens (Lamb et al. 2017). By trapping and settling the sediment and damping waves, seagrasses can help stabilise shorelines and reduce erosion (Githaiga et al. 2019; Green et al. 2021; Potouroglou et al. 2017). In the context of climate change mitigation, they sequester large amounts of atmospheric carbon dioxide, amounting to around 10% of the annual burial of organic carbon in ocean sediment (Fourqurean et al. 2012; Kennedy et al. 2010). They also provide cultural ecosystem services, being associated with religious, aesthetic and spiritual values (Gullström et al. 2012).

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Seagrass Distribution Worldwide

Seagrass has a global distribution, occurring in 191 countries in six bioregions (Fig. 1). The species diversity varies greatly within and between these regions (Short et al. 2007).

The presence and diversity of seagrasses are influenced by environmental factors, including sea surface temperature, salinity, turbidity, water currents, solar radiation and nutrients, and geomorphic factors, such as the configuration of the continental shelf (Chefaoui et al. 2015; Glasby et al. 2015; Kennedy et al. 2022). The genera *Cymodocea*, *Enhalus*, *Halodule*, *Halophila*, *Syringodium*, *Thalassodendron*, and *Thalassia* dominate tropical coasts while *Amphibolis*, *Phyllospadix*, *Posidonia*, and *Zostera* are characteristic of temperate regions (Short et al. 2007).

Estimates of the total global coverage of seagrass range from 177,000 to 600,000 km² (Duarte et al. 2010; Green and Short 2003; McKenzie et al. 2020). This variability arises partly because of inconsistencies in mapping efforts due to varying water clarity and depth, which affect remote sensing approaches (McKenzie et al. 2020) and hence also model accuracy. In addition, large areas of the world's oceans, including most of the coastline of the African continent, have not received detailed field-based or remote sensing mapping for seagrass. Therefore, simply knowing

where seagrass occurs and how much there is remains an important objective for environmental managers in many countries, particularly those with limited histories of seagrass research.

Threats to Seagrass and Trends in Cover

There is strong evidence that the area of seagrass cover is declining globally (Dunic et al. 2021; Gullstrom et al. 2002; Harcourt et al. 2018; Orth et al. 2006; UNEP 2020; Waycott et al. 2009). An analysis by Short et al. (2011) found seagrass meadows to be among the most threatened of all marine ecosystems. This is due to multiple drivers interacting together to cause changes in seagrass ecosystems on local, regional, or global scales (Wallner-Hahn et al. 2015). Environmental, biological, and climatological changes have all been identified as major drivers of seagrass meadow decline in both temperate and tropical regions (Orth et al. 2006). The most commonly identified drivers of decline, particularly in temperate waters, are eutrophication and turbidity caused by increased discharges of nutrients and sediments (Green and Short 2003; Marbà et al. 2006; Orth et al. 2006; Ralph et al. 2006). Additionally, fishing can cause seagrass loss, both directly through destructive activities, such as trawling and

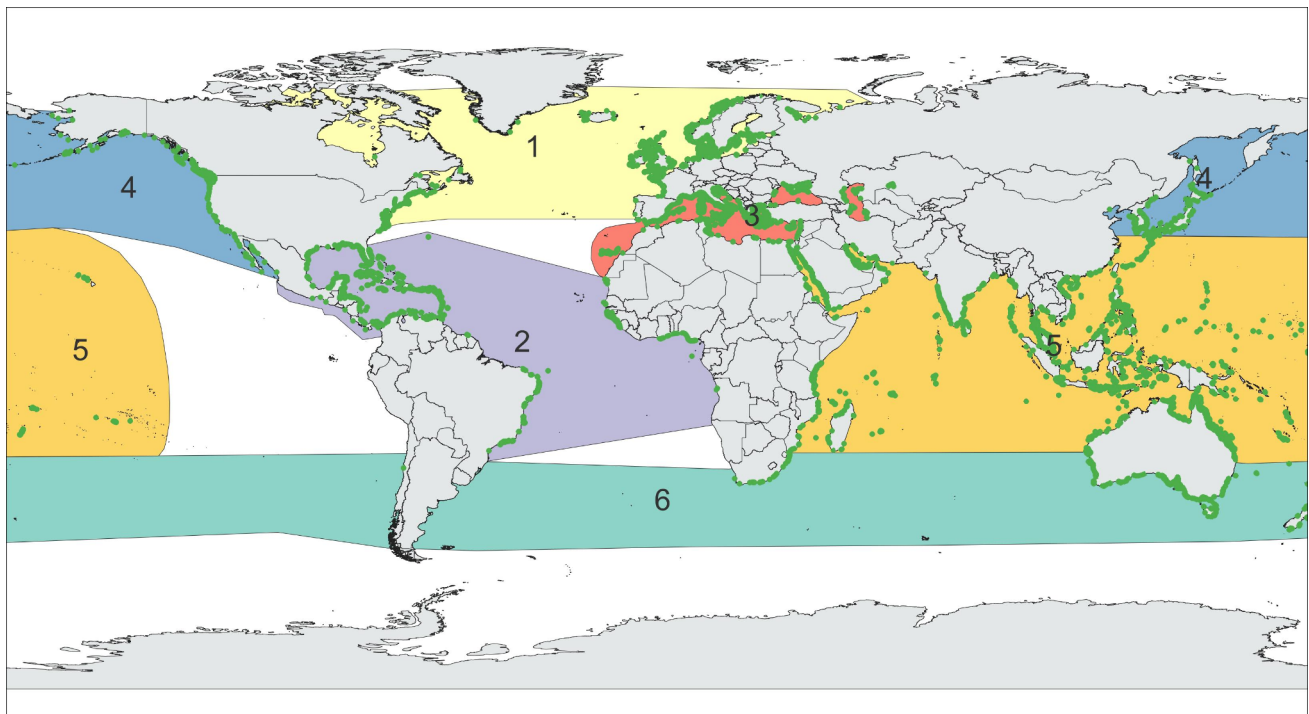


Fig. 1 Global distribution of seagrass and geographic bioregions, based on data from UNEP-WCMC and Short (2021) and Short et al. (2007). Records of seagrass have been exaggerated in size for clarity. Numbered geographic bioregions are: 1. Temperate North Atlantic,

2. Tropical Atlantic, 3. Mediterranean, 4. Temperate North Pacific, 5. Tropical Indo-Pacific, 6. Temperate Southern Oceans. Global administrative boundaries are taken from geoBoundaries data (Runfola et al. 2020)

the use of seine nets (Gullström et al. 2012), and indirectly by disturbing ecological balances through overfishing (Eklöf et al. 2008a, 2008b; Waycott et al. 2009). Increased tourism activities and seaweed farming (Gullström et al. 2012) are also reported as potential threats.

Several reviews have analysed seagrass cover change in different bioregions (Dunic et al. 2021; Green et al. 2021; Short et al. 2007; Waycott et al. 2009), and descriptions of the global distribution of seagrass have recently been completed (Jayathilake and Costello 2018; McKenzie et al. 2020). In general, estimates of change of seagrass cover show losses, sometimes at rapid rates. For example, Waycott et al. (2009) estimated a 7% yr⁻¹ global decline (which would make seagrass perhaps the most threatened of all global ecosystems). However, this analysis relied heavily on data from North America and Europe; work in the UK suggests total losses may be as high as 92% over the past century (Green et al. 2021). Whilst the global estimates are useful, they remain coarse-grained, often relying on poorly resolved satellite information; the best information combines site-based and remote sensing estimates. Trends in many regions are poorly known, with African coasts particularly under-researched (Cheikh et al. 2023; Unsworth et al. 2019), although recent work in Kenya estimated seagrass loss there at 1.59% yr⁻¹ (Harcourt et al. 2018).

Seagrass Distribution in Africa

The coastline of Africa includes 32 mainland countries and 9 associated island states (Fig. 4). The coastline comprises a narrow, low-lying coastal belt that includes the continental shelf with several ecosystems. Seagrass ecosystems have been documented in some of these countries and island states (Short et al. 2007). The African coastal region is divided into five regions: North Africa, West Africa, Central Africa, East Africa, and Southern Africa. The North African coastal region includes countries Algeria, Egypt, Libya, Eritrea, Sudan, Morocco, Tunisia, and Western Sahara. The West African coastal region includes Benin, Côte d'Ivoire, Guinea, Ghana, Guinea Bissau, Liberia, The Gambia, Togo, Senegal, Sierra Leone, Nigeria, and Mauritania. The Central African coastal region includes Angola, Cameroon, Congo, Equatorial Guinea and Gabon. The East African coastal region includes Djibouti, Somalia, Kenya, Tanzania and Mozambique. Finally, the Southern African coastal region includes South Africa and Namibia. The Island states include Cape Verde, Comoros, Madagascar, Mauritius, Mayotte, Re-Union, Sao Tome, Principe, Seychelles and Zanzibar (a semi-autonomous region of Tanzania).

These regions are rich in seagrass diversity, with East African being one of the most species-rich, with 14 seagrass

species documented (Amone-Mabuto et al. 2017; Bandeira and Björk 2001; Duarte et al. 2012; Githaiga et al. 2017; Gullstrom et al. 2002). Notable species here include *Cymodocea rotundata*, *Halodule uninervis*, *cymodocea serrulata*, *Enhalus acoroides*, *Halodule wrightii*, *Halophila ovalis*, *Halophila stipulacea*, *Halophila minor*, *Ruppia maritima*, *Zostera capensis*, *Thalassia hemprichii*, *Thalassodendron ciliatum*, *Thalassodendron leptocaula* and *Syringodium isoetifolium*. South Africa's extensive coastline of 3113 km contains common seagrass species, including *Zostera capensis* and *Halophila ovalis* (Mead et al. 2013). The western region of Africa, from Morocco to Angola, contains *Zostera noltii*, *Z. marina*, *Posidonia oceanica*, and *Cymodocea nodosa* as dominant species (Benmokhtar et al. 2021; Elso et al. 2017). Additionally, *P. oceanica* meadows are present in Egypt along with other common species such as *Thalassia hemprichii* and *Syringodium isoetifolium* (El Shaffai et al. 2011).

Aims

This review aimed to summarize knowledge on the extent, trends and drivers of change of seagrasses in Africa, and to identify gaps in knowledge.

Methods

Systematic Review

This study conducted a systematic literature review to identify publications related to seagrass coverage, trends and drivers of change in Africa. A comprehensive search was executed using five search engines between May to June 2023: Science Direct, Google Scholar, Yahoo, Scopus, and ISI Web of Sciences without a limitation on the year of publication. The search terms included: (Seagrass* OR SAV OR submerged aquatic vegetation OR meadow) AND (loss* OR change OR decline OR stability OR impact OR recovery OR increase OR gain OR status OR cover OR area OR distribution OR driver*), AND (Algeria OR Angola OR Benin OR Cameroon OR Cape Verde OR Comoros OR Congo OR Côte d'Ivoire OR Djibouti OR Democratic Republic of Congo OR Egypt OR Equatorial Guinea OR Eritrea OR Gabon OR Ghana OR Guinea OR Guinea-Bissau OR Kenya OR Liberia OR Libya OR Madagascar OR Mauritania OR Mauritius OR Mayotte OR Morocco OR Mozambique OR Namibia OR Nigeria OR Re-union OR Sao Tome and Principe OR Senegal OR Seychelles OR Sierra Leone OR Somalia OR South Africa OR Sudan OR Tanzania OR The Gambia OR Togo OR Tunisia OR Western Sahara). Searches from Google Scholar produced

the largest number of results for each country because of the term “seagrass”. In these searches, the first 200 results were screened for relevance. Where the results were less than 200, all the articles were screened for relevance. Results from certain countries on the Mediterranean coast, West Africa, and in western Indian Ocean (WIO) regions were reported as being from a region rather than a specific country. In such cases, the articles were read for the specific country’s coast where data was collected. If there was no specific country data presented, the article was excluded.

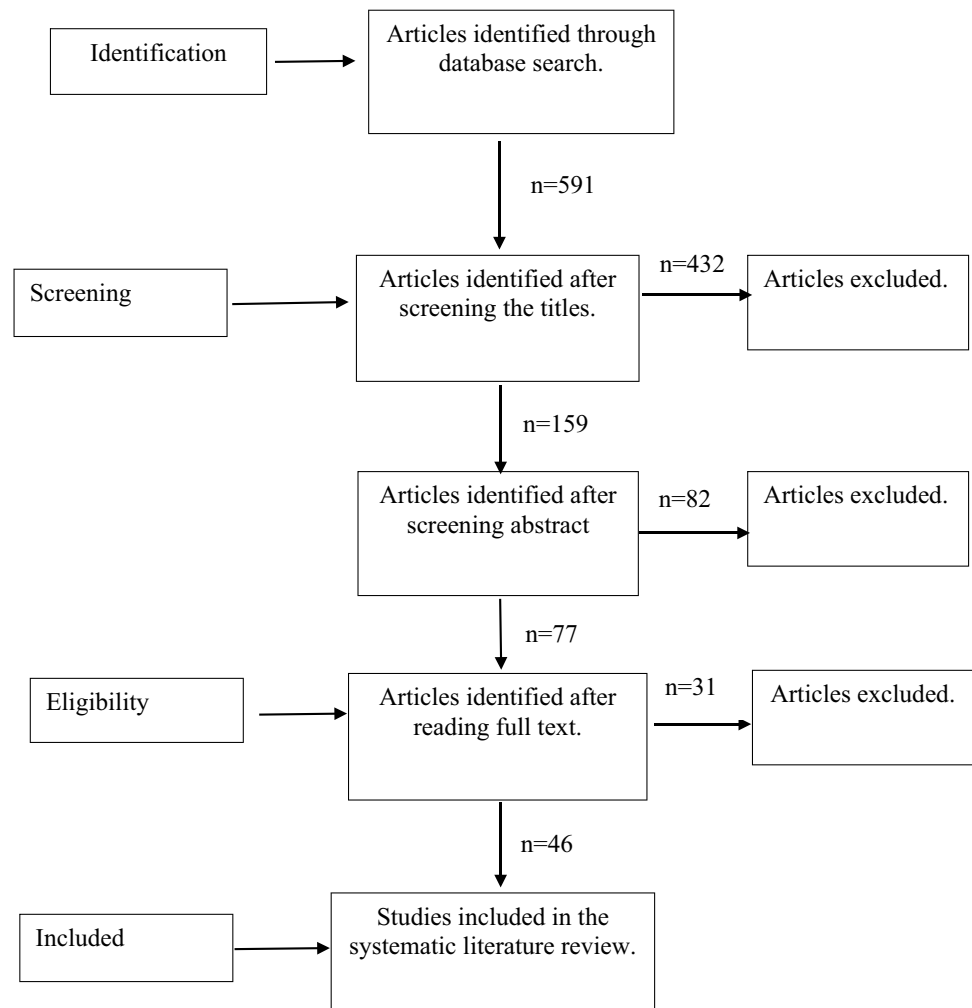
From the initial search, article titles were checked for relevance and were excluded if the work did not include information on seagrass area cover extent or drivers of cover change or both. The abstracts and full contents of the articles were then screened to ensure that the documents conformed to the study’s inclusion criteria, which were that: (1) the study was done within the African continent; (2) and had reported seagrass area cover extent at least on one site in the country where it was done; and/or (3) the study had indicated or mentioned seagrass drivers with or without mitigatory/conservation strategies aimed at increasing seagrass cover.

The initial search generated over 11,000 results. The search terms were subsequently refined to include the relevant African countries, resulting in the identification of 591 articles (Fig. 2). A systematic screening process was then employed to select articles that met the review criteria, resulting in the identification of 46 relevant articles for inclusion in the review (Fig. 2). Expert elicitation identified an additional three reports and one website link (ResilienSea 2023).

To supplement the research and gather more comprehensive information, six prominent researchers actively involved in seagrass studies in Africa were contacted for possible contributions, and two responded with useful information. Additionally, a thorough search was conducted for any reports and theses available on seagrass to acquire both primary and grey literature.

In instances where the sampling year was not explicitly stated, the year of publication or the year the article was received for publication was used for reference. Articles that presented information on macrophytes in general, without specific identification of seagrass or submerged aquatic vegetation, were excluded.

Fig. 2 Diagrammatic representation of the systematic literature review process, from the initial data search to the selection of the final articles for review



Other Data Sources

The global seagrass spatial maps located at the UNEP World Conservation Monitoring Centre (WCMC) (UNEP-WCMC and Short 2021) provide estimates of global seagrass cover. The global seagrass polygon data were downloaded in QGIS software. Data for all the African countries with a coastline (including island states) were extracted and clipped using the country's coastline boundary polygon. The country's boundary polygon was drawn using Google Earth Pro, to prevent overlap between the boundaries and ensure that each area is accounted for in one country, thus avoiding any omissions or duplications. There was no limitation imposed on the seaward distance as seagrass rarely occurs in the open deep sea. However, for Algeria and Morocco, which are close to Spain, the intervening area of the sea was divided into two. The same was done for Egypt and Sudan in the Red Sea. The seagrass cover area was then calculated from the extracted layers. This provided estimates for some African countries' seagrass cover. The seagrass polygon was clipped to individual countries, and the seagrass cover was determined from the resulting polygon layer.

Drivers of Seagrass Cover Change

Where available, quantitative estimates of change in seagrass cover over time, and drivers attributed to these changes, were recorded. More generally, and more commonly, drivers of seagrass change discussed in the literature were given qualitative categories indicating the strength of the evidence adduced for them. Using criteria adapted from Dunic et al. (2021), each mention of a driver was classified (in nominal order of increasing epistemic value): (1) speculative (an instance was attributed to change only in the discussion and no data were presented to link the driver to the change); (2) low (some description was given of change and how the driver could be linked to this and there may be qualitative comments on the effects); (3) moderate (the driver was linked to the change in the text and data were presented showing the cover before and after the driver); (4) high (experiments or surveys were carried out to test the impact of the driver and relevant data were provided). A median score for epistemic strength for each category of driver was calculated from the scores for each instance within each category. The years when the attributed loss of seagrass due to the driver occurred were also recorded. In cases where the year of data collection was not indicated, the year the manuscript was received was recorded or otherwise the year of publication.

Drivers were categorized into seven classes depending on the nature of the disturbance, based on a priori knowledge taken from the general literature but refined during

the review process to include any additional categories not provisionally identified as in Table 1.

Results

The search identified relevant articles published from 1987 to 2023. From 1987 to 2015, there were one or two relevant articles published per year. From 2016 to 2023, the number of relevant articles published increased, with 2017 and 2020 having the highest numbers ($n = 4$). Whilst 15 articles were published during the 2000–2010 decade, the same number have been published in the past 5 years (Fig. 3). There were more studies on drivers of change (34) than on cover only (23).

Table 1 Categories of potential drivers of seagrass cover change and examples of recorded disturbances associated with the different drivers

Driver	Examples of a reported disturbance
Biological	Grazing Overgrazing Invasive species
Climate change	Cyclone Flooding and sedimentation Flooding Change in pH Temperature Sedimentation Salinity
Eutrophication	Pollution Nutrient Enrichment Waste disposal Urban effluents
Fishing	Boating activity Fishing gear Trawling Destructive fishing gear Illegal Fishing gear Overfishing Trampling Gleaning Bait digging
Human development	Sand mining Human coastal development Turbidity Sedimentation
Seaweed farming	Seaweed farming
Tourism development	Destruction for swimming Tourism Tourism expansion

Seagrass Cover and Trends in Africa

Of the 41 African countries (including 9 island states) with a coastline, there was independent information (from the literature but excluding the UNEP-WCMC database) across the whole coastlines for 29% ($n = 12$, Fig. 4). Partial seagrass cover mapping was reported, from at least one locality within the coastal zones, for 44% ($n = 18$, Fig. 4) of these countries, while 27% ($n = 11$, Fig. 4) of coastal countries had no published records of seagrass (Table 2). The earliest seagrass cover information reported in the literature was from the Swartkops estuary in South Africa in 1987, where direct measurement was used to estimate the extent of *Zostera capensis* cover over the 490-ha estuary (Talbot and Bate 1987).

The UNEP-WCMC global database reported seagrass cover for 23 African countries, with the other 18 coastal countries recorded as being without seagrass (Table 2). Among the countries without cover in the UNEP-WCMC database, 11 did not have any other published data on seagrass area cover extent. However, published data did indicate the presence of seagrass in six countries, namely Cape Verde, Mauritania, Mauritius, Morocco, Sao Tome and Principe, and The Gambia, despite these not being recorded in the UNEP-WCMC database.

There were 23 articles that contained relevant information on seagrass area cover extent. Of these, 12 reported only the areal extent of seagrass, either along the entire coastline or within specific sections of the country (Table 2). Conversely, 11 documented both the area extent of seagrass cover and observed decreases in that area cover extent. However, there were limited data available on the rates of loss, with only Kenya, Mozambique, Tunisia, and certain areas of South Africa (Table 2) providing quantitative estimates of rates of decline.

Drivers of Seagrass Change in Africa

Thirty-one drivers of change of seagrass cover were identified in 34 research articles; all of them led to seagrass declines although four articles have reported some recovery/gains after decline. These drivers were classified into seven categories (Table 1 and 3).

Fishing was the most frequently reported driver, accounting for 29% of instances, while seaweed farming and tourism development had the lowest instance at 5% (Fig. 5). The drivers predominantly attributed to anthropogenic activities (eutrophication, fishing, human development, seaweed farming, and tourism development) constituted 66.7% of all instances, while climate change and biologically induced drivers accounted for 22.7% and 10.6%, respectively (Fig. 5).

The strength of evidence adduced for drivers was often low, with only seaweed farming having a median score of ‘high’ for evidence.

Among the anthropogenic threats to seagrass, fishing was reported in 15 articles, eutrophication (reported as urban effluents, waste disposal, nutrient loading and pollution) was reported in eight (17.4%) of the articles reviewed while seaweed farming and tourism development were the least frequent, being mentioned by three articles (7.0%). Among the natural threats (biological and climate change), flooding and overgrazing were the most cited drivers.

From the reviewed papers on drivers of seagrass cover loss, 32.4% ($n = 11$) reported the area or percentage cover lost due to the reported driver(s) investigated while 67.6% ($n = 23$) did not indicate the magnitude of the driver(s) although there was some evidence of cause (Table 3).

Regarding the strength of evidence for drivers of seagrass cover loss, experiments (either as field studies, mapping or controlled (mesocosm) experiments) were carried out on

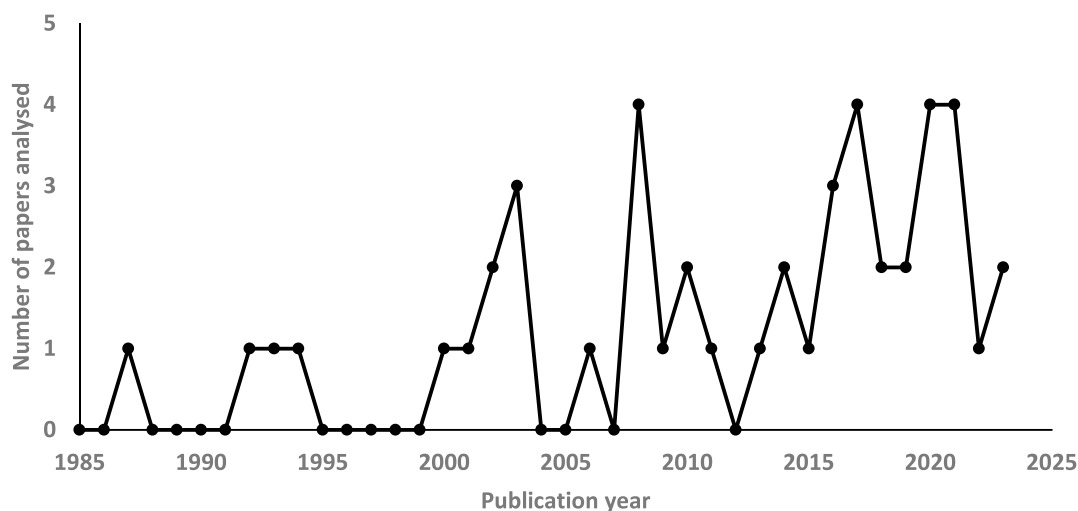


Fig. 3 Number of articles reviewed on African seagrass cover and drivers of change from 1987 to 2023

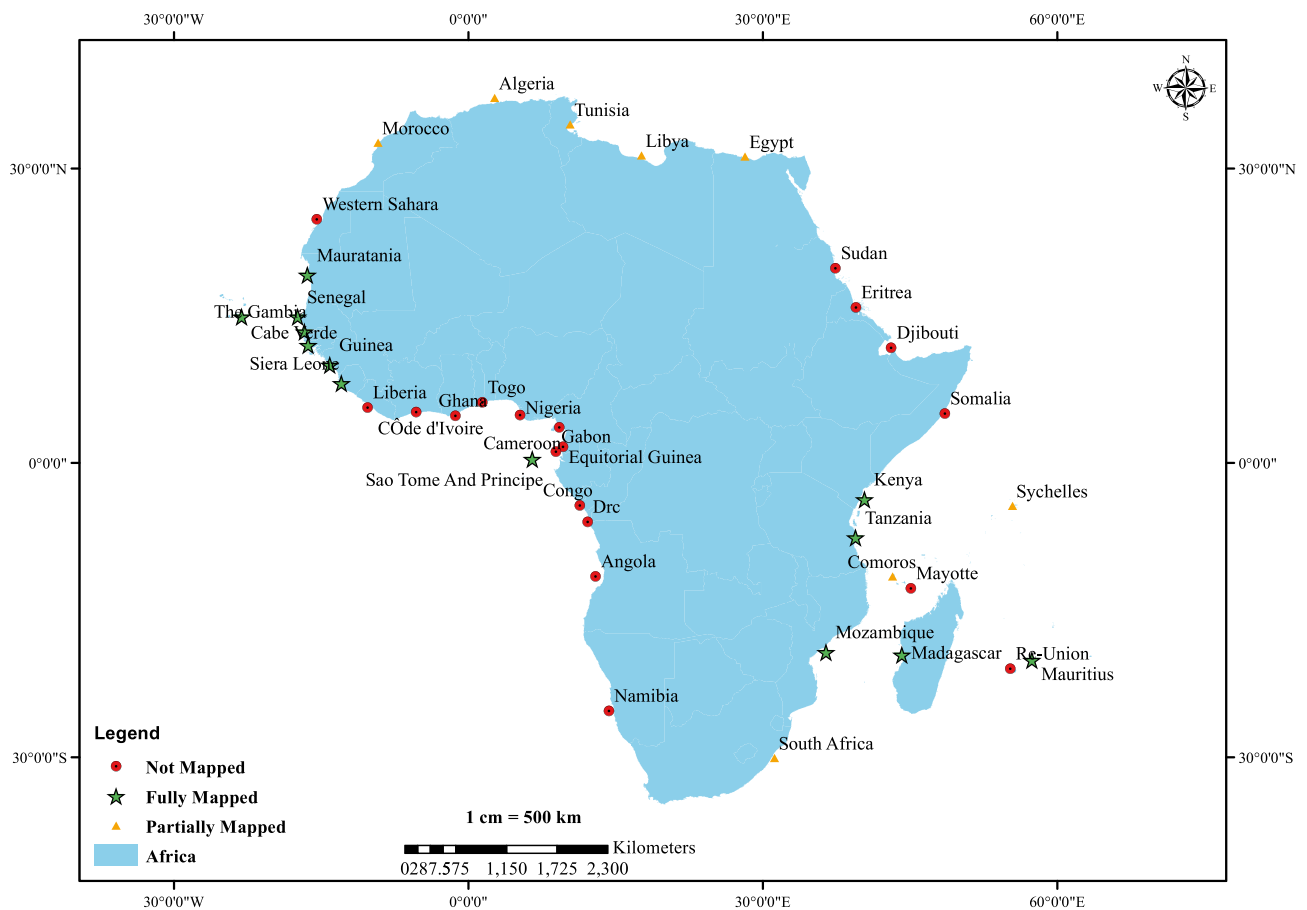


Fig. 4 Seagrass mapping status in coastal African countries based on published nation-specific, excluding data from the global UNEP–WCMC database

49% of the reviewed driver instances, 24% were observed in the field to lead to seagrass cover loss and 27% were speculative only.

Discussion

The present work highlights major gaps in information on current seagrass extent, trends in cover and potential drivers of change in the African continent. It is also the first document compiling information about the distribution and extent of seagrasses in Africa, pointing out possible drivers for reported seagrass loss and declines in the region.

Seagrass Extent

The UNEP–WCMC global database provides a useful course-grained resource for seagrass managers and conservationists which is particularly valuable for scrutinising global status. Because it purportedly covers all relevant nations it provides at least initial information for seagrass status in African countries. However, there are inevitably

errors and omissions in a global dataset making it of variable use for fine-grained, national purposes (Hossain et al. 2014, 2015; Komatsu et al. 2020). For example, there are six African nations with seagrass reported in the literature but with no records at all in the UNEP–WCMC database (Table 2). There are 11 nations with estimates for the whole coastline from the UNEP–WCMC database and from independent sources, and these estimates are often very different (Table 2). In six cases, the global database gave smaller estimates than those from the literature while in five cases it gave larger figures; hence there is no evidence of systematic bias. Taking the literature estimates as the denominator, the mean absolute (ignoring sign) percentage difference between the database and literature estimates in these cases was 299%. It is clear, therefore, that researchers and managers need to regard the UNEP–WCMC estimates with caution in any specific cases, especially where total areas of seagrass are small, water is turbid and confounding green algae are common. An additional and common source of uncertainty is ambiguity in the literature about threshold densities required before an area is designated as a seagrass meadow; some species

Table 2 Seagrass cover estimates in Africa, from the UNEP-WCMC global database and other published sources; ‘-’ indicates no data were available

Country	UNEP-WCMC (2021) cover estimates (km ²)	Data in addition to UNEP-WCMC					
		Extent (km ²)	Change	Type of study	Area mapped	No. of species	Reference
Algeria	40.56	40.72	-	Review	16%	1	(Telesca et al. 2015)
Angola	1193.34	-	-	-	-	-	-
Benin	2748.39	-	-	-	-	-	-
Cape Verde	-	0.0062		Field survey	Entire coastline		(Cheikh et al. 2023)
Cameroon	-	-		-	-	-	-
Cote d’Ivoire	-	-		-	-	-	-
Comoros	1272.91	3.33		Field survey	Northern Grande Comore Island	9	(Poonian et al. 2016)
				Field survey	Southern Grande Comore Island	-	(Poonian et al. 2016)
				Field survey	Anjouan Island	-	(Poonian et al. 2016)
				Field survey	North Eastern Grande Comore Island	-	(Poonian et al. 2016)
Congo	-	-		-	-	-	-
Djibouti	-	-		-	-	-	-
D. R. of Congo	-	-		-	-	-	-
Egypt	2349.53	17.8308		Field survey	Wadi El Gemal National Park, Red Sea	11	(El Shaffai et al. 2011)
Equatorial Guinea	-	-		-	-	-	-
Eritrea	3.12	-		-	-	-	-
Gabon	-	-		-	-	-	-
Ghana	5420.42	-		-	-	-	-
Guinea	13,661.37	4.28		Field survey	Entire mapping	4	(Cheikh et al. 2023)
Guinea Bissau	14,651.36	8.81		Field survey	-	4	(Cheikh et al. 2023)
Kenya		317	1.59%	Field survey	Entire mapping	12	(Harcourt et al. 2018)
	176.56	679.6		Field survey	Entire mapping	-	(Traganos et al. 2022)
Liberia	-	-		-	-	-	-
Libya	19.17	12.35		Review		1	(Telesca et al. 2015)
		1309.3		Field survey	Entire mapping	-	(Traganos et al. 2022)
		370		Field survey	Velondriake	8	(Hantanirina and Benbow 2013)
Mauritania	-	523		Field survey	Entire mapping	-	(Cheikh et al. 2023)
Mauritius	-	30		Descriptive	-	7	(Daby 2003b)
Mayotte	1493.43	-		-	-	-	-
Morocco		1.6076		Field survey	Merja Zerga lagoon	2	(Benmokhtar et al. 2021)
		0.000417		-	5 lagoons	1	(Elso et al. 2017)
	-	0.3873		Field survey	Jbel Moussa	1	(Boutahar et al. 2020)

Table 2 (continued)

Country	UNEP-WCMC (2021) cover estimates (km ²)	Data in addition to UNEP-WCMC					
		Extent (km ²)	Change	Type of study	Area mapped	No. of species	Reference
Mozambique		1779.3		-	Entire coastline	-	(Traganos et al. 2022)
	706.47	61.99	1.2%	-	Inhambane bay	8	(Amone-Mabuto et al. 2017)
		45.97	-		Eastern Maputo Bay	9	(Bandeira 2002)
		39.43	3.2	Survey	Inhaca Island		(Bandeira et al. 2014)
		0.73	86		Bairro dos Pescadores		(Bandeira et al. 2014)
Namibia	-	-		-	-	-	-
Nigeria	8824.80	-		-	-	-	-
Re-Union	-	-		-	-	-	-
Sao Tome and Principe	-	~15		Field survey	Entire coastline	1	(Alexandre et al. 2017)
Senegal	2981.57	83.72		Field survey	Entire mapping	-	(Cheikh et al. 2023)
Sierra Leone	4321.21	0.154		Field survey	Entire mapping	-	(Cheikh et al. 2023)
Somalia	-	-		-	-	-	-
South African		4.9		Descriptive	Swarrtkops estuary	-	(Talbot and Bate 1987)
		8.2334	-	Review	Estuaries	1	(Adams 2016)
	430.42	8.564		Field survey	Knysna estuary	1	(Wasserman et al. 2020)
Sudan	6.55	-		-	-	-	-
Seychelles	6508.91	44.33		Descriptive	Mahe	4	(Ingram and Dawson 2001)
Tanzania	46.07	548.2			Entire mapping		(Traganos et al. 2022)
		12.2	-	Field survey	Chwaka Bay	11	(Gullström et al. 2006)
The Gambia	-	1.11		Field survey	Entire Mapping		(Cheikh et al. 2023)
Togo	384.91	-		-	-	-	-
Tunisia		5186.85	2%	Review	81%	1	(Telesca et al. 2015)
		195.46		Field survey	El Bibane Lagoon	3	(Vela et al. 2008)
	1262.00	0.849		Field survey	Sidi rais barrier reef	2	(Hachani et al. 2016)
Western Sahara	-	-		-	-	-	-

may be growing very sparsely. For instance, an estimate of Kenyan seagrass cover in 2016, mapped using Sentinel 2 imagery supported by ground truthing, with an estimated accuracy of 82.8%, suggests that the UNEP-WCMC database underestimates the cover by 44.7% (Harcourt et al. 2018). The highest cover disparity is found in Guinea and Guinea Bissau where the UNEP-WCMC and Short (2021) cover estimates were 13,747.34 and 14,743.21 km², respectively. Mapping of these countries by Cheikh et al. (2023) found 4.28 and 8.81 km², respectively. Where possible, local and national efforts at seagrass conservation should use their own, recently sourced information that

is supported by ground truthing to complement what is available from global datasets.

Seagrass Cover Change

Although four articles reported some cover increases after disturbance (Aller et al. 2019; Gullström et al. 2006; Knudby et al. 2010; Talbot and Bate 1987), all the articles on cover changes across Africa reported overall declines. This concurs with the global picture of seagrass loss but may also represent some publication bias; we suspect reports of losses are more likely to be published than reports of gains.

Table 3 Reported incidences of potential seagrass drivers in Africa with their associated impact on cover change. ‘Info’ refers to the type of study; ‘Obs’ = field observation; ‘Exp’ = experimental or field study including mapping; ‘Pr’ = predicted after analysis; ‘Sp’ = speculative only

Category	Location	Country	Associated % cover loss	Year of reported loss	Info	Reference
Biological	Mombasa Lagoon	Kenya	23–85	1997–1998	Exp	(Alcoverro and Mariani 2002)
	Velondriake	Madagascar	-	2013	Exp, Sp	(Hantanirina and Benbow 2013)
	Oued El Mersa bay	Morocco	-	2014	Exp, Obs	(Boutahar et al. 2020)
	Chumbe and Bawe Islands	Tanzania	-	2001–2002	Obs	(Knudby et al. 2010)
	Chwaka bay	Tanzania	-	1987–2008	Exp, Obs	(Eklöf et al. 2008a; Gullström et al. 2006)
Climate change	Gunjur	The Gambia	-	2022	Obs	(Cheikh et al. 2023)
	Velondriake	Madagascar	-	2013	Sp	(Hantanirina and Benbow 2013)
	Andavadoaka	Madagascar	36.3	2013	Exp	(Côté-Laurin et al. 2017)
	Antsaragnaso	Madagascar	18.6	2013	Exp	(Côté-Laurin et al. 2017)
	Turtle Beach	Madagascar	15.3	2013	Exp	(Côté-Laurin et al. 2017)
	Banc d Arguin	Mauritania	14–78	Up to 2100	Exp, Pr	(Chefaoui et al. 2021)
	Maputo Bay, Inhaca Island	Mozambique	3.2–86	1991–2003	Exp, Obs	(Bandeira et al. 2014)
	Inhambane bay	Mozambique	51	1998–2001	Exp, Obs	(Amone-Mabuto et al. 2017)
	Mahe	Seychelles	-	2001	Exp	(Ingram and Dawson 2001)
	Kromme estuary	South Africa	50	1989	Exp, Obs	(Adams and Talbot 1992)
	West Coast	South Africa	-	2017	Exp	(Mvungi and Pillay 2019)
	Langebaan Lagoon	South Africa	-	2020	Exp	(Beltrand et al. 2021)
	St. Lucia	South Africa	-	1993	Exp	(Iyer and Barnabas 1993)
	Swartkops estuary	South Africa	-	1991	Exp	(Adams and Bate 1994)
	Eutrophication	Chumbe Island Coral Park	Tanzania	43	2007–2016	Exp
Sidi Rais barrier reef		Tunisia	-	2009	Sp	(Hachani et al. 2016)
Bou Ismaïl bay and Kouali		Algeria	-	2013	Exp	(Boumaza et al. 2014)
Praia		Cape Verde	-	2022	Obs, Sp	(Cheikh et al. 2023)
Anjouan Island		Comoros	-	2006–2007	Exp, Sp	(Poonian et al. 2016)
Safaga bay		Egypt	-	1984–1988	Exp, Sp	(Riegl and Piller 2000)
Chwaka bay		Tanzania	-	1987–2003	Sp	(Gullström et al. 2006)
Gulf of Gabes		Tunisia	88.6	2016	Exp	(El Zrelli et al. 2020)
Dakar		Senegal	-	2022	Sp	(Cheikh et al. 2023)
Mahe		Seychelles	-	2001	Exp	(Ingram and Dawson 2001)
	Seh Island	Siera Leone	-	2022	Sp, Obs	(Cheikh et al. 2023)
	West Coast	South Africa	-	2017	Exp	(Mvungi and Pillay 2019)

Table 3 (continued)

Category	Location	Country	Associated % cover loss	Year of reported loss	Info	Reference
Fishing	Northern Grande Comore Island,	Comoros	-	2006–2007	Exp, Sp	(Poonian et al. 2016)
	Bijagos Islands,	Guinea Bissau,	-	2022	Obs, Sp	(Cheikh et al. 2023)
	Gazi bay	Kenya	-	2017	Obs	(Harcourt et al. 2018)
	Velondriake	Madagascar	-	2013	Sp, Obs	(Hantanirina and Benbow 2013)
	Andavadoaka	Madagascar	-	2013	Exp	(Côté-Laurin et al. 2017)
	Banc d Arguin	Mauritania	-	2022	Sp, Ob	(Cheikh et al. 2023)
	Oued El Mersa bay	Morocco	-	2014	Obs	(Boutahar et al. 2020)
	Inhaca Island	Mozambique	-	2000	Obs, Sp	(Bandeira 2002)
	Bairro dos Pescadores (Maputo Bay)	Mozambique	50	1991–2003	Exp	(Bandeira and Gell 2003; Bandeira et al. 2014)
	Dakar	Senegal	-	2009	Obs	(Cunha and Araujo 2009)
	Dakar	Senegal	-	2022	Obs, Sp	(Cheikh et al. 2023)
	Seh Island	Sierra Leone	-	2022	Obs, Sp	(Cheikh et al. 2023)
	Several bays	South Africa	-	2020	Exp, Pr	(Phair et al. 2020)
	Langebaan Lagoon	South Africa	38–98	2007	Exp, Sp	(Pillay et al. 2010)
	Gunjur	The Gambia	-	2022	Obs, Sp	(Cheikh et al. 2023)
	Zanzibar	Tanzania	18.76–36.61	2019	Exp	(Purvis and Jiddawi 2023)
	Human development	Chwaka bay	Tanzania	-	1987–2003	Sp
Sidi Rais barrier reef		Tunisia	-	2009	Sp	(Hachani et al. 2016)
Praia		Cape Verde	-	2022	Obs, Sp	(Cheikh et al. 2023)
Southern Grande Comore Island		Comoros	-	2006–2007	Exp, Sp	(Poonian et al. 2016)
Safaga bay		Egypt	-	1984–1988	Exp, Sp	(Riegl and Piller 2000)
Gunjur		Gambia	-	2022	Sp, Obs	(Cheikh et al. 2023)
Maputo Bay		Mozambique	-	1991–2003	Exp, Obs	(Bandeira et al. 2014)
Mahe		Seychelles	-	2001	Exp	(Ingram and Dawson 2001)
Mhlathuze Estuary		South Africa	-	1996–1999	Exp	(Cyrus et al. 2008)
Langebaan Lagoon		South Africa	38	2007	Exp, Sp	(Pillay et al. 2010)
Seaweed farming	Several bays	South Africa	-	2020	Exp, Pr	(Phair et al. 2020)
	Chwaka bay, Zanzibar	Tanzania	-	2021	Exp	(Moreira-Saporiti et al. 2021)
	Zanzibar	Tanzania	18.76–32.61	2019	Exp	(Purvis and Jiddawi 2023)
	Chwaka bay, Zanzibar	Tanzania	-	2008	Exp, Obs	(Lyimo et al. 2008)
Tourism development	Safaga bay	Egypt	-	1984–1988	Exp, Sp	(Riegl and Piller 2000)
	Mauritius	Mauritius	-	2002	Obs	(Daby 2003a)
	Zanzibar	Tanzania	18.76–32.61	2019	Exp	(Purvis and Jiddawi 2023)

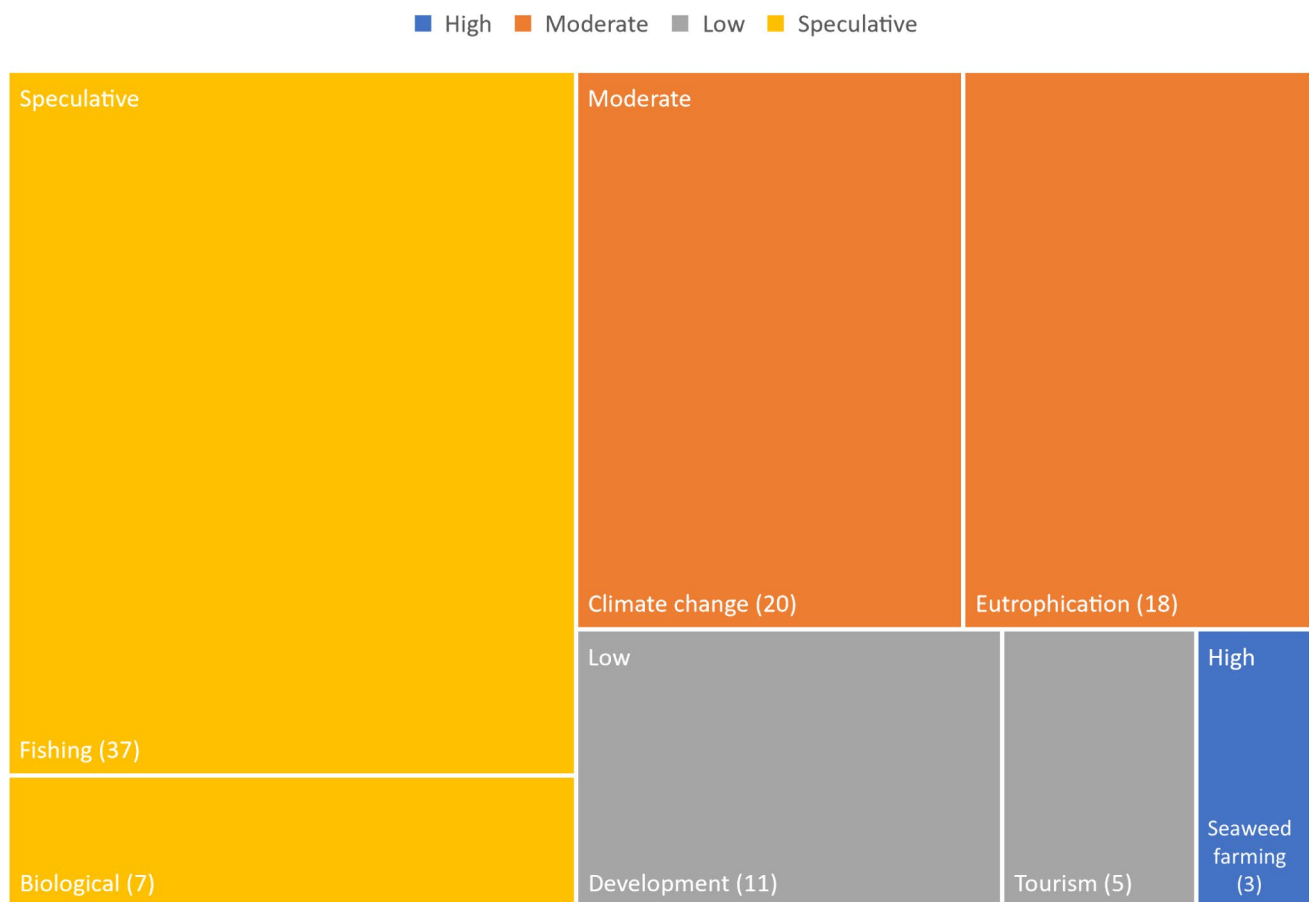


Fig. 5 Proposed drivers of seagrass decline in Africa. Numbers in parentheses represent the percentage of all published examples involving potential drivers. The legend indicates the median ranking of evidence strength for each driver

Information on quantitative rates of change was particularly sparse, being available for only Kenya, Mozambique, Tunisia and South Africa; the former two nations have published estimates for the whole coastline whilst South Africa has estimates only for key sites. Annual rates of loss of 0.29–1.59% (1986–2016), 0.26–7.2% (1991–2013), 2% (1972–2010) and 2.8–38% (1960–2007) in Kenya (Harcourt et al. 2018), Mozambique (Amone-Mabuto et al. 2017; Bandeira et al. 2014), Tunisia (Telesca et al. 2015) and South Africa (Pillay et al. 2010), respectively, show that at some locations Africa’s seagrass cover may be declining more than the global annual rate of 7% (Waycott et al. 2009). The absence of data on rates of change from Africa presents a major challenge for global estimates. This data gap hampers efforts to comprehend and address seagrass health concerns within African nations and underscores the importance of conducting further research on this topic within Africa. Given the challenges associated with mapping entire coastlines, it would be beneficial for this research to focus on analyzing specific sites that can serve as indicators for countries lacking nationwide information (McKenzie

et al. 2020). Additionally, this approach could suggest the need for further improvement in remote sensing techniques, ultimately leading to more accurate and robust large-scale estimates (McKenzie et al. 2020).

Drivers of Change in Seagrass Cover

Human-induced and associated drivers seem to be the biggest potential threats to African seagrass; 74% of instances of suggested drivers in the current review were directly related to human activity. This conforms to global studies that cite anthropogenic drivers leading to seagrass decline (Boudouresque et al. 2009; Dunic et al. 2021; Orth et al. 2006; Purvis and Jiddawi 2023; Waycott et al. 2009). Human population increase within 100 km of the coastline imposes increasing pressures on coastal ecosystems including seagrasses (Folorunsho et al. 2023; Mead et al. 2013). For example, West Africa’s coastal cities are home to a large percentage of the urban population, with Nigeria’s coastal zone hosting 20 million people (22.6% of the national population) (Folorunsho et al. 2023; IPCC 1997) and the Dakar

coastal area in Senegal supporting 4.5 million people (66.6% of the national population) (IPCC 1997). This has resulted to increased coastal erosion, eutrophication and pollution with significant effects on the coastal ecosystems (Almar et al. 2023).

Global reviews of the threats to seagrasses highlight eutrophication as the single most important problem (Burkholder et al. 2007; Orth et al. 2006). Eutrophication is also reported in the African literature. For example in Unguja, Zanzibar, high nutrient concentrations resulting from untreated sewage were found in the intertidal and subtidal zones (Purvis and Jiddawi 2023), which led to algal overgrowth harming seagrass through light reduction and ammonium toxicity (Burkholder et al. 2007; Purvis and Jiddawi 2023). However, in contrast with the global picture, eutrophication is not the most frequently cited potential driver of seagrass decline in Africa. Instead, fishing was identified as the most common source of negative impacts, with a frequency of 37% (Fig. 4). The coastal communities of Africa are heavily reliant on small-scale fishing for their food and livelihoods (March and Failler 2022; Musembi et al. 2019) due to paucity of alternative livelihood sources (Bandeira and Gell 2003). Small-scale fishing contributes significantly to Africa's economy, with 47% of landings derived from this activity and supporting the food security of over 200 million people (March and Failler 2022). Most artisanal fishing activities take place within seagrasses (de la Torre-Castro et al. 2014; Wallner-Hahn et al. 2022). About 80% of the 10 most caught fish species are associated with seagrasses (Herrera et al. 2022; Unsworth et al. 2018). This small-scale fishing is low technology, multi-gear, and open access and is largely unregulated (De la Torre-Castro et al. 2014). Seine netting, an illegal fishing gear in Kenya (GoK 2001; Samoilys et al. 2011) and in Madagascar (Hantanirina and Benbow 2013) is still commonly used and was associated with seagrass cover loss in Velondriake LMMA in Madagascar (Hantanirina and Benbow 2013). Destructive fishing methods, especially seine net fishing, have been associated with the 1.6% decline in Kenyan seagrass cover (Harcourt et al. 2018; Musembi et al. 2019) while seagrass meadows in Bijagos Island, Guinea Bissau are potentially impacted by beach seine dragging nets (Cheikh et al. 2023). Increasing fishing intensity (Chitará-Nhandimo et al. 2022) and the unregulated nature of fishing could be important factors in African seagrass loss. Additionally, activities such as gleaning, commonly practised by women and children who trample on seagrass meadows while searching for shells, holothurians, or crustaceans during low spring tide, can also impact seagrass negatively (Mead et al. 2013; Pillay et al. 2010). For example in Maputo and Inhambane Bay, Mozambique, gleaning has negatively affected the growth

and survival of seagrass through excavation, uprooting and trampling as the gleaners search for gastropods and crustaceans (Chitará-Nhandimo et al. 2022). In addition, digging of *Zostera capensis* to collect bivalves in Bairos dos Pescadores (Maputo Bay), reduced seagrass cover from 60 to 10% or less from 1992 to 2002 (Bandeira and Gell 2003). This review provides support for efforts to manage destructive fishing, although the strength of the evidence that was adduced is generally weak. Hence obtaining robust (ideally experimental) data on the impacts of different fishing types on seagrass health and extent is another research direction to emerge from this work.

Biological drivers of cover loss that were mentioned included overgrazing by sea urchins (*Tripneustes gratilla*) and green turtles (*Chelonia mydas*). Overgrazing in seagrass has been mostly documented in the WIO region (Alcoverro and Mariani 2002; Eklöf et al. 2008a; Hantanirina and Benbow 2013). In Kenya, overgrazing by sea urchins (*Tripneustes gratilla*) was found to reduce *Thalassondendron ciliatum* cover by 39% (Alcoverro and Mariani 2002). Lal et al. (2010) also found significantly lower seagrass cover in areas with higher densities of *Chelonia mydas*. The invasive seaweed *Caulerpa cylindracea* has been documented as a threat to seagrass (Boutahar et al. 2020), especially on the Mediterranean coast of Morocco and Tunisia. In Jbel Moussa, Oued Mersa bay for example, the seaweed covered 19% of the area and was associated with seagrass mortality (Boutahar et al. 2020).

The impacts of climate change were also identified as causing seagrass loss. For example in Inhambane Bay, Mozambique, cyclone Eline, which transited the region with a speed of 200 km/h in February 2000, led to the loss of 721 ha (Amone-Mabuto et al. 2017). From 2004 to 2013, approximately 400 ha of seagrass were lost in the bay. This loss was partially attributed to the impact of Cyclone Flavio, which struck the bay in 2007 with speeds reaching about 200 km/h (Amone-Mabuto et al. 2017). Cyclone Haruna (wind of 150 km/h) was also associated with 15.3–36.3% seagrass loss in Madagascar (Côté-Laurin et al. 2017). As an indirect effect of climate change, rainfall and flooding can bring about increased sediments into the marine areas leading to the loss of seagrass (Amone-Mabuto et al. 2017). Such losses in seagrass cover subsequently lead to loss of biodiversity. For instance, in Inhambane Bay in 2001 there was the lowest annual catch of the sardine *Amblygaster sirm* between 1999 and 2006 due to the loss of seagrass as a result of flooding (Amone-Mabuto et al. 2017).

A smaller but emerging threat to seagrass in Africa may be seaweed farming. Although Africa produces just a fraction of the 32.2 million tonnes yr⁻¹ of aquatic food produced by Asia, it is the second producer globally, particularly with the production of the carrageen-producing red algae in Zanzibar, Tanzania (Moreira-Saporiti et al. 2021;

Msuya et al. 2022). Seaweed farming is being promoted as an alternative livelihood to farming (Moreira-Saporiti et al. 2021). However, the practice may have negative impacts on seagrass cover as it occupies the same space within the intertidal zone (Moreira-Saporiti et al. 2021) and may bring trampling and shading (Lyimo et al. 2008; Moreira-Saporiti et al. 2021). Exploiting the possibilities of seaweed farming should include consideration of how to maintain seagrass in the same areas.

Africa's coastal environment is gaining popularity as a destination for global tourism, which is important for the economies of several countries (Arthurton et al. 2006) especially the East African countries of Kenya, Tanzania and Mozambique (Baitalik 2020). Various tourism activities can potentially impact seagrass cover. For example in Mauritius, dredging activities to create aesthetically pleasant swimming zones for tourists and good depths for boating and water-skiing have resulted in the destruction of seagrass cover through direct clearing (Daby 2003a). Between 2006 and 2019, the pristine seagrass beds in Unguja Island, Zanzibar experienced a substantial loss of 11% associated with the tourism activities taking place on the island (Purvis and Jiddawi 2023).

Conclusion

International developments are bringing greater attention and funding to seagrass research and conservation. For example, the implementation of the Paris Agreement has included the identification of seagrass as a contributor to adaptation and mitigation in Kenya's Nationally Determined Contributions (GoK 2020). Seagrass conservation and restoration activities within Africa are increasing, including trials of intensive restoration using planting (Uku et al. 2021; Wegoro et al. 2022). Despite this, understanding and managing seagrass ecology and conservation is at an early stage in many African countries and there are multiple opportunities for researchers, communities, and policymakers to improve the prospects for African seagrass. There are major gaps in our knowledge, particularly on trends in coverage and on the causes of change, although all the information available suggests declines. Fishing emerges here as a potentially important driver, although the evidence on its effects is mostly weak, hence further research and precautionary management (that recognises the rights of local users) are suggested. Seagrass ecosystems underpin millions of livelihoods in Africa, support biodiversity and contribute towards achieving Sustainable Development Goals 1, 2, 13, 14, 15 and 17. Most obviously, declines in seagrass health and extent could severely impact fisheries and many other ecosystem services in Africa (Pruckner et al. 2022); improved conservation and management of African seagrass, informed

by better research and with more resources, should be of local, national and international importance.

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Data Availability The authors confirm that most of the data supporting this study is within the article. Any other datasets generated by the study are available from the corresponding author upon request.

Declarations

Conflict of Interest The authors declare no competing interests.

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References

- Adams, J., and G. Bate. 1994. The Ecological implications of tolerance to salinity by *Ruppia cirrhosa* (Petagna) Grande and *Zostera capensis* Setchell. *Botanica Marina* 37: 449–456. <https://doi.org/10.1515/botm.1994.37.5.449>.
- Adams, J., and M.M.B. Talbot. 1992. The influence of river impoundment on the estuarine seagrass *Zostera capensis* Setchell. *Botanica Marina* 35: 69–75. <https://doi.org/10.1515/botm.1992.35.1.69>.
- Adams, J. 2016. Distribution and status of *Zostera capensis* in South African estuaries — A review. *South African Journal of Botany*. <https://doi.org/10.1016/j.sajb.2016.07.007>.
- Alcoverro, T., and S. Mariani. 2002. Effects of sea urchin grazing on seagrass (*Thalassodendron ciliatum*) beds of a Kenyan lagoon. *Marine Ecology Progress Series* 226: 255–263. <https://doi.org/10.3354/meps226255>.
- Alexandre, A., J. Silva, R. Ferreira, D. Paulo, E.A. Serrao, and R. Santos. 2017. First description of seagrass distribution and abundance in Sao Tome and Principe. *Aquatic Botany* 142: 48–52. <https://doi.org/10.1016/j.aquabot.2017.06.008>.
- Aller, E.A., J.S. Eklof, M. Gullstrom, U. Kloiber, H.W. Linderholm, and L.M. Nordlund. 2019. Temporal variability of a protected multispecific tropical seagrass meadow in response to environmental change. *Environmental Monitoring and Assessment*. <https://doi.org/10.1007/s10661-019-7977-z>.
- Almar, R., T. Stieglitz, K.A. Addo, K. Ba, G.A. Ondoa, E.W.J. Bergsma, F. Bonou, O. Dada, D. Angnuureng, and O. Arino. 2023. Coastal zone changes in West Africa: Challenges and opportunities for satellite earth observations. *Surveys in Geophysics* 44 (1): 249–275. <https://doi.org/10.1007/s10712-022-09721-4>.

- Amone-Mabuto, M., S. Bandeira, A. Silva, and d. 2017. Long-term changes in seagrass coverage and potential links to climate-related factors: the case of Inhambane Bay, southern Mozambique. *WIO Journal of Marine Science* 16: 213–225.
- Arthurton, R., K. Kwame, T. Forbes, M. Snoussi, J. Kitheka, J. Robinson, N. Shah, S. Taljaard, and P. Monteiro. 2006. Coastal and marine environments. *Africa Environment Outlook 2-Our Environment, Our Wealth*.
- Baitalik, A. 2020. Trends in global coastal tourism development and its eventuality in the era of Climate Change.
- Bandeira, S. 2002. Diversity and distribution of seagrasses around Inhaca Island, southern Mozambique. *South African Journal of Botany* 68: 191–198. [https://doi.org/10.1016/S0254-6299\(15\)30419-1](https://doi.org/10.1016/S0254-6299(15)30419-1).
- Bandeira, S.O., and M. Björk. 2001. Seagrass research in the eastern Africa region: Emphasis on diversity, ecology and ecophysiology. *South African Journal of Botany* 67 (3): 420–425. [https://doi.org/10.1016/s0254-6299\(15\)31158-3](https://doi.org/10.1016/s0254-6299(15)31158-3).
- Bandeira, S., and F. Gell. 2003. The seagrasses of Mozambique and southeastern Africa. *World atlas of seagrasses*, 93–100.
- Bandeira, S., M. Gullström, M. Balidy, D. Samussone, and D. Cossa. 2014. Seagrass meadows in Maputo Bay. In *The Maputo Bay Ecosystem*, ed. S. B and J. P, 147–169. Zanzibar Town: WIOMSA.
- Beltrand, M., A. Dineen, C. Hitzerth, B. Baum, C. de Cerff, C. de Vos, J. Lewis, S. Zarouf, and D. Pillay. 2021. Warming effects on two autogenic engineers (*Zostera capensis* and *Gracilaria gracilis*): Consequences for macrofaunal assemblages and benthic heterogeneity in intertidal sandflat ecosystems. *Estuaries and Coasts* 45 (1): 247–259. <https://doi.org/10.1007/s12237-021-00949-8>.
- Benmokhtar, S., M. Robin, M. Maanan, and H. Bazairi. 2021. Mapping and quantification of the dwarf eelgrass *Zostera noltei* using a random forest algorithm on a SPOT 7 satellite image. *ISPRS International Journal of Geo-Information* 10: 313. <https://doi.org/10.3390/ijgi10050313>.
- Boudouresque, C., G. Bernard, G. Pergent, A. Shili, and M. Verlaque. 2009. Regression of Mediterranean seagrasses caused by natural processes and anthropogenic disturbances and stress: a critical review. *Botanica Marina*. <https://doi.org/10.1515/BOT.2009.057>.
- Boumaza, S., N. Boudefoua, R. Boumaza, and R. Semroud. 2014. Effects of urban effluents on spatial structure, morphology and total phenols of *Posidonia oceanica*: Comparison with a reference site. *Journal of Experimental Marine Biology and Ecology* 457: 113–119. <https://doi.org/10.1016/j.jembe.2014.04.009>.
- Boutahar, L., F. Espinosa, J. Richir, G. Lepoint, S. Gobert, M. Maanan, and H. Bazairi. 2020. Deep-water *Zostera marina* meadows in the Mediterranean. *Aquatic Botany*. <https://doi.org/10.1016/j.aquabot.2020.103269>.
- Burkholder, J.M., D.A. Tomasko, and B.W. Touchette. 2007. Seagrasses and eutrophication. *Journal of Experimental Marine Biology and Ecology* 350 (1–2): 46–72. <https://doi.org/10.1016/j.jembe.2007.06.024>.
- Chefaoui, R.M., J. Assis, C.M. Duarte, and E.A. Serrão. 2015. Large-scale prediction of seagrass distribution integrating landscape metrics and environmental factors: The case of *Cymodocea nodosa* (Mediterranean–Atlantic). *Estuaries and Coasts* 39 (1): 123–137. <https://doi.org/10.1007/s12237-015-9966-y>.
- Chefaoui, R.M., C.M. Duarte, A.I. Tavares, D.G. Frade, M.A. Sidi Cheikh, M. Abdoull Ba, and E.A. Serrao. 2021. Predicted regime shift in the seagrass ecosystem of the Gulf of Arguin driven by climate change. *Global Ecology and Conservation* 32: e01890. <https://doi.org/10.1016/j.gecco.2021.e01890>.
- Cheikh, M.A.S., S. Bandeira, S. Soumah, G. Diouf, E. Diouf, O. Saneh, N. Cardoso, A. Kujabie, M. Ndure, L. John, L. Moreira, Z. Radwan, I. Santos, A. Ceesay, M. Vinaccia, and M. Potouroglou. 2023. Seagrasses of West Africa: New discoveries, distribution limits and prospects for management. *Diversity* 15: 5. <https://doi.org/10.3390/d15010005>.
- Chitará-Nhandimo, S., A. Chissico, M. Mubai, A. Cabral, A. Guissamulo, and S. Bandeira. 2022. Seagrass invertebrate fisheries, their value chains and the role of LMMAs in sustainability of the coastal communities—Case of Southern Mozambique. *Diversity* 14: 170. <https://doi.org/10.3390/d14030170>.
- Côté-Laurin, M.-C., S. Benbow, and K. Erzini. 2017. The short-term impacts of a cyclone on seagrass communities in Southwest Madagascar. *Continental Shelf Research* 138: 132–141. <https://doi.org/10.1016/j.csr.2017.03.005>.
- Cunha, A.H., and A. Araujo. 2009. New distribution limits of seagrass beds in West Africa. *Journal of Biogeography* 36 (8): 1622–1622.
- Cyrus, D.P., C.F. MacKay, and S.P. Weerts. 2008. Intrusion of beach-disposed dredger spoil in the Mhlathuze Estuary, South Africa, and its impact on *Zostera capensis*. *African Journal of Aquatic Science* 33: 223–231. *African Journal of Aquatic Science* 33: 223–231.
- Daby, D. 2003b. Some quantitative aspects of seagrass ecology in a coastal lagoon of Mauritius. *Marine Biology* 142 (1): 193–203. <https://doi.org/10.1007/s00227-002-0924-4>.
- Daby, D. 2003a. Effects of seagrass bed removal for tourism purposes in a Mauritian bay. *Environmental Pollution (Barking, Essex: 1987)* 125: 313–324. [https://doi.org/10.1016/S0269-7491\(03\)00125-8](https://doi.org/10.1016/S0269-7491(03)00125-8).
- de la Torre-Castro, M., G. Di Carlo, and N.S. Jiddawi. 2014. Seagrass importance for a small-scale fishery in the tropics: The need for seascape management. *Marine Pollution Bulletin* 83 (2): 398–407. <https://doi.org/10.1016/j.marpolbul.2014.03.034>.
- Duarte, M., S. Bandeira, and M. Romeiras. 2012. Systematics and ecology of a new species of seagrass (Thalassodendron, Cymodoceaceae) from Southeast African coasts. *Novon A Journal for Botanical Nomenclature* 22: 16–24. <https://doi.org/10.3417/2010079>.
- Duarte, C.M., N. Marbà, E. Gacia, J.W. Fourqurean, J. Beggins, and C. Barrón. 2010. Seagrass community metabolism: assessing the carbon sink capacity of seagrass meadows. *Global Biogeochemical Cycles*. <https://doi.org/10.1029/2010GB003793>.
- Dunic, J., C. Brown, R. Connolly, M. Turschwell, and I. Côté. 2021. Long-term declines and recovery of meadow area across the world's seagrass bioregions. *Global Change Biology*. <https://doi.org/10.1111/gcb.15684>.
- Eklöf, J., M. Gullström, M. Björk, M. Asplund, L. Hammar, A. Dahlgren, and M. Öhman. 2008a. The importance of grazing intensity and frequency for physiological responses of the tropical seagrass *Thalassia hemprichii*. *Aquatic Botany* 89: 337–340. <https://doi.org/10.1016/j.aquabot.2008.03.009>.
- Eklöf, J.S., M. Torre-Castro, and d. I., Gullström, M., Uku, J., Muthiga, N., Bandeira, S., & Lyimo, T. 2008b. Sea urchin overgrazing of seagrasses: A review of current knowledge on causes, consequences and management. *Estuarine, Coastal and Shelf Science*. <https://doi.org/10.1016/j.ecss.2008.05.005>.
- El Shaffai, A.M., and A. Gab-Alla. 2011. Distribution, abundance and species composition of seagrasses in Wadi El Gemal National Park, Red Sea, Egypt. *Indian Journal of Applied Research*. <https://doi.org/10.15373/2249555X/MAR2014/161>.
- El Zrelli, R., L. Rabaoui, R.H. Roa-Ureta, N. Gallai, S. Castet, M. Gregoire, N. Bejaoui, and P. Courjault-Rade. 2020. Economic impact of human-induced shrinkage of *Posidonia oceanica* meadows on coastal fisheries in the Gabes Gulf (Tunisia. Southern Mediterranean Sea): Marine Pollution Bulletin. <https://doi.org/10.1016/j.marpolbul.2020.111124>.
- Elso, M.Z., P. Manent, A. Luque, M. Ramdani, and R.R. Robaina. 2017. Genetic description and remote sensing techniques as

- management tools for *Zostera noltii* seagrass populations along the Atlantic Moroccan coast. *Journal of Coastal Research* 33 (1): 78–87. <https://doi.org/10.2112/JCOASTRES-D-15-00111.1>.
- Folorunsho, R., M. Salami, A. Ayinde, and N. Gyuk. 2023. The salient issues of coastal hazards and disasters in Nigeria. *Journal of Environmental Protection* 14: 361–372. <https://doi.org/10.4236/jep.2023.145021>.
- Fourqurean, J.W., C.M. Duarte, H. Kennedy, N. Marbà, M. Holmer, and M.A. Mateo. 2012. Seagrass ecosystems as a globally significant carbon stock. *Natural Geosciences* 5: 505–509. <https://doi.org/10.1038/ngeo1477>.
- Githaiga, M.N., J.G. Kairo, L. Gilpin, and M. Huxham. 2017. Carbon storage in the seagrass meadows of Gazi Bay. *Kenya. Plos One* 12: e0177001. <https://doi.org/10.1371/journal.pone.0177001>.
- Githaiga, M.N., A.M. Frouws, J.G. Kairo, and M. Huxham. 2019. Seagrass removal leads to rapid changes in fauna and loss of carbon. *Frontiers in Ecology and Evolution*. <https://doi.org/10.3389/fevo.2019.00062>.
- Gasly, T.M., S.L. Taylor, and G.P. Housefield. 2015. Factors influencing the growth of seagrass seedlings: A case study of *Posidonia australis*. *Aquatic Botany* 120: 251–259. <https://doi.org/10.1016/j.aquabot.2014.09.003>.
- Government of Kenya. 2001. *The Fisheries Act (No. 378). The Gazette Notice of 9th September 2001, No. 7565, CIII on Imposition of management measures*. Nairobi: Government Printer.
- Government of Kenya. 2020. *Kenya's Update Nationally Determined Contributions (NDCs)*. Nairobi: Ministry of Environment and Forestry.
- Green, A.E., R.K.F. Unsworth, M.A. Chadwick, and P.J.S. Jones. 2021. Historical analysis exposes catastrophic seagrass loss for the United Kingdom. *Frontiers in Plant Science*. <https://doi.org/10.3389/fpls.2021.629962>.
- Green, E.P., and F. Short. 2003. *World atlas of seagrasses*. Berkeley, USA.: University of California Press.
- Gullstrom, M., M. de la Torre Castro, S.O. Bandeira, M. Bjork, M. Dahlberg, N. Kautsky, and M. Ohman. 2002. Seagrass ecosystems in the Western Indian Ocean. *Ambio* 31: 588–596. <https://doi.org/10.1579/0044-7447-31.7.588>.
- Gullström, M., B. Lundén, M. Bodin, J. Kangwe, M. Öhman, M. Mtolera, and M. Björk. 2006. Assessment of changes in the seagrass-dominated submerged vegetation of tropical Chwaka Bay (Zanzibar) using satellite remote sensing. *Estuarine, Coastal and Shelf Science* 67: 399–408. <https://doi.org/10.1016/j.ecss.2005.11.020>.
- Gullström, M., T. Lyimo, J. Eklöf, M. Björk, S. Semesi, and M. Torre-Castro. 2012. Seagrass meadows in Chwaka Bay: Socio-ecological and management aspects. In *People, Nature and Research in Chwaka Bay, Zanzibar, Tanzania*, ed. M. de la Torre-Castro and T.J. Lyimo, 89–109. WIOMSA: United Republic of Tanzania.
- Hachani, M., B. Ziadi, H. Langar, D. Sami, S. Turki, and L. Aleya. 2016. The mapping of the *Posidonia oceanica* (L.) Delile barrier reef meadow in the southeastern Gulf of Tunis (Tunisia). *Journal of African Earth Sciences*. <https://doi.org/10.1016/j.jafrearsci.2016.05.030>.
- Hantanirina, J., and S. Benbow. 2013. Diversity and coverage of seagrass ecosystems in south-west Madagascar. *African Journal of Marine Science* 35: 291–297. <https://doi.org/10.2989/1814232X.2013.800580>.
- Harcourt, W.D., R.A. Briers, and M. Huxham. 2018. The thin(ning) green line? Investigating changes in Kenya's seagrass coverage. *Biology Letters*. <https://doi.org/10.1098/rsbl.2018.0227>.
- Herrera, M., A. Tubío, P. Pita, E. Vázquez, C. Olabarria, C.M. Duarte, and S. Villasante. 2022. Trade-offs and synergies between seagrass ecosystems and fishing activities: a global literature review. *Frontiers in Marine Science*. <https://doi.org/10.3389/fmars.2022.781713>.
- Hossain, M.S., J.S. Bujang, M.H. Zakaria, and M. Hashim. 2014. The application of remote sensing to seagrass ecosystems: An overview and future research prospects. *International Journal of Remote Sensing* 36 (1): 61–114. <https://doi.org/10.1080/01431161.2014.990649>.
- Hossain, M.S., J.S. Bujang, M.H. Zakaria, and M., H. 2015. Application of Landsat images to seagrass areal cover change analysis for Lawas, Terengganu and Kelantan of Malaysia. *Continental Shelf Research* 110: 124–148.
- Ingram, J., and T. Dawson. 2001. The impacts of a river effluent on the coastal seagrass habitats of Mahé, Seychelles. *South African Journal of Botany* 67: 483–487. [https://doi.org/10.1016/S0254-6299\(15\)31167-4](https://doi.org/10.1016/S0254-6299(15)31167-4).
- IPCC. 1997. *The Regional Impacts of Climate Change: An Assessment of Vulnerability*, 517. UK: Cambridge University Press, UK.
- Iyer, V., and A. Barnabas. 1993. Effects of varying salinity on leaves of *Zostera capensis* Setchell. *I. Ultrastructural Changes. Aquatic Botany* 46: 141–153. [https://doi.org/10.1016/0304-3770\(93\)90042-U](https://doi.org/10.1016/0304-3770(93)90042-U).
- Jayathilake, D., and M. Costello. 2018. A modelled global distribution of the seagrass biome. *Biological Conservation* 226: 120–126. <https://doi.org/10.1016/j.biocon.2018.07.009>.
- Kennedy, H., J. Beggins, C.M. Duarte, J.W. Fourqurean, M. Holmer, N. Marbà, and J.J. Middelburg. 2010. Seagrass sediments as a global carbon sink: isotopic constraints. *Global Biogeochemical Cycles*, 24.
- Kennedy, H., J. Pagès, D. Lagomasino, A. Arias-Ortiz, P. Colarusso, J. Fourqurean, M. Githaiga, J. Howard, D. Krause-Jensen, T. Kuwae, P. Lavery, P. Macreadie, N. Marba, P. Masqué, I. Mazarrasa, T. Miyajima, O. Serrano, and C. Duarte. 2022. Species traits and geomorphic setting as drivers of global soil carbon stocks in seagrass meadows. *Global Biogeochemical Cycles*. <https://doi.org/10.1029/2022GB007481>.
- Knudby, A., C. Newman, Y. Shaghude, and C. Muhando. 2010. Simple and effective monitoring of historic changes in nearshore environments using the free archive of Landsat imagery. *International Journal of Applied Earth Observation and Geoinformation* 12: S116–S122. <https://doi.org/10.1016/j.jag.2009.09.002>.
- Komatsu, T., M. Hashim, N. Nurdin, T. Noiraksar, A. Prathep, M. Stankovic, T. Phuoc, T. Phuoc Hoang Son, P. Minh-Thu, C. Luong, S. Wouthuyzen, S. Phauk, A.M. Muslim, N. Yahya, G. Terauchi, T. Sagawa, and K. Hayashizaki. 2020. Practical mapping methods of seagrass beds by satellite remote sensing and ground truthing. *Coastal Marine Science* 43: 1–25. <https://doi.org/10.15083/00079480>.
- Lal, A., R. Arthur, N. Marba, A.W.T. Lill, and T. Alcoverro. 2010. Implications of conserving an ecosystem modifier: Increasing green turtle (*Chelonia mydas*) densities substantially alters seagrass meadows. *Biological Conservation* 143 (11): 2730–2738. <https://doi.org/10.1016/j.biocon.2010.07.020>.
- Lamb, J.B., J.A.J.M. van de Water, D.G. Bourne, C. Altier, M.Y. Hein, E.A. Fiorenza, N. Abu, J. Jompa, and C.D. Harvell. 2017. Seagrass ecosystems reduce exposure to bacterial pathogens of humans, fishes, and invertebrates. *Science* 355: 731–733. <https://doi.org/10.1126/science.aal1956>.
- Lyimo, T.J., E.F. Mvungi, and Y.D. Mgya. 2008. Abundance and diversity of seagrass and macrofauna in the intertidal areas with and without seaweed farming activities on the east coast of Zanzibar. *Tanzania Journal of Science*. <https://doi.org/10.4314/tjs.v34i1.44287>.
- Macreadie, P., J. Jarvis, S. Trevathan-Tackett, and A. Bellgrove. 2018. Seagrasses and macroalgae: importance, vulnerability and impacts. In *Climate change impacts on fisheries and aquaculture*

- a global analysis, vol. 1, 729–770. Chichester, England: John Wiley & Sons.
- Marbà, N., R. Santiago, E. Díaz-Almela, E. Álvarez, and C.M. Duarte. 2006. Seagrass (*Posidonia oceanica*) vertical growth as an early indicator of fish farm-derived stress. *Estuarine, Coastal and Shelf Science* 67: 475–483. <https://doi.org/10.1016/j.ecss.2005.11.034>.
- March, A., and P. Failler. 2022. Small-scale fisheries development in Africa: Lessons learned and best practices for enhancing food security and livelihoods. *Marine Policy* 136: 104925. <https://doi.org/10.1016/j.marpol.2021.104925>.
- McKenzie, L.J., L.M. Nordlund, B.L. Jones, L.C. Cullen-Unsworth, C. Roelfsema, and R.K.F. Unsworth. 2020. The global distribution of seagrass meadows. *Environmental Research Letters* 15 (7): 074041. <https://doi.org/10.1088/1748-9326/ab7d06>.
- Mead, A., C.L. Griffiths, G.M. Branch, C.D. McQuaid, L.K. Blamey, J.J. Bolton, R.J. Anderson, F. Dufois, M. Rouault, P.W. Froneman, A.K. Whitfield, L.R. Harris, R. Nel, D. Pillay, and J.B. Adams. 2013. Human-mediated drivers of change — impacts on coastal ecosystems and marine biota of South Africa. *African Journal of Marine Science* 35 (3): 403–425. <https://doi.org/10.2989/1814232X.2013.830147>.
- Moreira-Saporiti, A., D. Hoeijmakers, F.E. Msuya, H. Reuter, and M. Teichberg. 2021. Seaweed farming pressure affects seagrass and benthic macroalgae dynamics in Chwaka Bay (Zanzibar, Tanzania): Regional Environmental Change. <https://doi.org/10.1007/s10113-020-01742-2>.
- Msuya, F.E., J. Bolton, F. Pascal, K. Narrain, B. Nyonje, and E.J. Cottier-Cook. 2022. Seaweed farming in Africa: Current status and future potential. *Journal of Applied Phycology* 34 (2): 985–1005. <https://doi.org/10.1007/s10811-021-02676-w>.
- Musembi, P., B. Fulanda, J. Kairo, and M. Githaiga. 2019. Species composition, abundance and fishing methods of small-scale fisheries in the seagrass meadows of Gazi Bay, Kenya. *Journal of the Indian Ocean Region* 15 (2): 139–156. <https://doi.org/10.1080/19480881.2019.1603608>.
- Mvungi, E., and D. Pillay. 2019. Eutrophication overrides warming as a stressor for a temperate African seagrass (*Zostera capensis*). *PLoS ONE* 14: e0215129. <https://doi.org/10.1371/journal.pone.0215129>.
- Orth, R., T. Carruthers, W. Dennison, C. Duarte, J. Fourqurean, L. Heck Jr., and K. Hughes, A., Kendrick, G., Kenworthy, W., Olyarnik, S., Short, F., Waycott, M., & Williams, S. 2006. A global crisis for seagrass ecosystems. *BioScience* 56: 987–996. [https://doi.org/10.1641/0006-3568\(2006\)56\[987:AGCFSE\]2.0.CO;2](https://doi.org/10.1641/0006-3568(2006)56[987:AGCFSE]2.0.CO;2).
- Phair, N., R. Toonen, I. Knapp, and S. von der Heyden. 2020. Anthropogenic pressures negatively impact genomic diversity of the vulnerable seagrass *Zostera capensis*. *Journal of Environmental Management* 255: 109831. <https://doi.org/10.1016/j.jenvman.2019.109831>.
- Pillay, D., G. Branch, C.L. Griffiths, C. Williams, and A. Prinsloo. 2010. Ecosystem change in a South African marine reserve (1960–2009): role of seagrass loss and anthropogenic disturbance. *Marine Ecology-progress Series*. <https://doi.org/10.3354/meps08733>.
- Poonian, C.N.S., K. Tuharska, and M.D. Hauzer. 2016. Diversity and distribution of seagrasses in the Union of the Comoros. *African Journal of Marine Science* 38: 1–6. <https://doi.org/10.2989/1814232X.2016.1181103>.
- Potouroglou, M., J.C. Bull, K.W. Krauss, H.A. Kennedy, M. Fusi, D. Daffonchio, M.M. Mangora, M.N. Githaiga, K. Diele, and M. Huxham. 2017. Measuring the role of seagrasses in regulating sediment surface elevation. *Scientific Reports* 7: 11917. <https://doi.org/10.1038/s41598-017-12354-y>.
- Pruckner, S., J. Bedford, L. Murphy, J.A. Turner, and J. Mills. 2022. Adapting to heatwave-induced seagrass loss: prioritizing management areas through environmental sensitivity mapping. *Estuarine, Coastal and Shelf Science*. <https://doi.org/10.1016/j.ecss.2022.107857>.
- Purvis, D., and N. Jiddawi. 2023. Seagrass cover reduction in Zanzibar from 2006 to 2019. *Western Indian Ocean Journal of Marine Science*. <https://doi.org/10.4314/wiojms.v22i1.1>.
- Ralph, P.J., D. Tomasko, K. Moore, S. Seddon, and C.M.O. Macinnis-Ng. 2006. Human impacts on seagrasses: Eutrophication, sedimentation, and contamination. In *Seagrasses: Biology, Ecology and Conservation*, ed. A.W.D. Larkum, R.J. Orth, and C.M. Duarte, 567–593. Netherlands: Springer.
- ResilienSea. (2023). Seagrasses in West Africa. Retrieved from <https://resiliensea.org/>
- Riegl, B., and W. Piller. 2000. Mapping of benthic habitats in northern Safaga Bay (Red Sea, Egypt): A tool for proactive management. *Aquatic Conservation-Marine and Freshwater Ecosystems - AQUAT CONSERV* 10: 127–140. [https://doi.org/10.1002/\(SICI\)1099-0755\(200003/04\)10:23.O.CO;2-L](https://doi.org/10.1002/(SICI)1099-0755(200003/04)10:23.O.CO;2-L).
- Runfola, D., A. Anderson, H. Baier, M. Crittenden, E. Dowker, S. Fuhrig, S. Goodman, G. Grimsley, R. Layko, G. Melville, M. Mulder, R. Oberman, J. Panganiban, A. Peck, L. Seitz, S. Shea, H. Slevin, R. Youngerman, and L. Hobbs. 2020. geoBoundaries: A global database of political administrative boundaries. *PLoS ONE* 15 (4): e0231866. <https://doi.org/10.1371/journal.pone.0231866>.
- Samoyls, M., G. Maina, and K. Osuka. 2011. *Artisanal fishing gears of the Kenyan coast*.
- Short, F., T.J.B. Carruthers, W.C. Dennison, and M. Waycott. 2007. Global seagrass distribution and diversity: A bioregional model. *Journal of Experimental Marine Biology and Ecology* 350: 3–20. <https://doi.org/10.1016/j.jembe.2007.06.012>.
- Short, F., B. Polidoro, S.R. Livingstone, K.E. Carpenter, S. Bandeira, J.S. Bujang, H.P. Calumpang, T.J.B. Carruthers, R.G. Coles, W.C. Dennison, P.L.A. Erfteimeijer, M.D. Fortes, A.S. Freeman, T.G. Jagtap, A.H.M. Kamal, G.A. Kendrick, W. Judson Kenworthy, Y.A. La Nafie, I.M. Nasution, R.J. Orth, A. Prathep, J.C. Sanciangco, B. Tussenbroek, and v., Vergara, S. G., Waycott, M., & Zieman, J. C. 2011. Extinction risk assessment of the world's seagrass species. *Biological Conservation* 144 (7): 1961–1971. <https://doi.org/10.1016/j.biocon.2011.04.010>.
- Sievers, M., C.J. Brown, V.J.D. Tulloch, R.M. Pearson, J.A. Haig, M.P. Turschwell, and R.M. Connolly. 2019. The role of vegetated coastal wetlands for marine megafauna conservation. *Trends in Ecology & Evolution* 34: 807–817. <https://doi.org/10.1016/j.tree.2019.04.004>.
- Talbot, M., and G. Bate. 1987. The Distribution and biomass of the seagrass *Zostera capensis* in a warm-temperate estuary. *Botanica Marina* 30: 91–99. <https://doi.org/10.1515/botm.1987.30.1.91>.
- Telesca, L., A. Belluscio, A. Criscoli, G. Ardizzone, E. Apostolaki, S. Frascetti, M. Gristina, K. Leyla, C. Martin, G. Pergent, A. Alagna, F. Badalamenti, G. Garofalo, V. Gerakaris, M.L. Zammit Pace, C. Pergent-Martini, and M. Salomidi. 2015. Seagrass meadows (*Posidonia oceanica*) distribution and trajectories of change. *Scientific Reports*. <https://doi.org/10.1038/srep12505>.
- Traganos, D., A.P. Pertiwi, C.B. Lee, A. Blume, D. Poursanidis, and A. Shapiro. 2022. Earth observation for ecosystem accounting: Spatially explicit national seagrass extent and carbon stock in Kenya, Tanzania, Mozambique and Madagascar. *Remote Sensing in Ecology and Conservation* 8 (6): 778–792. <https://doi.org/10.1002/rse2.287>.
- Uku, J., L. Daudi, C. Muthama, V. Alati, A. Kimathi, and S. Ndirangu. 2021. Seagrass restoration trials in tropical seagrass meadows of Kenya. *Western Indian Ocean Journal of Marine Science* 22 (1): 1–14. <https://doi.org/10.4314/wiojms.v20i2.6>.
- UNEP. 2020. *Protecting Seagrass Through Payments for Ecosystem Services: A Community Guide*. Nairobi, Kenya.: UNEP

- UNEP-WCMC, and F.T. Short, eds. 2021. *Global distribution of seagrasses (version 7.1)*. Cambridge (UK): UN Environment World Conservation Monitoring Centre.
- Unsworth, R., L. Nordlund, and L. Cullen-Unsworth. 2018. Seagrass meadows support global fisheries production. *Conservation Letters* 12: e12566. <https://doi.org/10.1111/conl.12566>.
- Unsworth, R., L.J. McKenzie, C.J. Collier, L.C. Cullen-Unsworth, C.M. Duarte, J.S. Eklöf, J.C. Jarvis, B.L. Jones, and L.M. Nordlund. 2019. Global challenges for seagrass conservation. *Ambio* 48 (8): 801–815. <https://doi.org/10.1007/s13280-018-1115-y>.
- Vela, A., V. Pasqualini, V. Leoni, A. Djelouli, H. Langar, G. Pergent, C. Pergent-Martini, L. Ferrat, M. Ridha, and H. Djabou. 2008. Use of SPOT 5 and IKONOS imagery for mapping biocenoses in a Tunisian Coastal Lagoon (Mediterranean Sea). *Estuarine, Coastal and Shelf Science* 79: 591–598. <https://doi.org/10.1016/j.ecss.2008.05.014>.
- Wallner-Hahn, S., M. de la Torre-Castro, J.S. Eklöf, M. Gullström, N.A. Muthiga, and J. Uku. 2015. Cascade effects and sea-urchin overgrazing: An analysis of drivers behind the exploitation of sea urchin predators for management improvement. *Ocean & Coastal Management* 107: 16–27. <https://doi.org/10.1016/j.ocecoaman.2015.01.010>.
- Wallner-Hahn, S., M. Dahlgren, and M. de la Torre-Castro. 2022. Linking seagrass ecosystem services to food security: The example of southwestern Madagascar's small-scale fisheries. *Ecosystem Services* 53: 101381. <https://doi.org/10.1016/j.ecoser.2021.101381>.
- Wasserman, J., L. Claassens, and J.B. Adams. 2020. Mapping subtidal estuarine habitats with a remotely operated underwater vehicle (ROV). *African Journal of Marine Science* 42 (1): 123–128. <https://doi.org/10.2989/1814232X.2020.1731598>.
- Waycott, M., C.M. Duarte, T.J. Carruthers, R.J. Orth, W.C. Dennison, S. Olyarnik, A. Calladine, J.W. Fourqurean, K.L. Heck Jr., A.R. Hughes, G.A. Kendrick, W.J. Kenworthy, F.T. Short, and S.L. Williams. 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. *Proceedings of the National Academy of Sciences* 106 (30): 12377–12381. <https://doi.org/10.1073/pnas.0905620106>.
- Wegoro, J., S. Pamba, R. George, Y. Shaghude, J. Hollander, and B. Lugendo. 2022. Seagrass restoration in a high-energy environment in the Western Indian Ocean. *Estuarine, Coastal and Shelf Science* 278: 108119. <https://doi.org/10.1016/j.ecss.2022.108119>.