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Review Article

Environmental Impacts of Israel's Ongoing War of Genocide and Ethnic Cleansing (2023-2026) on the Marine Ecosystem of the Gaza Strip, Palestine

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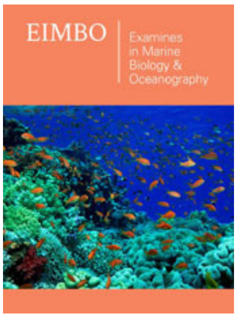

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Abstract

The Gaza Strip, located along the southeastern Mediterranean coast, supports marine ecosystems of high ecological and socioeconomic importance. Prior to October 2023, these ecosystems were already under chronic environmental stress due to inadequate wastewater treatment, persistent marine pollution, habitat degradation, overfishing, and long-standing infrastructural constraints. However, the ongoing Israeli war of genocide and ethnic cleansing (2023-2026) has dramatically intensified these pressures, leading to unprecedented deterioration of marine and coastal environments. This study presents a qualitative environmental assessment of the war's impacts on the marine ecosystem of the Gaza Strip through the synthesis of scientific literature, institutional reports, fisheries data, environmental assessments, and field observations, with comparisons between pre-war and wartime conditions.

The findings indicate severe degradation in marine water quality driven by the collapse of wastewater treatment systems and the discharge of large volumes of untreated sewage, mixed hazardous effluents, and solid waste. Significant ecological consequences include sediment contamination, habitat degradation, biodiversity loss, disruption of ecosystem functioning, and the near-total collapse of fisheries and aquaculture sectors. The generation of more than 68 million metric tons of war-related rubble containing hazardous materials has further intensified contamination risks, with potential long-term impacts on marine sediments and food webs. In addition, oceanographic connectivity raises concerns regarding possible transboundary environmental effects across the southeastern Mediterranean Sea. While war-derived debris presents a major environmental burden, carefully decontaminated materials may offer future opportunities for ecological restoration through artificial reef and coastal rehabilitation initiatives. The study concludes that the environmental consequences of the ongoing war extend far beyond immediate humanitarian impacts, representing a severe case of marine ecosystem degradation with long-term regional implications. Comprehensive environmental remediation, habitat restoration, infrastructure rehabilitation, and sustained monitoring are essential for future ecological recovery.

Keywords: Mediterranean Sea; Gaza strip; Marine ecosystem; Environmental impacts; Wastewater discharge; Sediment contamination; Coastal habitats; Biodiversity loss; Fisheries collapse; Aquaculture; Wadi Gaza; Al-Mawasi; Ecological restoration; Artificial reefs; Artificial islands and Palestine

Introduction

The Gaza Strip is a Palestinian coastal territory situated along the southeastern Mediterranean Sea within the Levantine Basin (Figure 1), a region of paramount ecological significance. Despite its small area (~365km^2) and a 42-km coastline, it supports over 2.4 million inhabitants, rendering it one of the most densely populated regions globally [1,2]. This exceptional demographic pressure, paired with prolonged political instability and severe resource limitations, has historically generated profound environmental challenges across both terrestrial and marine ecosystems.

Figure 1: Map of Palestine showing the location of the Gaza Strip along the southeastern Mediterranean coast.

As an integral component of the Mediterranean Sea-a global biodiversity hotspot containing remarkable habitat diversity within less than one percent of the world's ocean surface-the coastal waters of the Gaza Strip sustain highly complex ecological networks. Despite its oligotrophic nature and high salinity, this southeastern marine system provides critical habitats for diverse marine organisms, including commercially vital fish, crustaceans, mollusks, plankton, marine reptiles, seabirds, and marine mammals. Research over the past two decades confirms that these waters support rich biological diversity despite continuous anthropogenic pressures [3-5]. Notably, various sharks, rays, and skates-taxa of global conservation concern-are routinely documented here [6-22]. Furthermore, marine reptiles like the Green Sea Turtle (*Chelonia mydas Linnaeus*, 1758) and Loggerhead Sea Turtle (*Caretta* Linnaeus, 1758) rely on these waters and sandy beaches for feeding and migration [23], underscoring the area's ecological weight within the Levantine environment. Concurrently, the rise of invasive non-indigenous species, such as the Silver-cheeked Toadfish (*Lago Cephalus sceleratus* Gmelin, 1789), has introduced severe public health risks including envenomation and fatalities, highlighting emerging socio-ecological crises [24,25].

Beyond intrinsic value, these marine ecosystems yield indispensable socioeconomic services. Historically, the fisheries sector has been a vital productive pillar, providing essential animal protein, employment, and income for tens of thousands of Gazan families [26,27]. These networks also drive nutrient cycling, shoreline stabilization, and food-web maintenance while offering profound cultural value [28]. Thus, marine degradation directly undermines regional food security, public health, and community well-being. Critically, these water resources have faced long-term structural stress from groundwater depletion, climate variability, and human activity, which have further intensified following the Israeli war of genocide and ethnic cleansing (2023-2026) [29].

This marine environment is dynamically linked to adjacent coastal interfaces, specifically the Wadi Gaza Wetland and the Al-Mawasi coastal ecosystem. Wadi Gaza, the territory's sole major wetland, acts as a primary hydrological conduit transporting freshwater, sediments, and nutrients to the sea [30], though point-source pollution within Wadi Gaza has heavily contributed to coastal contaminant loading [31]. Similarly, Al-Mawasi supports fragile dunes, sandy habitats, and agricultural lands essential to regional biodiversity and coastal stability [32,33]. Consequently, disruptions within these terrestrial systems trigger cascading degradation in neighboring marine habitats through altered sediment transport and broken habitat connectivity.

Prior to October 2023, this interconnected environment suffered from chronic, progressive ecological decay driven by a debilitating blockade, restrictions on infrastructure, rapid population growth, and resource scarcity, which systematically eroded municipal capacity and environmental resilience [34-36]. War-induced environmental crises represent a critical, long-lasting dimension of contemporary wars [37]. In the Gaza Strip, wastewater treatment plants routinely operated far below capacity due to electricity shortages, leaving monitoring programs financially and logistically paralyzed. This pre-war stress manifested in the continuous discharge of untreated or partially treated sewage, which elevated levels of microbial contamination, nutrients, organic pollutants, and heavy metals in marine waters and sediments [38-45]. This microbial pollution also introduced antibiotic-resistant bacteria (e.g., *Staphylococcus aureus*, *Pseudomonas aeruginosa*), threatening public health and bathing-water quality [46]. Yet, despite these acute stresses, the ecosystems managed to preserve baseline functionalities and sustain localized fisheries.

However, the onset of the ongoing Israeli war of genocide and ethnic cleansing (2023-2026) has completely shattered this baseline, plunging the Gaza Strip into an unprecedented humanitarian and environmental catastrophe [47]. This warfare illustrates the tragic link between Israeli war and total ecological collapse [48]. While global attention has focused on the staggering humanitarian toll, the impacts on the biophysical environment represent a profound crisis of ecocide that fundamentally redefines the region's ecological future [49-55]. The relentless destruction of wastewater treatment plants, sewage networks, desalination facilities, and municipal infrastructure has completely dismantled the Gaza Strip's environmental management capacity.

This total collapse has exponentially accelerated pollutant loads entering the Levantine Basin. Hundreds of thousands of cubic meters of untreated sewage, hazardous hospital effluents, fuel residues, and toxic solid waste are discharged daily into coastal waters [56]. This severe influx has induced acute sediment contamination and widespread benthic habitat degradation, directly threatening endangered sea turtles and native cartilaginous fish [57]. Simultaneously, this destruction has breached terrestrial and atmospheric boundaries; the forced mass displacement of millions of Palestinians into sensitive zones like the Al-Mawasi dunes and Wadi Gaza fringes has overwhelmed these landscapes with solid waste, vegetation stripping, and raw sewage [58]. Furthermore, bombardment has generated millions of tons of rubble contaminated with asbestos, heavy metals, and toxic weaponry residues, triggering severe soil and agricultural degradation [59,60] alongside hazardous atmospheric particulate pollution [61]. Compounded by the deliberate destruction of fishing harbors and aquaculture facilities, the ongoing Israeli war of genocide and ethnic cleansing (2023-2026) has dismantled local sustainable production while introducing alarming, transboundary risks across the southeastern Mediterranean basin [62,63]. Ultimately, these compounding disruptions represent one of the most severe episodes of marine and coastal ecocide in modern history, establishing a crisis that will require decades of cross-border monitoring, international accountability, and intensive ecological remediation [64,65].

Despite growing international alarm, comprehensive scientific evaluations tracking the systemic impacts of the ongoing war on marine and coastal ecosystems remain critically limited. This study aims to bridge this analytical gap by assessing the environmental impacts of the Israeli war of genocide and ethnic cleansing (2023-2026) on the marine ecosystem of the Gaza Strip through a rigorous synthesis of scientific literature, environmental reports, fisheries data, institutional assessments, and direct field observations. Particular emphasis is placed on quantifying marine pollution, mapping habitat degradation, evaluating biodiversity threats-specifically regarding data-deficient cartilaginous fishes-analyzing fisheries collapse, and projecting the long-term, transboundary ecological consequences affecting the broader southeastern Mediterranean marine environment.

Methodology

Study area

The study was conducted within the marine and coastal environment of the Gaza Strip, Palestine, extending along approximately 42km of the southeastern Mediterranean coastline (Figure 1). The study area includes nearshore marine waters, sandy beaches, coastal dunes, fishing harbors, fish landing sites, estuarine environments, Wadi Gaza Wetland, Al-Mawasi coastal ecosystems, and adjacent marine habitats. These environments collectively support diverse ecological communities and provide important ecosystem services to the Palestinian population.

Study design

This investigation employed a qualitative environmental assessment approach designed to evaluate the impacts of Israel's war of genocide and ethnic cleansing (2023-2026) on the marine ecosystem of the Gaza Strip. The study was structured as an integrative environmental review combining ecological, fisheries, pollution, and coastal-environmental information from multiple sources. Environmental conditions documented prior to October 2023 were compared with conditions observed during the war period in order to identify major environmental changes and evaluate their ecological implications.

Data sources

Data were compiled from a wide range of scientific and institutional sources, including peer-reviewed publications, environmental reports, technical assessments, governmental documents, fisheries statistics, environmental monitoring reports, and publications produced by international organizations. Major information sources included reports issued by UNEP, WHO, FAO, UNDP/PAPP, PCBS, and relevant Palestinian institutions. Additional information was obtained from published studies addressing marine pollution, biodiversity, fisheries, coastal geomorphology, environmental degradation, wastewater management, and marine conservation within the Gaza Strip. The role of citizen science and social media mining was of great importance as well in monitoring local Mediterranean biodiversity as pointed out by Rizgalla [66].

Field observations

The assessment was supplemented by field observations conducted at various times along the Gaza Strip coastline, including fishing harbors, fish landing sites, fish markets (Figure 2), coastal habitats, and environmentally affected locations whenever access and security conditions permitted. These observations were further supported by the author's long-term professional experience in marine ecology, fisheries biology, biodiversity assessment, and environmental monitoring in the Gaza Strip.

Figure 2: Field observations conducted over several decades to monitor the marine environment and marine fisheries at fish landing sites and fish markets along the Gaza Strip.

Data analysis

Collected information was reviewed, categorized, and synthesized using a thematic analytical framework. Environmental impacts were classified into major categories including marine pollution, wastewater discharge, sediment contamination, habitat degradation, biodiversity threats, fisheries disruption, aquaculture impacts, environmental consequences of displacement, and transboundary environmental effects. Comparative analysis was applied to evaluate differences between pre-war and wartime environmental conditions.

Study limitations

The study was conducted under conditions of ongoing Israeli war, restricted access to many affected locations, and limited availability of recent environmental monitoring data. Consequently, the assessment relied primarily on published scientific literature, institutional reports, documented observations, and available field evidence. Nevertheless, the integration of multiple independent information sources provided a comprehensive and scientifically robust assessment of the principal environmental impacts affecting the marine ecosystem of the Gaza Strip during the study period.

Results & Discussion

Marine water pollution and water quality deterioration

Prior to October 2023, the marine waters of the Gaza Strip were already subjected to chronic environmental degradation resulting from rapid population growth, prolonged blockade conditions, insufficient wastewater treatment capacity, recurrent electricity shortages, and restrictions on environmental infrastructure development [67-69]. These factors contributed to the continuous discharge of untreated or partially treated wastewater into the Mediterranean Sea through several coastal outfalls distributed along the Gaza Strip coastline, including Rafah, Khan Younis, Deir Al-Balah, Gaza City, and Wadi Gaza (Figure 3). Estimates indicated that approximately 89,000-110,000m^3 of wastewater were discharged daily into coastal waters, equivalent to nearly 33-40 millionm^3 annually (Table 1). Numerous investigations documented elevated concentrations of fecal coliforms, pathogenic microorganisms, nutrients, suspended solids, organic pollutants, and heavy metals in seawater and coastal sediments, particularly near sewage discharge points and densely populated urban areas [70-80]. These conditions contributed to periodic deterioration of bathing-water quality, ecological stress on marine organisms, and increased public-health risks. Seasonal environmental variability has also been shown to influence the distribution and abundance of fecal indicator bacteria in the Gaza Strip's seawater [81]. Early environmental management frameworks for the Gaza Strip coastal and marine zone already highlighted the need for protection and pollution control measures [82]. Nevertheless, wastewater treatment facilities remained partially operational, and natural hydrodynamic dispersion processes allowed some offshore areas to retain a degree of ecological functionality.

Figure 3: Discharge of untreated or partially treated wastewater into the Mediterranean Sea via multiple coastal outfalls along the Gaza Strip coastline.

Table 1: Wastewater discharge volume dynamics into Gaza's Coastal Waters (m³/day).

Temporal Baseline	Volumetric Discharge Rate (m^3/day)
Pre-October 2023 Baseline	89,000 - 110,000 (Partially Treated)
Initial War Phase (Late 2023)	130,000 (Completely Raw / Untreated)
Prolonged war (2024-2026)	80,000 - 100,000 (Completely Raw)

Since the outbreak of the ongoing Israeli war on the Gaza Strip in October 2023, the destruction of wastewater treatment plants, sewage pumping stations, drainage networks, and electricity infrastructure has caused the near-total collapse of sanitation services throughout the territory [83,84]. Water resource systems in the Gaza Strip have historically relied on constrained infrastructure and non-conventional supply options such as desalination, which also carries environmental pressures on the coastal system [85]. Consequently, the volume of untreated wastewater discharged into coastal waters and Wadi Gaza increased dramatically, reaching approximately 130,000m^3/day during the initial stages of the war and remaining at an estimated 80,000-100,000m^3/day thereafter [86] (see Table 1). These discharges consist not only of raw municipal sewage but also hospital effluents, fuel residues, decomposing organic matter, and solid waste, resulting in unprecedented levels of marine contamination.

Hydrodynamic plume-tracking models developed for the Gaza Strip's coastal waters indicate that the continuous release of untreated wastewater has substantially reduced the effectiveness of natural marine dilution processes and facilitated the spread of pollution along the nearshore environment [87]. Microbiological contamination has intensified considerably, with concentrations of fecal coliforms and pathogenic microorganisms exceeding historical levels and posing severe risks to public health and marine resource utilization [88]. Extreme rainfall events and pluvial flooding in the Gaza Strip coastal plain further influence runoff dynamics and the transport of pollutants toward coastal and marine environments [89].

Simultaneously, the excessive input of nutrients, particularly nitrates and phosphates derived from untreated domestic and hospital wastewater, has increased the risk of eutrophication, oxygen depletion, and ecological imbalance in shallow coastal waters [90]. The cumulative effects of microbial contamination, nutrient enrichment, and organic pollution threaten marine biodiversity, fisheries productivity, ecosystem functioning, and coastal environmental quality. Furthermore, hydrodynamic circulation patterns within the southeastern Mediterranean Sea may facilitate the transport of pollutants beyond the Gaza Strip's coastal waters, creating potential transboundary environmental impacts affecting neighboring marine environments [91-94].

Sediment contamination and benthic habitat degradation

Prior to October 2023, marine sediments along the Gaza Strip coast were already influenced by chronic pollutant inputs derived from wastewater discharge, urban runoff, fishing harbor activities, and other land-based sources of contamination. Elevated concentrations of heavy metals and various pollutants were documented in coastal sediments, particularly around Gaza Fishing Harbor, major sewage outfalls, and the Wadi Gaza estuary [95-99]. Although sediment contamination was evident, its distribution remained relatively localized around major pollution hotspots. Nevertheless, benthic habitats continued to support diverse invertebrate communities and ecological processes essential for nutrient cycling, organic matter decomposition, and marine productivity [100-103]. These ecological functions contributed to maintaining the overall stability and resilience of coastal marine ecosystems despite persistent environmental pressures.

Since the outbreak of the ongoing war, the Gaza Strip coastal seabed has increasingly become a major sink for contaminants derived from widespread urban destruction. The generation of tens of millions of tons (more than 68 million tons) of rubble, demolition debris, hydrocarbons, plastics, combustion ash, asbestos-containing materials, concrete dust, fuel residues, and other hazardous compounds has dramatically increased pollutant inputs into the marine environment (Figure 4) [104-106]. Large-scale aerial bombardment and the destruction of civilian infrastructure throughout the Gaza Strip have generated extensive environmental damage. This includes the release of hazardous materials, widespread debris accumulation, and long-term contamination risks affecting terrestrial, coastal, and marine ecosystems [107]. Through rainfall runoff, shoreline erosion, wind-driven transport, and direct coastal deposition, these materials have been transported into nearshore waters and incorporated into marine sediments. As a result, contaminant accumulation is no longer restricted to localized hotspots but is increasingly affecting broader depositional zones along the Gaza coastline [108].

Figure 4: Since October 2023, the ongoing Israeli war of genocide and ethnic cleansing has generated more than 68 million metric tons of hazardous rubble and demolition debris across the Gaza Strip, substantially increasing pollutant inputs into the marine environment.

The accumulation of war-derived contaminants in marine sediments is expected to modify sediment geochemistry, elevate concentrations of heavy metals such as Lead (Pb), Cadmium (Cd), Chromium (Cr), and Copper (Cu), and degrade benthic habitats that support marine biodiversity. Such contamination may reduce benthic macroinvertebrate abundance and diversity, disrupt nutrient recycling processes, and impair ecological functions performed by benthic communities. Moreover, the accumulation and persistence of toxic substances within marine sediments create opportunities for bioaccumulation through marine food webs, potentially affecting demersal fishes and higher trophic levels. Given the long residence time of many contaminants in marine sediments, these environmental impacts are expected to persist for years or even decades after the cessation of hostilities, posing major challenges for future ecosystem recovery and restoration.

Coastal habitat disturbance, shoreline instability and erosion

Prior to October 2023, the Gaza Strip coastline was already experiencing continuous environmental pressures associated with coastal erosion (Figure 5), urban expansion, harbor construction, land reclamation activities, and modifications of natural sediment transport pathways [109-113]. Coastal dunes, beach ridges, and native vegetation communities played important ecological and geomorphological roles by stabilizing sediments, protecting the shoreline from erosion, and supporting coastal biodiversity [114]. Although several sectors of the Gaza Strip coast exhibited localized instability and erosion hotspots, shoreline dynamics generally remained regulated by natural sediment transport processes, maintaining a relative balance between erosion and accretion and preserving the overall geomorphological functionality of the coastal zone [115,116].

Figure 5: Coastal erosion in the Gaza Strip is an ongoing problem exacerbated by Israeli wars and limited resources and solutions.

Since the outbreak of the ongoing war, extensive military activities have significantly altered coastal habitats and shoreline dynamics throughout the Gaza Strip. Bombardment, coastal shelling, excavation works, movement of heavy military vehicles, destruction of infrastructure, and large-scale population displacement have caused widespread disturbance of coastal landscapes, particularly in the Al-Mawasi coastal zone. These activities have accelerated vegetation removal, dune degradation, substrate compaction, debris accumulation, and disruption of natural drainage systems, thereby increasing the susceptibility of coastal habitats to erosion and storm damage.

In addition, the deposition of war-generated rubble and the destruction of coastal infrastructure have disrupted longshore sediment transport pathways that historically contributed to shoreline stability [117,118]. Remote sensing analyses and previous coastal assessments suggest that these disturbances may accelerate beach retreat, create localized erosion hotspots, and alter patterns of sediment deposition along the Gaza coast. Consequently, the losses of beach width, degradation of dune systems, and increasing geomorphological instability have reduced the capacity of the coastline to buffer seasonal storms and environmental disturbances. These impacts are expected to increase the long-term vulnerability of the Gaza Strip's coastal ecosystems and infrastructure to future climate-driven sea-level rise, storm surges, and other coastal hazards [119,120].

Marine biodiversity degradation and ecosystem disruption

Prior to October 2023, the marine ecosystem of the Gaza Strip supported diverse assemblages of cartilaginous and bony fishes, sea turtles, jellyfishes, marine mammals, seabirds, benthic organisms, and other marine taxa that contributed significantly to biodiversity conservation and ecosystem stability in the southeastern Mediterranean Sea (Figure 6) [121]. Studies documented native Mediterranean species, commercially important fishes, non-indigenous species, and several species of conservation concern inhabiting the Gaza Strip's coastal waters [122-124]. Although pollution, habitat degradation, and fishing pressures existed, ecological connectivity among marine, coastal, and wetland ecosystems remained functional, supporting feeding, migration, recruitment, and reproductive processes, particularly through interactions with the Wadi Gaza wetland system.

Since October 2023, marine biodiversity has been subjected to multiple war-related stressors, including habitat destruction, severe water pollution, sediment contamination, underwater explosions, elevated turbidity, noise disturbance, and the collapse of environmental management systems. These pressures have disrupted ecological processes, altered species distributions, and increased physiological stress across multiple trophic levels, affecting primary producers, zooplankton, fishes, and higher predators such as sharks and rays [125]. Field observations and fisheries landing records indicate changes in fish assemblage composition, declining species richness, and increasing ecological instability in nearshore habitats. Furthermore, continuous pollution and habitat disturbance have weakened ecological connectivity with adjacent ecosystems, including Wadi Gaza, disrupting recruitment pathways and ecosystem functioning. Collectively, these impacts are expected to alter community structure, disrupt food-web dynamics, reduce ecosystem resilience, and accelerate biodiversity loss throughout the Gaza Strip's marine environment. In addition, the destruction of biological collections, museums, environmental laboratories, and scientific archives has severely compromised biodiversity monitoring and conservation efforts (Figure 7) [126].

Figure 6: The marine ecosystem of the Gaza Strip supports diverse assemblages of marine biota, contributing significantly to biodiversity conservation and ecosystem stability in the southeastern Mediterranean Sea: (A) Spiny Butterfly Ray (*Gymnura altavela* Linnaeus, 1758), (B) Sandbar Shark (*Carcharhinus plumbeus* Nardo, 1827) , (C) Common Guitarfish (*Rhinobatos rhinobatos* Linnaeus, 1758), (D) Narrow-barred Spanish Mackerel (*Scomberomorus commerson* Lacepède, 1800), (E) Ocean Sunfish (*Mola mola* Linnaeus, 1758), (F) Silver-cheeked Toadfish (*Lagocephalus sceleratus* Gmelin, 1789), (G) Loggerhead Sea Turtle (*Caretta caretta* Linnaeus, 1758), (H) Sandwich Tern (*Thalasseus sandvicensis* Latham, 1787), (I) Yellow-legged Gull (*Larus michahellis* Naumann, 1840), (J) Sanderling (*Calidris alba* Pallas, 1764), and (K) Common Bottlenose Dolphin (*Tursiops truncatus* Montagu, 1821).

Figure 7: Many Gazans museums housing rare marine biological collections have been damaged or destroyed during the Israeli war, undermining biodiversity monitoring and conservation efforts. The photograph shows the author and colleagues displaying a preserved specimen of the exotic Reef Stonefish (*Synanceia verrucosa* Bloch & Schneider, 1801) at the Marine Biology Museum of the General Directorate of Fisheries, Ministry of Agriculture, Gaza Strip.

Impacts on marine megafauna and threatened species

The coastal waters of the Gaza Strip constituted an important component of the eastern Mediterranean ecological network and supported numerous threatened, rare, and migratory marine species. Scientific records documented the occurrence of Green Sea Turtle (*Chelonia mydas* Linnaeus, 1758), Loggerhead Sea Turtle (*Caretta caretta* Linnaeus, 1758), Leatherback Sea Turtle (*Dermochelys coriacea* Vandelli, 1761), cetaceans, Ocean Sunfish or Common Mola (*Mola* Linnaeus, 1758), Mediterranean Monk Seal (*Monachus monachus* Hermann, 1779), Whale Shark (*Rhincodon typus* Smith, 1828), and several threatened species of rays and sharks [127-132]. These observations highlighted the ecological significance of the Gaza Strip's coastal waters as feeding grounds, migratory corridors, refuge habitats, and occasional breeding areas for marine megafauna. Although these species were already exposed to regional pressures such as fisheries interactions, habitat degradation, and pollution, their populations continued to utilize the Gaza Strip's coastal habitats for critical life-history functions.

Since October 2023, the ongoing war has substantially increased risks to threatened marine species through habitat destruction, severe pollution, food-web disruption, and chronic physical disturbance. Intensive naval activities, coastal bombardments, and underwater detonations have generated persistent acoustic disturbances capable of causing behavioral disorientation, physiological stress, and potential injury to marine mammals, sea turtles, and other sensitive species. Critical nesting and foraging habitats used by Loggerhead Sea Turtles (*Caretta caretta* Linnaeus, 1758) have been heavily degraded by infrastructure destruction, large-scale human displacement, and habitat modification along the central and southern Gaza Strip coastline [133].

At the same time, deteriorating water quality, increased contaminant loads, sediment toxicity, and habitat degradation have intensified ecological pressures on sharks, rays, and another marine megafauna. Species such as the critically endangered Angel Shark (*Squatina squatina* Linnaeus, 1758) and other elasmobranchs may be particularly affected by heavy-metal accumulation, degradation of benthic habitats, and declining prey availability. Furthermore, severe food insecurity and famine conditions have reportedly contributed to the capture and consumption of protected marine species, including sea turtles, dolphins, and Whale Sharks [134] (Figure 8). The collapse of conservation and monitoring programs has further limited the ability to assess population trends and implement protective measures, increasing the risk of long-term population declines and localized extinctions among threatened marine species throughout the southeastern Mediterranean region.

Figure 8: During the ongoing Israeli war of genocide and ethnic cleansing (2023-2026) in the Gaza Strip, severe food insecurity and famine conditions reportedly contributed to the capture and consumption of protected marine species, including (A) the Striped Dolphin (*Stenella coeruleoalba* Meyen, 1833), (B & C) the Loggerhead Sea Turtle (*Caretta caretta* Linnaeus, 1758), and (D) the Whale Shark (*Rhincodon typus* Smith, 1828).

Degradation of coastal wetlands and adjacent dune ecosystems (wadi Gaza and Al-Mawasi)

Wadi Gaza represented the most important wetland ecosystem in the Gaza Strip and served as a vital ecological corridor linking terrestrial, freshwater, and marine environments [135]. Despite chronic pollution and urban encroachment, the wetland continued to support migratory birds, aquatic organisms, reptiles, amphibians, and diverse plant communities (Figure 9) [136-140]. Similarly, the Al-Mawasi coastal ecosystem contained dunes, agricultural lands, and semi-natural habitats that contributed to biodiversity conservation, groundwater recharge, and shoreline stability [141-143]. Together, these ecosystems maintained ecological connectivity between inland and marine environments.

Figure 9: Despite chronic pollution, Wadi Gaza remains the most important wetland ecosystem in the Gaza Strip, supporting diverse flora and fauna communities.
Source: https://e360.yale.edu/features/gaza-war-environment.

The ongoing Israeli war of genocide and ethnic cleansing has caused unprecedented degradation of both ecosystems. Wadi Gaza has experienced increased inflows of untreated wastewater (Figure 10), solid waste accumulation, hydrological disruption, and habitat fragmentation resulting from extensive infrastructure destruction and environmental management collapse. Simultaneously, Al-Mawasi became a major refuge area for displaced populations, resulting in extensive vegetation removal, waste accumulation, groundwater contamination, and habitat disturbance. These transformations have weakened ecological connectivity, reduced habitat quality, and intensified environmental stress throughout adjacent coastal and marine ecosystems.

Figure 10: Comparison of pre-war and wartime conditions shows that Wadi Gaza has experienced increased inflows of untreated wastewater into its channel, ultimately discharging into the Mediterranean Sea.

Collapse of marine fisheries and fishing activities

Marine fisheries constituted one of the most important productive sectors in the Gaza Strip, providing livelihoods for thousands of fishermen and contributing significantly to local food security. Annual fish production ranged between approximately 2,000 and 4,000 metric tons depending on environmental conditions, fishing effort, and maritime restrictions [144-146]. The sector was dominated by artisanal fisheries and supported a fleet of approximately 1,741 registered vessels, including trawlers, purse seiners, motorized Hasakas, feluccas, and rowing Hasakas as pointed out by Hussein et al. [146] (Table 2).

Table 2: Composition of the fishing fleet in the Gaza Strip prior to 7 October 2023*.

Vessel Type	Local Name	Number of Vessels	Percentage of Total Fleet (%)
Trawlers	Gar	14	0.8
Large Purse Seiners	Shanshula	54	3.1
Small Purse Seiners	Shanshula	130	7.5
Motorized Hasakas	Hasaka with Motor	731	42
Feluccas	Felucca	33	1.9
Rowing (Non-motorized) Hasakas	Hasaka with Oars	779	44.7
Total	—	1,741	100

Source: Adapted from Hussein et al. [146].

Following the outbreak of war, the fisheries sector experienced a near-total collapse due to widespread destruction of fishing vessels (Figure 11), ports, landing sites, workshops, storage facilities, and ice plants [147]. Fuel shortages, restrictions on maritime access, and the collapse of navigation and communication systems have further disrupted fishing operations. Consequently, fish production declined dramatically, resulting in severe socioeconomic impacts on fishing communities and reducing an important source of local food production. The collapse of fisheries monitoring and management systems has also created additional challenges for future resource sustainability and recovery.

Figure 11: Damage to fishing boats in the Gaza Strip resulting from Israeli bombardment during the war following 7 October 2023.
Source: https://www.un.org/unispal/wp-content/uploads/2025/06/OPT-Protection-Cluster_Building-to-Starvation-Systematic-Attacks-on-Fishing-in-Gaza.pdf

Israeli restrictions and interference in maritime solidarity and access

For many years, international maritime solidarity initiatives, particularly the Freedom Flotilla campaigns, attempted to reach the Gaza Strip in order to deliver humanitarian assistance and challenge the naval blockade (Figure 12). These initiatives were repeatedly intercepted, restricted, or prevented from reaching the Gaza Strip, attracting significant international attention and generating legal and humanitarian debate concerning maritime access and freedom of navigation [148,149].

Figure 12: Several international maritime solidarity initiatives, most notably the Freedom Flotilla campaigns, attempted to reach the Gaza Strip, Palestine, in order to deliver humanitarian aid and challenge the Israeli naval blockade.

Following October 2023, maritime restrictions intensified considerably as part of the broader military and security measures imposed on the Gaza Strip. International civilian vessels and maritime humanitarian initiatives were effectively prevented from accessing the Gaza Strip's coastline, further reinforcing the isolation of the territory and limiting opportunities for humanitarian maritime assistance. These restrictions have compounded existing challenges affecting fisheries, coastal livelihoods, and marine-related economic activities.

Impacts on aquaculture and fish farming systems

Aquaculture represented a relatively small but growing component of the Gaza Strip's food-production sector. Production systems included earthen ponds, concrete tanks, and offshore marine cages culturing different species of bony fishes (Table 3) (Figure 13) [150,151]. The establishment of the Gaza Strip's first offshore marine cage farm in 2021 represented an important milestone in fisheries development and demonstrated the feasibility of marine aquaculture under local environmental conditions [152,153]. Recent aquaculture literature highlights the biological performance, farming practices, and production challenges of key cultured species such as gilthead Seabream (*Sparus aurata* Linnaeus, 1758), which is among the species relevant to regional aquaculture systems [154].

Figure 13: Aquaculture in the Gaza Strip represents a promising sector for fish production, involving several commercially important bony fish species, including (A) Nile Tilapia (*Oreochromis niloticus* Linnaeus, 1758), (B) Hybrid Tilapia (*Oreochromis* × *spp.*), and (C) Gilthead Seabream (*Sparus aurata* Linnaeus, 1758). (D) Offshore marine cages established in 2021 for the culture of Gilthead Seabreams.

Table 3: Various species of bony fish are raised in earthen ponds, concrete tanks, or sea cages in the open sea in the Gaza Strip.

Order	Family	Scientific Name	Common Name
Cichliformes	Cichlidae	*Oreochromis niloticus* Linnaeus, 1758	Nile Tilapia
Cichliformes	Cichlidae	*Oreochromis × spp.*	Hybrid Tilapia
Acanthuriformes	Sparidae	*Sparus aurata* Linnaeus, 1758	Gilthead Seabream
Acanthuriformes	Moronidae	*Dicentrarchus labrax* Linnaeus, 1758	European Seabass
Mugiliformes	Mugilidae	*Mugil cephalus* Linnaeus, 1758	Flathead Grey Mullet
Siluriformes	Clariidae	*Clarias gariepinus* Burchell, 1822	African Catfish

The war caused severe disruption to both inland and marine aquaculture systems. Fish farms, wells, pumping stations, energy infrastructure, transportation networks, and supply chains were damaged or rendered non-operational. The deterioration of water quality, shortages of fuel and feed, restricted access to production facilities, and interruption of fingerling supplies further undermined production. Offshore marine cages ceased operation entirely, eliminating one of the most promising fisheries development projects previously implemented in the Gaza Strip.

Transboundary environmental impacts on the southeastern Mediterranean Sea

The marine environment of the Gaza Strip has always been ecologically connected to neighboring sectors of the southeastern Mediterranean through ocean currents, larval dispersal, biological migrations, and nutrient transport processes. Although wastewater discharge and coastal pollution occasionally generated localized transboundary concerns, most environmental impacts remained relatively limited in geographic extent [155,156].

The ongoing war has substantially increased the risk of regional environmental consequences. Massive releases of untreated wastewater, contaminated runoff, fuel residues, microplastics, and war-generated debris into the Mediterranean Sea create conditions that facilitate the transport of pollutants beyond the Gaza Strip's territorial waters. Oceanographic circulation may distribute contaminants, pathogens, and floating debris toward neighboring coastal regions, potentially affecting marine biodiversity, fisheries resources, and water quality across parts of the southeastern Mediterranean basin [157].

Degradation of fishing harbors and coastal landing sites

Fishing harbors and coastal landing sites along the Gaza Strip served as critical infrastructure supporting fisheries production, vessel maintenance, seafood trade, and local recreation. Gaza Fishing Harbor functioned as the principal center of artisanal fisheries and represented an important cultural and recreational waterfront. Coastal spits and sandy shoreline extensions also contributed to sediment regulation, shoreline protection, and geomorphological stability [158-160].

Extensive wartime destruction has severely damaged fishing harbors, quays, workshops, warehouses, fuel stations, and landing facilities. Simultaneously, many coastal spits and shoreline areas have been transformed into temporary displacement sites for internally displaced people. The concentration of displaced populations in these coastal environments has increased sanitation problems, waste accumulation, and coastal contamination while reducing shoreline resilience to erosion, flooding, and storm impacts. These changes represent a major socio-environmental transformation of the Gaza Strip's coastal zone.

Long-term ecological consequences and environmental recovery challenges

Prior to the war, the marine and coastal ecosystems of the Gaza Strip already exhibited chronic environmental stress associated with pollution, infrastructure deficiencies, overexploitation of natural resources, habitat degradation, and prolonged blockade conditions. Nevertheless, ecological functions remained largely operational, marine biodiversity persisted, and environmental institutions continued limited monitoring, conservation, and management activities despite substantial constraints.

The cumulative impacts of the ongoing war indicate a trajectory toward large-scale ecological degradation affecting interconnected marine, coastal, wetland, and terrestrial ecosystems. Habitat destruction, pollution, biodiversity decline, fisheries collapse, sediment contamination, and environmental infrastructure loss may generate consequences that persist for decades [161-164]. Mitigation and post-war environmental recovery strategies have been proposed to address and reduce the long-term ecological risks associated with the Gaza Strip environmental crisis [165]. Recent analyses further emphasize the severity of the environmental disaster in the Gaza Strip under siege conditions and highlight the implications for environmental security and policy responses [166,167]. Future recovery will require comprehensive environmental assessments, restoration of wastewater treatment facilities, remediation of contaminated sediments, rehabilitation of fisheries and aquaculture infrastructure, reconstruction of environmental monitoring programs, and long-term biodiversity conservation initiatives. Without substantial intervention, environmental degradation is likely to continue affecting ecosystem services, public health, food security, and biodiversity throughout the Gaza Strip and the adjacent Mediterranean region.

Prospects for utilizing war-derived vehicle hulls as artificial reefs in the restoration of the marine ecosystem

The concept of utilizing artificial structures to enhance marine habitats is not new to the Gaza Strip. Prior to the ongoing Israeli war on the Gaza Strip, local fishermen were familiar with the use of submerged structures, including sunken vessels, vehicle hulls, and other durable materials, as fish aggregation sites locally known as "Al-Allaqat". Since the early 1970s, several shipwrecks along the Gaza Strip coast have served as artificial habitats that attracted diverse fish and invertebrate communities. Such structures increased habitat complexity, provided hard substrates for the settlement of marine organisms, and contributed to local biodiversity enhancement, reflecting the ecological functions of artificial reefs reported from Mediterranean and other marine ecosystems worldwide [168-170].

In the aftermath of the Israeli war of genocide and ethnic cleansing (2023-2026), enormous quantities of metallic debris, including tens of thousands of damaged and destroyed vehicles, have accumulated throughout the Gaza Strip as part of the unprecedented volume of war-generated rubble (Figure 14). Although these materials currently represent a major environmental and management challenge, selected vehicle hulls may offer future opportunities for marine habitat restoration if incorporated into scientifically planned artificial reef programs. Nevertheless, the direct deployment of war-damaged vehicles in the marine environment would be environmentally unacceptable because of the potential presence of fuels, lubricants, batteries, plastics, paints, heavy metals, and other hazardous substances that may contaminate seawater and marine sediments and negatively affect marine biota [171-173]. Therefore, any future artificial reef initiative based on war-derived vehicle hulls should comply with strict environmental standards, including complete decontamination, removal of hazardous materials, structural safety assessment, environmental impact evaluation, and long-term monitoring. If implemented according to internationally recognized environmental guidelines, such an approach could transform part of the war-generated debris into a resource for ecological restoration, biodiversity enhancement, and fisheries rehabilitation along the Mediterranean coast of the Gaza Strip [174].

Figure 14: Accumulation of tens of thousands of damaged and destroyed vehicles across the Gaza Strip as part of the unprecedented volume of war-generated rubble since October 2023.

Prospects for utilizing war-generated rubble in coastal and marine ecosystem restoration and artificial island development

Prior to the ongoing Israeli war, the coastal and marine environment of the Gaza Strip was already subjected to multiple anthropogenic pressures, including chronic wastewater pollution, habitat degradation, coastal erosion, overfishing, and increasing urban encroachment [175]. In response to land scarcity and shoreline erosion, construction and demolition debris were occasionally used in certain coastal areas for shoreline reinforcement, land reclamation, and informal coastal rehabilitation activities [176]. However, these interventions were generally carried out without comprehensive environmental assessments, engineering design standards, or ecological monitoring, resulting in limited consideration of their potential impacts on marine biodiversity, sediment transport processes, water quality, and ecosystem functioning. Nevertheless, these practices demonstrated the technical feasibility of utilizing inert construction materials within the coastal zone of the Gaza Strip and provided an early local precedent for their potential contribution to coastal stabilization and development when properly managed within an environmental framework.

Since October 2023, the unprecedented destruction of buildings, infrastructure, roads, ports, and public facilities has generated an estimated more than 68 million metric tons of rubble and demolition debris throughout the Gaza Strip as shown in the previous (Figure 4) [177-179]. This material consists primarily of reinforced concrete, cement blocks, stones, bricks, asphalt, steel, glass, wood, plastics, and other construction materials, with significant portions potentially contaminated by heavy metals, asbestos, hydrocarbons, and unexploded ordnance, posing serious environmental and public health risks. Despite these challenges, properly sorted and treated inert fractions of rubble may represent a valuable resource for post-war environmental restoration and sustainable coastal development [180,181]. Recycled concrete and rock materials could be used in the construction of artificial reefs to enhance marine biodiversity and fisheries productivity, submerged breakwaters to mitigate shoreline erosion, habitat restoration structures, and the expansion of fishing harbors and maritime infrastructure [182].

Furthermore, the exceptionally large volume of available rubble may enable long-term strategic projects such as offshore platforms and artificial islands [183]. These artificial islands could provide additional space for tourism, recreation, fisheries support services, maritime transport infrastructure, scientific research centers, renewable energy installations, desalination plants, and marine protected areas. In the context of the Gaza Strip's extremely limited land area and high population density, such developments may contribute to economic recovery, job creation, coastal resilience, and sustainable spatial expansion, provided that they are preceded by rigorous environmental impact assessments, contamination screening, and hydrodynamic and ecological feasibility studies to ensure long-term environmental sustainability [184]. In fact, the "Palm Islands" project in Dubai, United Arab Emirates [185], may provide valuable lessons for the potential construction of artificial islands in the marine environment of the Gaza Strip using the enormous quantities of rubble generated during the ongoing Israeli war (Figure 15).

Figure 15: The Palm Jumeirah, part of the "Palm Islands" project in Dubai, United Arab Emirates.
Source: https://blogs.timesofisrael.com/artificial-island-off-gaza-could-rebuild-the-strips-economy/.

Conclusion

The marine and coastal ecosystems of the Gaza Strip were already experiencing significant environmental stress prior to October 2023 due to chronic pollution, inadequate wastewater treatment, habitat degradation, overfishing, and prolonged socio-political constraints. The ongoing Israeli war of genocide and ethnic cleansing (2023-2026) has markedly intensified these pressures, resulting in severe deterioration of marine water quality, widespread sediment and habitat contamination, substantial biodiversity loss, and the near-collapse of fisheries and aquaculture systems.

The destruction of critical environmental infrastructure, including wastewater treatment plants, sewage networks, desalination facilities, and fishing harbors, has led to the uncontrolled discharge of large volumes of untreated and hazardous waste into the coastal marine environment. In parallel, the accumulation of massive quantities of war-generated rubble has amplified long-term contamination risks, affecting marine sediments, food webs, and ecosystem resilience, with potential transboundary implications for the southeastern Mediterranean Sea.

Although the ecological damage is extensive and likely to persist for decades, targeted restoration strategies-such as habitat rehabilitation, pollution remediation, and the carefully controlled use of treated inert materials for artificial reefs-may contribute to long-term recovery. Ultimately, effective restoration will require comprehensive environmental management, reconstruction of infrastructure, sustained monitoring programs, and coordinated international support to restore the ecological integrity and functionality of the Gaza Strip's marine ecosystems.

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