Section 4

Subchapter 6B

Erosion and sedimentation

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Key points

- Global and regional coastal erosion and sedimentation assessments based on satellite data have proliferated since the mid-2010s, offering insights into trends and patterns of change. However, uncertainties and limitations of satellite-derived methods must be carefully considered.
- People, property and economic activities are increasingly exposed to coastal flooding and erosion across all latitudes, which is often associated with climate change impacts.
- The literature has been focused more on coastal erosion than on sedimentation changes.
- Growing evidence suggests that coastal erosion in the Arctic is intensifying due to permafrost thaw and increased wave action. This accelerated erosion is releasing large amounts of nutrients into the Arctic Ocean, with potential implications for carbon sequestration and marine ecosystems.
- Nature-based solutions, such as the renaturalization of floodplains and intertidal areas, are increasingly being applied to catchments and coastal regions in the northern hemisphere. While such measures can improve long-term resilience, they may lead to rapid short-term changes.

1. Introduction

The present subchapter contains a summary of key findings published from 2018 to2023 concerning trends and changes in erosion and sedimentation processes that might affect the world's oceans, highlighting major changes from previous *World Ocean Assessments*. In the first *Assessment*, key processes related to erosion and sedimentation are discussed in chapter 26. In the second *Assessment*, the topic is featured more prominently in chapter 13, which contains summaries of key findings concerning each ocean region in dedicated subsections.

Previous *World Ocean Assessments* have been focused mostly on coastal areas rather than erosion and sedimentation changes at sea, with a greater emphasis on erosion due to a bias in the literature. The first *Assessment* contains a detailed discussion of anthropogenic pressures, particularly the extent and impacts of land reclamation and catchment disturbances. In the second *Assessment*, emphasis is placed on global assessments of shoreline change using satellite-derived data (Luijendijk and others, 2018).

During the period covered by the third *World Ocean Assessment*, there was an increase in satellite-derived shoreline change assessments at the global, regional and local (Konstantinou and others, 2023; Vos and others, 2023a, 2023b; Bishop-Taylor and others, 2021; Mao and others, 2021; Konlechner and others, 2020; Mentaschi and others, 2018). Satellites can be used to bridge gaps in data availability in difficult-to-reach areas and cover large areas. However, the methods and algorithms used to extract shoreline positions vary and have intrinsic limitations (Warrick and others, 2024) that must be fully appreciated before results are used to inform policy or decision-making, particularly at the local level. It is also important to understand that magnitudes and rates of change are specific to time intervals and geographical locations, varying greatly in space and time and according to averaging and aggregation methods.

2. Environmental change since the second *World Ocean Assessment*

Pressures due to human interventions and climate change impacts continue to influence coastal erosion and sedimentation patterns (Cabana and others, 2023). Global warming is projected to exacerbate conditions along coasts due to sea level rise and more extreme weather conditions, strengthening storm surges, winds and waves (Ewans and Jonathan, 2023; Narita and others, 2024). Such changes are discussed in detail in section 4, chapter 3 and in subsection 5B, chapter 4. Polar regions, particularly the Arctic, are fast-changing. Sea ice protects high-latitude shorelines and sediment deposited on continental shelves from wave action. In polar regions, coastal erosion results from increased wave exposure caused by reduced sea-ice cover, prolonged ice-free seasons or permafrost thaw. These effects have been linked to global warming (Cassidy and others, 2024; Irrgang and others, 2022).

Changes in wind direction and speed influence cross- and long-shore currents and, by extension, sediment transport, affecting coastal erosion and sedimentation (Ibaceta and others, 2023). Coastal erosion is projected to increase in many areas due to sea level rise and increased wave activity (López-Olmedilla and others, 2022; Ranasinghe and others, 2023; Dong and others, 2024). Potential impacts of coastal erosion include habitat, property and land loss, destruction of cultural and natural heritage, migration and other economic losses (Pouye and others, 2024; Solihuddin and others, 2024; Thepsiriamnuay and Pumijumnong, 2024), as detailed in section 4, chapter 5. On some coasts, sedimentation may increase (Anderson and others, 2022) due sediment supplied by rivers (Yoon and others, 2023).

Coastal development disrupts or alters local sediment budget, often triggering or worsening coastal erosion (Wang and others, 2022; Saengsupavanich and others, 2024; see also subsect. 5A, chap. 9). Nature-based solutions, including restoration of mangroves (Uddin and others, 2022) and coastal marshes (Fairchild and others, 2021), have been a preferred approach (van der Meulen and others, 2023) to mitigating coastal erosion and promoting shoreline accretion.

Changes in the overall status

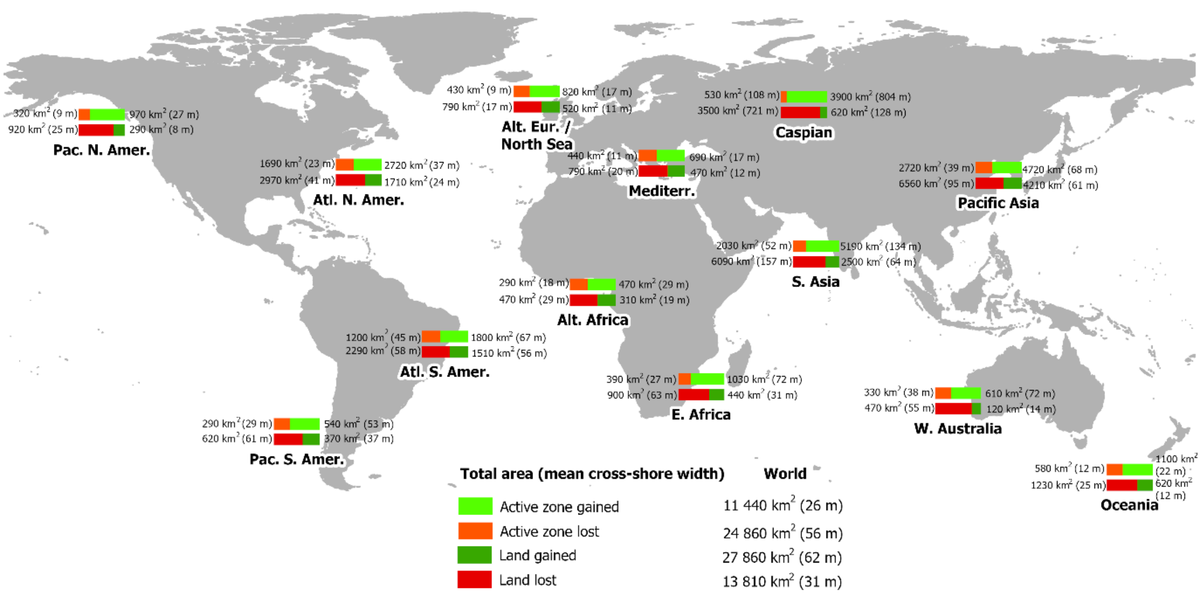
Research continues to unveil the magnitude of anthropogenic disturbances on the sediment cycle and fluxes. Between 1950 and 2010, soil erosion caused by human activities more than quadrupled the mobilization of fluvial sediment, while supply from land to the coast reduced by 23%, mostly due to retention in dams (Syvitski and others, 2022). Natural variability contributes to a very small proportion of these changes.

Shoreline changes are determined by regional drivers and site-specific factors, including geomorphological settings and human activities (Pang and others, 2023). Human activities areas are a main cause of the largest shoreline changes observed worldwide (Luijendijk and others, 2018; Mentaschi and others, 2018), while natural cycles, such as El Niño/Southern Oscillation (Vos and others, 2023b) and major hazards, such as cyclones and tsunamis (Bozzeda and others, 2023) can have important effects at the regional and local scales. Although global and regional assessments of shoreline change have been published, the methods used in those assessments differ, preventing comparative analysis of results.

Using satellite data but different methods, Luijendijk and others (2018) assessed sandy beaches worldwide, while Mentaschi and others (2018) covered all coastal typologies (although parts of the South-West Pacific and polar regions were excluded). The aggregated results of the former identified overall erosion for Australasia and Africa and mean accretion for other continents, while the latter reported net land loss in all continents and regions (net global loss of 14,050 km^2, see the figure below). Based on field data from 315 sandy beaches, Bozzeda and others (2023) indicated that 21% were intensely eroding, similar to the findings by Luijendijk and others (2018), but they diverge on the proportion of stable and accreted beaches.

Figure

Mean regional losses and gains of coastal (dry) land and active (intermittently wet, including intertidal) areas and mean cross-shore width change, 1984–2015



Source: Based on satellite data; adapted from Mentaschi and others (2018).

Globally, there has been a transition from hard engineering solutions towards integrated, sustainable approaches that merge natural, technological and community-driven inputs. Combined with ecosystem-based management, these approaches are considered to enhance resilience to climate change impacts (Gebrael and others, 2024; van Westen and others, 2024). Arguably, this is one of the most crucial changes in recent years due to the effects on both short and long-term local coastal responses. Growing interest in nature-based solutions stems from a better understanding of the undesired consequences of coastal engineering on natural coastal dynamics.

3. Region-specific changes

Arctic Ocean

The Arctic has warmed faster than other regions since the mid-1960s (England and others, 2021), almost four times faster than the global average over the period 1979–2021 (Rantanen and others, 2022). Sea-ice cover has been declining for the past 46 years (Irrgang and others, 2022). It is well-established that Arctic coastlines are eroding, with growing evidence suggesting acceleration. These rapid changes in the Arctic threaten settlements, infrastructure, traditional lifestyles and archaeological sites (Irrgang and others, 2022).

Nutrient and sediment fluxes are changing due to release from melting ice, eroding permafrost and increased wave interactions with the seabed. Predicting the rates and magnitudes of change is difficult (Irrgang and others, 2022) due to complex air-ice-sea interactions and the increased supply from river discharge due to land ice melt. Emerging research suggests positive feedback between carbon release from melting permafrost and global warming, as higher input of carbon into coastal waters reduces their potential to absorb atmospheric carbon (Manizza, 2024; Nielsen and others, 2022).

North Atlantic Ocean, Baltic Sea, Black Sea, Mediterranean Sea and North Sea

Erosion and sedimentation rates on the Baltic coast vary due to isostatic uplifting in the north and subsiding in the south, which contributed to accretion and erosion, respectively, at rates higher than 1 m/year over the period 2007–2017 (Weisse and others, 2021). Based on satellite data validated with field measurements, Castelle and others (2024) estimated that sandy European shores on the Atlantic accreted at a mean rate of 0.21 m/year over the period 1984–2021, although coasts exposed to high wave energy (such as those in northwest France and in Portugal) are prone to long-term erosion. The Mediterranean coast experiences moderate erosion rates of 0.4–1.0 m/year due to sea level rise and human activity, particularly along coasts undergoing subsidence (Vecchio and others, 2024). Using satellite data from 1984 to 2017, Tătui and others (2019) reported that 68% of the Black Sea coast was stable, with erosion exceeding 1 m/year along 19% of the coast, mostly in Georgia, Romania, Ukraine, and low-lying areas affected by severe storms.

South Atlantic Ocean and wider Caribbean

Studies on erosion and sedimentation changes in the South Atlantic are site-specific. The region’s diverse coasts face challenges from catchment changes (Riquetti and others, 2022), limited sediment input from rivers (Oliveira and others, 2023) and beach sand extraction (Pilkey and others, 2022). Storms threaten infrastructure and populations across the region (Serafim and others, 2019; Queiroz and others, 2022; Isla and Cortizo, 2023).

In West Africa, research highlights natural and anthropogenic factors driving coastal changes mostly in Ghana, Nigeria and Senegal (Ankrah and others, 2023). Delta morphology, sedimentation, fisheries and habitats are affected by changes in river discharge and sediment supply, including in the Volta and the Niger Deltas (Ideki and Ajoku, 2024), but limited data hinder comprehensive understanding.

Caribbean small island States face coastal erosion and sedimentation issues triggered by hurricanes and sea level rise, which reduce the natural protection offered by beaches, mangroves and reefs, as observed in The Bahamas and Jamaica (Rangel-Buitrago and others, 2018). The Caribbean Disaster Emergency Management Agency is a key player in regional risk reduction measures, including nature-based solutions (Rhiney and Baptiste, 2019).

Indian Ocean, Arabian Sea, Bay of Bengal, Red Sea, Gulf of Aden and Persian Gulf

There is limited literature in English covering erosion and sedimentation in this diverse ocean region. Available data are mostly from local or global assessments, which limits comparative analysis. Coastal variability due to changing sediment supply from rivers has been identified in Bangladesh, India, Indonesia, Malaysia and Sri Lanka, with an increasing tendency for erosion where downstream sediment transfer is disrupted (Syvitski and others, 2022). Ecological damage to wetlands, particularly mangroves, has been linked to coastal erosion due to disruption of sediment transfers.

Impacts from human activities on erosion and sedimentation have been reported across the Indian Ocean region. Recent large-scale activities include the Mumbai Coastal Road Project in India, involving extensive land reclamation protected by a seawall (Movik and others 2023), and the Jakarta Sea Wall in Indonesia, which is an effort to protect against the combined impacts of subsidence and climate change (Purnomo and others 2024).

North Pacific Ocean

Coastal erosion is a constant threat in the North Pacific, especially on densely populated and economically significant coastlines (Dong and others, 2024; Siringan and others, 2024; Vitousek and others, 2023; Yum and others, 2023; Cai and others, 2022). According to the "State of the Global Climate 2023" report prepared by the World Meteorological Organization, the Pacific Ocean is experiencing rates of sea level rise faster than the global average. Sea level rise can trigger or increase erosion (Siringan and others, 2024; Vitousek and others, 2023), which is already a critical problem due to artificial sediment retention in many Asian rivers (Binh and others, 2020), and is exacerbated by land subsidence in some locations (Siringan and others, 2024). Studies have shown that tropical cyclones have intensified in recent decades (Li and others, 2023; Xu and others, 2024) likely due to climate change (Bloemendaal and others, 2022; Wood and others, 2023), often linked to extreme erosion events. Projections indicate that the mean wave height in the region should decrease by the end of the century (Casas-Prat and others, 2024).

Sea level changes along the North Pacific coasts are highly affected by changes in oceanic circulation (Cha and others, 2023) and sea temperature (Ran and others, 2023). From 1960 to 2013, extreme sea level events along the North-West Pacific coasts were 1.5 to 2 times more intense and lasted longer than the ones recorded along the Eastern Pacific (Fan and Du, 2023).

South Pacific Ocean

Systematic assessments of the longer South Pacific coasts have been undertaken (Thom and others, 2018; Bishop-Taylor and others, 2021; Dickson and others, 2021; Vallarino-Castillo and others, 2024). However, the diverse morphology across the South Pacific islands confounds the characterization of erosion patterns (Nunn and others, 2020), except through aggregated assessment (Vos and others, 2023a). There is a strong awareness of erosion and land loss related to sea level rise in the region, particularly for low-lying atolls, such as Tuvalu (Harun-al-rashid and others, 2023).

El Niño and La Niña have regional effects across the South Pacific (Vos and others, 2023(b)), influencing prevailing winds, storm incidence, sea levels and wave conditions (Vallarino-Castillo and others, 2024). More energetic conditions occur during El Niño phases in the eastern half of the South Pacific, and during La Niña in the western half, affecting the distribution of erosion pressures across the region (Ramsay, 2011; Vos and others, 2023b). In recent decades, La Niña phases have had greater influence, and, perhaps coincidentally, there have been exceptional storm events in the western South Pacific, including tropical cyclone Gabrielle in New Zealand in 2023 and multiple storms affecting the east coast of Australia from 2016 to 2024 (Turner and others, 2024).

Southern Ocean

In the Southern Ocean, ice-cover changes show high temporal and spatial variability within an overall trend of net increase over the period 1979–2020 (Reid and Massom, 2022), except on the Amundsen-Bellingshausen Seas (West Antarctica), despite an emerging positive trend since 2007 (Parkinson, 2019). Based on sea-ice extent, the maximum length of coastal exposure in Antarctica decreased 30 km per year over the period 1979–2020 (Reid and Massom, 2022). However, sea-ice cover reached record minima in February 2022, 2023 and 2024 (Riordon, 2024), remaining persistently low in recent years. It is too soon to know whether this is a temporary fluctuation (Riordon, 2024) or the inception of a new state in the Southern Ocean triggered by long-term global warming (Purich and Doddridge, 2023; Eayrs and others, 2021).

4. Key remaining knowledge and capacity gaps and new gaps

The bias in research coverage and volume persists, with large gaps in the global South, where insufficient generation, transmission and use of reliable in situ data are pervasive, despite emerging or growing research in parts of South America, Africa and South-East Asia. As nature-based risk reduction approaches become increasingly popular, a deeper understanding of the applicability of and uncertainties surrounding ecosystem-based management in different geographical contexts is required (Gracia and others, 2018; Doelle and Puthucherril, 2023). Post-erosion recovery efforts often lack sufficient research, leading to vulnerability to future events (Garzon and others, 2024). The practice of integrating Indigenous knowledge and scientific data must be expanded to improve the understanding of site-specific socioenvironmental systems and promote cooperation among stakeholders (Loch and Riechers, 2021).

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