Blue Diplomacy: Transboundary Efforts for Red Sea Coral Reefs

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Coral reefs are biodiversity hotspots vital for marine life and human livelihoods. Yet, they face existential threats from climate change and local stressors, with projections warning that up to 90% of global coral reefs could disappear by 2050 under current trends. The coral reefs of the northern Red Sea – particularly in the Gulf of Aqaba (GoA) offer a rare refuge, demonstrating remarkable resistance to thermal stress. However, this resilience to warming will only translate into long-term survival if local pressures such as pollution, overfishing, and coastal development are stringently managed. Effective conservation in this region transcends national boundaries, as the GoA is bordered by four countries (Egypt, Israel, Jordan, and Saudi Arabia) sharing interconnected marine ecosystems. This manuscript examines the critical role of Transboundary Environmental Cooperation (TEC) in safeguarding the GoA's coral reefs as a global "reef refuge." We review successful TEC examples in coral reef regions worldwide to draw lessons for the Red Sea. We then detail past and present transboundary initiatives in the Red Sea, highlighting achievements and chronic challenges – from regional conflicts (e.g. the war in Gaza) that have derailed joint efforts, to shifts in international support (such as the Trump administration's funding cuts) that have left

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cooperation projects in limbo. In the discussion, we explore pathways to bolster regional environmental security, including open science and data-sharing platforms considering political fragmentation and active violent conflict and the proposal of a multi-nation UNESCO World Heritage Site in the GoA to institutionalize cooperation. These strategies could enhance environmental peacebuilding and resilience, ensuring that the Red Sea's reefs of hope endure as a bastion for coral survival and regional stability.

Keywords: *Transboundary Environmental Cooperation, Coral Reefs, Red Sea, Gulf of Aqaba*

INTRODUCTION

Coral reefs are among the most diverse and productive ecosystems on the planet, supporting roughly 25% of all marine species at some point in their life cycles. They provide critical ecosystem services – from sustaining fisheries and tourism to protecting coastlines from storms – which underpin the food security and economies of hundreds of millions of people (Woodhead et al. 2019). Despite their importance, coral reefs are in crisis (Hoegh-Guldberg et al., 2011). Warming ocean temperatures and ocean acidification due to rising CO_2 levels have triggered mass coral bleaching events worldwide (Donner et al., 2005). Localized human impacts – pollution, coastal development, and overfishing – compound the stress, leading to drastic declines in reef health. Over the past few decades, live coral cover has plummeted in many regions; scientists estimate that if current trends continue, only a small fraction of the world's coral reefs will remain by mid-century. Indeed, projections suggest that on our current warming trajectory, over 90% of coral reefs are at risk of collapse by 2050 (Hughes et al., 2017; Henley et al., 2024). This "coral reef crisis" has made reef conservation a global priority, intertwining ecological concerns with socio-economic and security implications.

Amid this grim outlook, the coral reefs of the northern Red Sea, especially those in the GoA (the northeastern arm of the Red Sea), stand out as a beacon of hope. Multiple studies have revealed that GoA corals possess an unusual tolerance to heat stress, bleaching at significantly higher temperatures than most coral populations elsewhere (Kleinhaus et al. 2020). Experiments indicate these corals can withstand water temperatures several degrees Celsius above their current summer maxima without experiencing bleaching (Fine et al., 2013; Bellworthy and Fine, 2017; Krueger et al., 2017; Evensen et al., 2021; Savary et al., 2021). Furthermore, resilience to repetitive marine heatwaves was also reported (Kochman-Gino and Fine, 2023). This resilience is hypothesized to be a legacy of their biogeographic history – as ocean waters warmed after the last ice age, only heat-tolerant genotypes migrated into the Red Sea (Fine et al., 2013). As a result, the GoA's reefs may not reach their thermal bleaching threshold until decades after other reefs have

succumbed. In effect, the region could serve as a "climate refuge" for coral reefs in a heating world, potentially outliving reefs in the Indo-Pacific and Caribbean that are projected to suffer annual bleaching in coming decades.

However, this hopeful scenario will only materialize if the GoA's reefs are protected from local anthropogenic threats (Hall et al., 2018; Banc-Prandi and Fine, 2019; Fine et al., 2019; Banc-Prandi et al., 2021). Coral resilience to climate stress does not confer immunity to pollution, uncontrolled coastal development, habitat destruction, or overfishing. On the contrary, the Gulf's corals are highly sensitive to water quality degradation and other immediate disturbances. For example, sedimentation or oil spills can smother or poison corals just as easily in the Red Sea as anywhere else. Unregulated tourism or infrastructure construction along the coast can damage reef structure and water clarity. Overfishing of herbivores can allow algal overgrowth, undermining reef health. In short, while climate change might spare the GoA's corals longer than others, chronic local stressors could severely degrade or even destroy these reefs in the near term. This paradox underscores that resilience is not persistence without proper management.

The Gulf of Aqaba is a semi-enclosed sea bordered by four countries – Jordan, Israel, Egypt, and Saudi Arabia – each with jurisdiction over portions of the coastline and adjacent coral reefs. The marine ecosystem and oceanographic processes (currents, larval dispersal, water quality) are continuous across political boundaries. Actions (or inactions) in one country's coastal waters can directly affect reef health in neighboring countries. For instance, a pollution event or oil spill off the coast of Aqaba, Jordan could drift and impact reefs in Eilat, Israel and vice versa. Overfishing on one side of the gulf can deplete fish populations that would otherwise roam and help control algae on reefs across the border. Simply put, ecological boundaries do not align with political boundaries in the Red Sea. The Tragedy of the Commons (Hardin 1968), describes a scenario where individual actors overuse a shared resource for short-term economic incentives, conflicting with long-term sustainability. The Red Sea, a common pool resource, is sensitive to Tragedy of the Commons due to lack of effective governance, enforcement and mostly transboundary coordination (Hoegh-Guldberg et al., 2022).

Therefore, overfishing and pollution are not just environmental concerns but environmental security threats that can exacerbate geopolitical tensions, economic instability in coastal communities and economic disparities in the region. For example, Egypt hosts the region's largest reef tourism industry, relying on coral ecosystems for significant GDP contributions and employment. The potential implications to Egypt's economy, in case this ecosystem is impaired and not attractive for tourists, will be devastating (Al-Hammady and Mahmoud, 2013). This is true for the local economies of Aqaba and Eilat as well, which rely on tourism as their main source of income.

The Gulf of Aqaba is undergoing rapid development, with multiple large-scale infrastructure projects posing significant transboundary environmental security

risks. Oil transit via the Eilat-Ashkelon Pipeline (EAPC) would significantly increase the risk of marine pollution, coral reef damage, and cross-border environmental hazards. The Gulf of Aqaba's enclosed nature means that even a minor oil spill could rapidly spread to Jordanian and Egyptian waters, threatening coastal tourism and fisheries (Burke et al., 2011). Similarly, megaprojects, part of Saudi Arabia's Vision 2030 initiative (NEOM, Amaala, Oxagon, Red Sea project, Saudi–Egypt Causeway), aiming to diversify the economy and establish the Red Sea region as a premier global tourism and industrial hub, are both fascinating and alarming given their scale. The potential environmental costs, especially in such fragile marine ecosystems, are deeply concerning.

Transboundary Environmental Cooperation (TEC) is not just desirable but essential for the GoA. TEC involves neighboring states working together to manage and protect shared natural resources and ecosystems. TEC is a fast-evolving multi-disciplinary field addressing environmental concerns worldwide including cooperation between countries in active conflict and with a history of conflict (Bruch et al., 2019). In regions like the Red Sea, robust cooperation can ensure that protective measures (such as marine reserves or pollution control) in one area are complemented and reinforced by similar measures next door (Mackelworth et al., 2019). TEC does not ignore harsh political realities, such as the current war in the Middle East, rather seeks opportunities in which cooperation can happen also during active conflict to mitigate dire environmental concerns (Martin et al., 2013).

The concept of regional cooperation for the Gulf's environmental protection is not new. Over the years, various bilateral and multilateral initiatives have attempted to operationalize this vision – with mixed success. One notable example includes the Israel-Jordan peace treaty of 1994, which explicitly called for collaboration in protecting the shared GoA marine environment (Feitelson and Levy, 2006). Political tensions and conflict have often impeded or interrupted progress, underscoring how fragile such cooperation can be in a geopolitically volatile region (Arieli, 2012; Kedem et al., 2024a). In this paper, we examine global examples of successful transboundary reef management to extract lessons applicable to the Red Sea, review the history of cooperation efforts in the GoA and broader Red Sea region, and discuss future pathways – including open science frameworks and a joint World Heritage designation – that could secure the Red Sea's coral refuge for generations to come.

TRANSBOUNDARY ENVIRONMENTAL COOPERATION IN CORAL REEF REGIONS WORLDWIDE

Coral reef ecosystems straddle political borders in several parts of the world, and many regions have recognized that cooperative management is key to their conservation. Below we highlight examples of successful or promising transboundary

environmental cooperation in coral reef areas, which illustrate how countries can overcome political barriers to protect shared marine resources:

Mesoamerican Barrier Reef (MAR)

The Mesoamerican Reef extends for over 1,000 km along the coasts of Mexico, Belize, Guatemala, and Honduras, forming the world's second-longest barrier reef system. In 2004, these four countries jointly established the Mesoamerican Barrier Reef System (MBRS) Initiative, committing to collaborate on reef protection. A centerpiece of regional efforts is the *Healthy Reefs for Healthy People Initiative* (HRI), a multi-institutional network that has operated for over 15 years (Arrivillaga and Arreola 2016). HRI coordinates standardized reef health monitoring and publishes a biennial "reef health report card" for the entire MAR region. The collaboration has led to tangible conservation outcomes, such as the expansion of marine protected areas and consistent fishing regulations (Arrivillaga and Arreola, 2016; McField et al., 2017). The MAR region's experience shows how a coalition of neighboring countries and stakeholders can unite around a shared reef system, using open data and joint strategies to improve reef management at an ecoregional scale.

Caribbean Challenge Initiative

In the Caribbean Sea, which comprises many small island nations and territories, a regional partnership known as the Caribbean Challenge Initiative (CCI) has made strides in cooperative ocean governance (Fund, 2024; Leotaud et al., 2024). Launched in 2008 with support from The Nature Conservancy and other partners, the CCI brought together 11 Caribbean countries that committed to effectively conserve at least 20% of their near-shore marine and coastal environments by 2020 (Initiative CC, 2013). Several transboundary protected areas were declared. While not without hurdles, the CCI demonstrates how high-level political commitment, combined with a regional financing mechanism and technical support, can drive multi-country conservation progress (Knowles et al., 2015).

Coral Triangle Initiative

The Coral Triangle in Southeast Asia is often cited as the global epicenter of marine biodiversity, harboring over 500 species of reef-building corals and thousands of reef fish species. This region spans the waters of six countries – Indonesia, the Philippines, Malaysia, Papua New Guinea, Solomon Islands, and Timor-Leste. Recognizing the shared stake in this priceless natural heritage, those nations came together in 2009 to launch the Coral Triangle Initiative (CTI); (Pietri et al., 2015; Christie et al., 2016). The CTI is a multilateral partnership aimed at confronting the Coral Triangle's common threats: overfishing, habitat destruction, and climate change. Under the CTI, the six governments agreed on a Regional Plan of Action that includes establishing a network of marine protected areas, adopting an ecosystem-

based fisheries management approach, and improving resilience to climate change. The Coral Triangle example underscores the value of a formal intergovernmental mechanism dedicated to a shared reef system – it provides continuity, accountability, and a platform for resolving issues through dialogue and science (Anugrah and Putra, 2020).

East African Transboundary Marine Protected Areas (MPAs)

In the Western Indian Ocean, countries are also pursuing transboundary marine conservation. One notable effort is the proposed Kenya–Tanzania Transboundary Conservation Area (TBCA) along the adjacent coasts of southern Kenya and northern Tanzania. This initiative aims to link and jointly manage marine parks and reserves across the international boundary (Tuda et al., 2019; Horigue et al., 2025). The goal is to ensure ecological connectivity and protect contiguous coral reefs and mangrove habitats under a cooperative management plan. Both governments, with support from regional bodies (like the Nairobi Convention) and NGOs, have been working to complement policies and conduct joint patrols in this area. The Kenya-Tanzania TBCA reflects the growing recognition in East Africa that marine resources require coordinated stewardship.

Florida Straits (USA–Cuba)

Another example, outside the tropics, comes from the Florida Straits where the United States and Cuba share ocean currents that connect coral reef ecosystems (such as the Florida Keys and Cuba's Guanahacabibes Peninsula). Even during times of political estrangement, marine scientists from the two countries found ways to cooperate on coral reef research and conservation. This led to a historic agreement in 2015 between the US, Cuba and Mexico to collaborate on marine protected area management in the Gulf of Mexico and Caribbean region (Portman and Teff-Seker, 2017). Joint workshops were held to compare reef monitoring methods, and knowledge exchange. This case shows how science diplomacy – scientists building relationships across borders – can lay groundwork for formal environmental agreements, even between countries with limited diplomatic ties.

The Coral Reef Rescue Initiative (CRRI)

CRRI is a coral reef conservation effort led by WWF, in collaboration with NGOs and academia. Launched in 2019, the initiative focuses on safeguarding climate-resilient coral reefs across seven countries: Fiji, Indonesia, the Philippines, Solomon Islands, Tanzania, Madagascar, and Cuba. The primary goal is to protect these reefs, considered "climate refugia," to ensure their survival and support coral regeneration worldwide. CRRI combines high-level funding and policy guidance with on-the-ground community engagement, making it a hybrid model that incorporates both top-down and bottom-up elements. It aims to build long-term conservation

capacity through national strategies, sustainable livelihoods, and innovative finance mechanisms. CRRI's work is science-driven, drawing on research identifying climate-resilient reef locations, and has been recognized as a key model for global coral reef management under climate change (Kuempel et al., 2022).

Instructive Themes for The Red Sea

These global cases demonstrate several recurring themes that are instructive for the Red Sea: (1) the importance of high-level political commitment to shared conservation targets (as seen in the Caribbean Challenge and CTI); (2) the value of establishing regional institutions or agreements to coordinate efforts (e.g., CTI's secretariat, MBRS Initiative, Nairobi Convention for WIO); (3) the need for sustainable financing mechanisms for joint initiatives (trust funds like the CBF and MAR Fund); (4) the central role of science in building trust and a common understanding of the resource through ongoing data collection and information sharing (e.g. CRRI); and (5) the potential of environmental cooperation to happen with political tensions, by focusing on mutual benefits. We next turn to the Red Sea region to review how transboundary cooperation has unfolded there, and how recent initiatives could be strengthened learning from these global experiences.

CASE STUDY: RED SEA AND GULF OF AQABA

Past and Present TEC Initiatives in The Red Sea

The Red Sea is a unique and strategically important waterbody bordered by countries from two continents – Northeast Africa (Egypt, Sudan, Eritrea, Djibouti) and the Arabian Peninsula (Saudi Arabia, Yemen), as well as Jordan and Israel at its northern tip (GoA). Its coral reef habitats form a contiguous ecosystem through the Red Sea and Gulf of Aden. Cooperative environmental management in this region has long been recognized as necessary, and several frameworks have been created over the past few decades. We will review a few in chronological order.

Jeddah Convention

In 1982, Red Sea littoral states (minus Israel) signed the *Jeddah Convention* for conservation of the Red Sea and Gulf of Aden, laying the foundation for a regional environmental organization. This led to the establishment of *The Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden* (PERSGA) in 1995 (Kleinhaus et al., 2020). Headquartered in Saudi Arabia under the umbrella of the Arab League, PERSGA's mission has been to facilitate cooperation among its member states (Djibouti, Egypt, Jordan, Saudi Arabia, Sudan, Yemen, and Somalia) in protecting the Red Sea marine environment. PERSGA has coordinated regional action plans on issues like marine pollution, endangered species, and coral reef monitoring. For example, it helped develop a regional network of marine

protected areas and organized training for marine protected area (MPA) rangers across countries. However, due to political complexities, PERSGA's membership does *not* include Israel and Eritrea (Guzansky et al., 2024). Additionally, PERSGA's activity has waxed and waned with regional stability and funding availability. The last comprehensive "Status of coral reefs" report it produced was in 2009 (Kotb, 2010), highlighting the need to reinvigorate and update regional collaboration. PERSGA provides an existing multilateral platform and legal basis for Red Sea conservation, but its effectiveness has been constrained by geopolitical rifts and resource limitations. Bridging the gap so that all Red Sea bordering states participate in such a framework remains an important yet challenging goal.

Resolution for the Red Sea Region

The International Coral Reef Initiative (ICRI) 38th General Meeting, held in September 2024 in Jeddah, Saudi Arabia adopted a resolution emphasizing the Red Sea's global significance (Reimer et al. 2024). The resolution highlights the region's role as a biodiversity hotspot, containing 12,696 km² of coral reefs and over 265 coral species. Acknowledging the Red Sea as an "open-sky laboratory" for studying biodiversity and coral resilience to climate change, the resolution underscores its critical importance for over 28 million coastal residents who rely on these ecosystems for fisheries, tourism, and coastal protection (ICRI, 2024).

Key elements from the resolution include: 1) Strengthening partnerships among nations to enhance the collection, monitoring, and sharing of coral reef data; 2) fostering a unified approach to conservation and expanding the network of protected zones to achieve regional and global targets, such as the 30 by 30 initiative – a global conservation effort aiming to protect 30% of the planet's land and ocean areas by 2030 to combat biodiversity loss and ecosystem degradation (Dinerstein et al., 2019); 3) safeguarding critical coral reef habitats; 4) developing conservation skills at all levels, from local communities to scientific and policy-making circles; 5) promoting ocean literacy, community involvement, encouraging engagement with private industries, and fostering stewardship of marine resources; and 6) engaging local communities in conservation and restoration efforts, co-management of resources and sustainable practices to support livelihoods while reducing pressure on coral reef ecosystems. This resolution provides a strong framework for protecting and restoring coral reefs in the GoA and the broader Red Sea.

Israel–Jordan Peace Treaty and Bilateral Cooperation

A breakthrough for transboundary environmental cooperation in the northern Red Sea came with the 1994 Israel–Jordan Peace Treaty. This landmark agreement not only ended decades of hostilities between the two neighbors, but also explicitly incorporated environmental cooperation. Article 18 of the treaty committed the parties to work together on environmental protection, "including conservation of nature and prevention of pollution," with a specific Annex (Annex IV) dedicated to the environment. Additionally, Article 23 on Aqaba and Eilat called for negotiations

on the joint development of these two Red Sea port cities, listing areas of cooperation such as *prevention of pollution, maritime matters*, and *health*. In the spirit of the treaty, Israel and Jordan – with support from the United States and others – moved to create concrete joint initiatives for the GoA.

One early outcome was the *GoA Environmental Action Plan (GAEAP)* in 1995. With backing from the World Bank and Global Environment Facility, separate national environmental action plans for the GoA were developed by Jordan, Israel, and Egypt around that time. These plans aimed at a coordinated approach to managing coastal development, pollution control (e.g., oil spill response), and marine conservation in the gulf. For instance, Jordan established the Aqaba Marine Park and tightened industrial discharge standards, while Israel expanded protections in the Coral Beach Nature Reserve. The GAEAP process fostered cross-border dialogue; however, implementation remained largely at national levels with parallel efforts rather than a fully integrated regional plan.

In 1997, a more ambitious project began: the creation of a *Red Sea Marine Peace Park (RSMPP)* jointly managed by Israel and Jordan. The RSMPP concept envisioned a contiguous marine peace park spanning the Israel-Jordan maritime border in the northern GoA, effectively linking the coral reef reserves of Eilat (Israel) and Aqaba (Jordan) into one transboundary protected area (Crosby et al., 2002). The United States, eager to support the peace dividend, heavily funded this initiative – the U.S. Department of State and NOAA provided financial and technical support from its inception. The RSMPP program (launched in 1999) had three major components: (1) Joint Management – establishing cooperative patrols, regulations, and planning for the combined park; (2) Joint Scientific Monitoring – a unified ecosystem monitoring program for water quality, coral health, and fisheries; and (3) Public Outreach – engaging local communities and tourists about the peace park and reef conservation (Portman and Teff-Seker, 2017). A trilateral agreement (Israel, Jordan, U.S.) under the USAID Middle East Regional Cooperation (MERC) program provided initial funding for three years. By the early 2000s, the RSMPP had achieved some success: scientists from the Interuniversity Institute in Eilat (IUI) and Jordan's Marine Science Station (MSS) were conducting joint research dives and sharing data, and an emergency response system for oil spills was jointly developed. In fact, a Joint Oil Spill Contingency Plan (JOSCP) for the northern Gulf was one of the first practical outcomes – Israel, Jordan (and also Egypt) agreed on protocols for mutual aid in case of spills. This proved vital in 1999 when an oil spill of ~30 tons occurred, and rapid bilateral action prevented serious damage to the coral reefs. Collaborative scientific monitoring yielded improved understanding of the gulf's ecology; as one example, by comparing data across borders, researchers could distinguish localized pollution effects from natural fluctuations.

Despite these positive aspects, the RSMPP faced substantial challenges that hindered its full realization. Over time, high-level political support and funding waned. After 2003, U.S. funding for the Peace Park program ceased as the initial

project term ended. Israel and Jordan did sign a Memorandum of Understanding to continue joint monitoring and data exchange, and indeed, some bi-annual joint research expeditions persisted into the mid-2000s (Amatzia Genin, personal communication, 2025).

Nonetheless, the legacy of the Peace Park effort was not lost. The joint monitoring program established a valuable long-term dataset and fostered personal relationships between Israeli and Jordanian marine experts (Portman and Teff-Seker 2017). Even during periods of "official" separation, scientists from both sides have maintained communication and continue to share data and attend the same scientific fora (often outside the region) – effectively forming an epistemic community with a common interest in the Gulf's well-being (Crosby et al., 2002). This bottom-up connectivity has kept alive the notion that, when political conditions allow, a more integrated management of the gulf's reefs could be rekindled (Crosby et al., 2000).

The joint monitoring cruises of the (MSS) and the IUI, which started about 25 years ago, served for many years as a key activity of the Jordanian and Israeli monitoring programs in their goal to understand and quantify the oceanographic conditions in the northern GoA and assess the occurrence of trends related to climate change and other processes. For about 16 years those cruises operated twice a year (late winter and summer) using the research vessel of the IUI.

Transnational Research and Monitoring Initiatives

Outside of formal treaties, there have been internationally sponsored programs fostering Red Sea cooperation in marine science and conservation.

Middle East Regional Cooperation (MERC) Program

MERC, (funded by USAID) has, since the 1990s, supported numerous collaborative research projects involving Israelis, Jordanians, Egyptians, and Palestinians. Several MERC grants have focused on Red Sea marine issues – for example, joint studies on coral reef diseases, Red Sea fisheries, and oceanography. These projects not only produced scientific insights but also built professional networks among regional scientists (Kedem et al. 2024b). A key achievement has been the establishment of standardized coral reef monitoring protocols used by multiple countries, allowing data comparison across borders. However, the MERC program's continuity has been subject to U.S. foreign aid policies. In the late 2010s, the Trump administration significantly cut funding for cooperative Middle East science initiatives, leading to some MERC-supported environmental projects being scaled down or paused (anecdotally referred to as a setback for regional environmental cooperation). In the early 2020s, MERC funding has resumed under new U.S. support, reviving some joint Red Sea projects but ceased again with Trump's second presidential term in early 2025.

Red Sea Program

Germany's Federal Ministry of Education and Research (BMBF) funded a major Red Sea research initiative (1994-1999), that brought together scientists from Germany,

Egypt, the Palestinian Authority, Jordan, and Israel. The program made valuable scientific contributions, trained a cohort of regional marine scientists and demonstrated the benefits of external "neutral" support to overcome regional fragmentation in research (Amatzia Genin, personal communication, 2025; Lahl et al., 2023).

NATO Science for Peace and Security (SPS) Projects

Through its civil science cooperation program, NATO has funded environmental collaborations in the Red Sea (Stanford University, 2009). One SPS project (circa 2010-2015) helped Israel and Jordan develop an early-warning system for marine hazards in the GoA. This included deploying real-time monitoring buoys for detecting harmful algal blooms and oil slicks and creating joint emergency response protocols. Such technical projects provided practical mutual benefits (e.g., better disaster preparedness) and implicitly encouraged data sharing and trust-building between the countries (Simón et al. 2022). These "science for peace" initiatives indicate that even security-focused organizations see value in ecological cooperation as a confidence-building measure.

Transnational Red Sea Center (TRSC)

A very recent development in regional marine cooperation is the creation of the Transnational Red Sea Center in 2019. Uniquely, this center is based in neutral Switzerland (at the École Polytechnique Fédérale de Lausanne) with the backing of the Swiss government. The TRSC's mission is to serve as a hub for region-wide coral reef research and monitoring, explicitly bridging all Red Sea countries (including Israel and those that do not have formal ties with Israel). By leveraging Switzerland's diplomatic neutrality and scientific reputation, the TRSC has been able to convene researchers from Saudi Arabia, Sudan, Yemen, Eritrea, Israel, Jordan, Egypt and Djibouti under one umbrella. The center promotes standardized survey methods and data sharing across the Red Sea and has organized multinational research expeditions – one of its major achievements was a collaborative survey of coral reef health along the entire Red Sea in 2021-2022, involving scientists from 9 countries. Such an endeavor was unprecedented and yielded the first comprehensive baseline of reef conditions from the GoA to the Bab-el-Mandeb. The TRSC also emphasizes capacity-building, running workshops to train regional marine scientists in advanced techniques (e.g., genomic tools for coral research). Importantly, the TRSC operates with an ethos of "science diplomacy" – it treats science as a common language that can transcend political divides.

In addition to these initiatives, there have been various collaborations led by NGOs such as underwater cleaning operations including Jordanian and Israeli divers and joint actions to reduce plastic in the GoA vicinity through education, public awareness and innovation. Another notable output of the Israeli–Jordanian peace treaty was the creation of the Aqaba-Eilat committee in 1996, which was established through an MOU between Aqaba and Eilat and recognized by both governments (Arieli and Cohen, 2013). The Aqaba-Eilat committee included several sub-committees. One of them focused on the environment. The role of

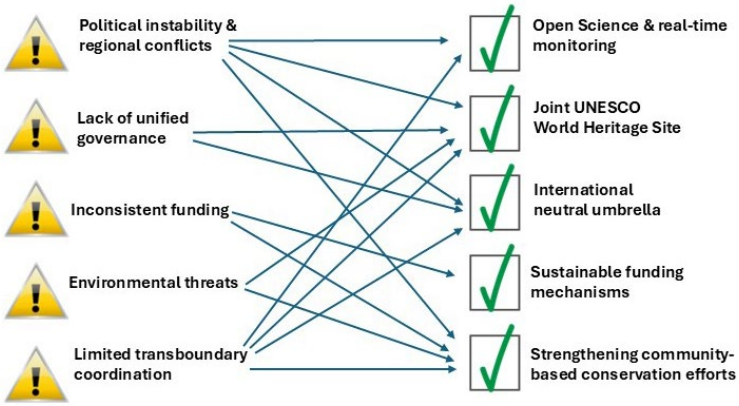
the committees was to map and prioritize shared interests and needs and promote joint action plans. The environmental sub-committee developed a program for a transboundary Integrated Coastal Zone Management platform and outputs, plans to renew the shared scientific monitoring and the shared marine pollution control. The committee was active up to the recent war of 2023. Since the Israel-Jordan peace treaty other initiatives led by civil society and local authorities took place, that do not focus on the GoA directly, rather on other environmental concerns and economic development and therefore are not included in the scope of this paper.

In summary, the Red Sea region has seen a mix of promising initiatives and frustrating setbacks in transboundary reef conservation. The 1990s and early 2000s delivered a hopeful burst of cooperation (peace treaty, RSMPP, PERSGA's SAP), which demonstrably improved some environmental safeguards. Subsequent years were more tumultuous, with periods of stalled progress amid conflict. Yet, the pressing urgency of climate adaptation, combined with diplomatic shifts (e.g., the Abraham Accords in 2020 normalizing Israel-UAE/Bahrain relations and potentially opening doors with Saudi Arabia), present a window to reinvigorate TEC for the Red Sea reefs.

DISCUSSION

In this discussion we explore the challenges and opportunities such cooperation faces and strategies to strengthen and sustain TEC in the Red Sea (Figure 1). We consider how open science and data-sharing could maintain collaborative momentum even during diplomatic downturns and propose the designation of the *GoA as a UNESCO World Heritage Site* as a step to lock-in international commitment and joint management.

Figure 1: Challenges & Solutions for Coral Reef Conservation in the Red Sea



A list of challenges for Coral reef conservation in the Red Sea (left) and potential solutions (right).

Conflict, Informal TEC, and the Need for an Integrated Approach

Despite this array of efforts, significant obstacles have repeatedly hampered sustained transboundary environmental governance in the Red Sea. Geopolitical instability is a primary factor: regional conflicts including the Israeli–Palestinian clashes and the civil wars in Yemen, Sudan and Somalia, create atmospheres of mistrust or direct security barriers that spill over into environmental domains (Winckler, 2021; Kedem et al., 2024b). Yemen's civil war since 2015 has preoccupied Red Sea countries and sidelined collective environmental initiatives in the southern Red Sea, e.g., delaying responses to the decaying *FSO Safer* oil tanker threat (Charlebois and Griffiths, 2024). PERSGA, the primary regional environmental body, excluded Israel and Eritrea due to political sensitivities, limiting truly inclusive conservation efforts. The RSMPP saw slow progress due to geopolitical tensions, with projects pausing during conflicts.

Nevertheless, cooperation does not solely occur at the inter-governmental level. One of the most under-recognized forces in fostering TEC has been the community of regional environmental professionals – scientists, park managers, NGO activists – who persistently work across borders often *regardless* of high politics (Kedem et al 2024a and 2024b). These individuals can act as "policy entrepreneurs" and peacebuilders in the environmental arena (Arieli and Cohen, 2012). Scientists and conservationists from Israel, Jordan, and other Red Sea nations have continued joint reef monitoring and data sharing, often informally or under international sponsorship. For instance, the NATO-funded project enabled Israeli and Jordanian scientists to collaborate on coral studies even when formal government-to-government coordination was frozen. More recently, the Transnational Red Sea Center, established in Switzerland, has engaged researchers from Red Sea countries in joint marine science efforts, bypassing direct diplomatic barriers. These informal collaborations have been vital for continued research and monitoring, demonstrating that science can serve as a bridge even amid political divides.

A recent study focusing on Israel and Jordan found that local environmental experts played a pivotal role in sustaining transboundary projects after the 1994 peace accord, even when official political engagement waned. They leveraged personal networks and shared technical goals to keep cooperation alive, essentially filling gaps when formal agreements stalled. Notably, these professionals reported that through working together their willingness to end the conflict in the Middle East in non-violent ways, increased, and they developed understanding and trust toward their counterparts from the other side. However, they also face pressures, for example, Jordanian experts sometimes confront anti-normalization sentiments at home, and Israelis may get criticized for engaging with neighbors during tense times (Kedem et al. 2024b). Supporting these "epistemic communities" with safe platforms for dialogue and recognition of their work is crucial. They form fabric that can hold TEC together during political storms.

However, International diplomacy and funding instability remains a major challenge for informal TEC efforts. Many rely on external donors, particularly U.S.

foreign aid, which has fluctuated with changing administrations. The Middle East Regional Cooperation (MERC) program, a key U.S.-funded initiative supporting Israeli-Arab scientific partnerships, has suffered periodic funding cuts. Under the Trump administration (2017–2020), MERC grants were scaled back, stalling some joint Red Sea projects. Though funding resumed in the early 2020s, Trump's second term in 2025 brought renewed cuts to USAID and MERC, further restricting support for transboundary environmental science. Without sustained funding, even the most resilient bottom-up efforts struggle to continue long-term monitoring and conservation initiatives.

The Red Sea's experience mirrors other geopolitically sensitive marine regions where informal TEC has filled governance gaps. In the Caribbean, U.S.-Cuba tensions long prevented formal agreements, but marine scientists collaborated informally for years, paving the way for a formal "sister sanctuaries" agreement in 2015. Similarly, in the South China Sea, where territorial conflict hinders formal cooperation, scientists have used joint coral reef studies as a tool for confidence-building. These cases suggest that informal, science-led initiatives can support environmental cooperation even in conflict zones, but their long-term impact depends on stable funding and, ultimately, political will.

Finally, engaging local stakeholders at every step is vital. The demonstrated endurance of the informal environmental and scientific collaboration during times of conflict emphasizes the importance of collaboration between communities, NGOs, and the private sector, which follows peacebuilding conceptual frameworks (Lederach, 1997). Expanding such cooperation can include diving alliances of operators from Eilat, Aqaba, Sinai, and Saudi Arabia's Tabuk promoting reef-friendly tourism guidelines and reporting environmental violations. Fisherfolk communities could agree on shared no-take zones and seasonal closures, acknowledging fish populations don't respect borders. Environmental NGOs, such as Eilat's marine conservation groups and counterparts in Aqaba, could run joint education campaigns: possibly under the banner of the proposed World Heritage site, to instill a sense of shared heritage and collective responsibility among the public.

The challenges posed by the political complexities in the region created a gap in environmental governance. The gap is filled by informal networks, that like those in other regions, have shown resilience and creativity in the face of conflict, but scaling them into lasting, formalized cooperation will likely require more stable funding commitments and eventually, improved diplomatic relations. The approaches we suggest below include an integrative approach of combining formal and informal efforts.

Open Science and Data-sharing as Enablers

In an environment often fragmented by political boundaries and limited direct communication, embracing an open science ethos can be transformative. Open science entails making research methods, data, and results widely accessible to all

stakeholders, and encouraging collaborative participation in knowledge generation (Ramachandran et al. 2021). Adopting such practices in the Red Sea region can yield several benefits, including collaboration, transparency and trust, capacity building and resilience to political shocks.

The International Coral Reef Initiative (ICRI), a global partnership for coral reefs, already encourages data-sharing and could support a Red Sea open data hub. In fact, ICRI's 2024 meeting in Jeddah highlighted strengthening regional data sharing as a priority. The tools and technology exist; what is needed is collective agreement by countries to contribute data and respect scientific transparency. Another international example is The Allen Coral Atlas, which provides a freely accessible global platform for mapping and tracking coral reefs via satellite imagery (Lyons et al., 2020; Andréfouët et al., 2024). Users can visualize reef conditions within any country's waters and download up-to-date data, exemplifying how open data tools make conservation information widely available. Similarly, global databases like ReefBase (McManus, 1994) have aggregated reef health and monitoring data from over 100 countries for public use, and collaborative networks such as the Global Coral Reef Monitoring Network (GCRMN) unite hundreds of scientists to pool data and assess reef status trends worldwide (Wicquart et al., 2022).

There are two open science initiatives in the GoA that we are aware of: The National Monitoring Program (NMP) of the GoA serves as a model for open science. Operated from the IUI and funded by the Israeli Ministry of Environmental Protection, this long-term program systematically collects oceanographic, ecological, and environmental data, providing critical insights into coral reef health, water quality, and anthropogenic impacts in the region. Researchers, policymakers, and the public can download datasets directly from the NMP website or through its annual reports, ensuring that scientific findings are widely available for regional and global research efforts.

Another open science system in the GoA includes the Coral Monitoring Station (CMS) network, which was recently launched in the GoA as a real-time, open-access coral health observatory (https://iui-eilat.ac.il/Info/PamDashboard.aspx). The first CMS node was installed off Eilat (Israel) in late 2021, followed by a second in Aqaba (Jordan) in 2022, with additional stations planned at strategic sites along the Red Sea. These stations continuously stream data on coral physiological performance (e.g. photosynthetic health) and local environmental conditions, functioning as an early-warning system for stress events like bleaching. Crucially, the live data are openly accessible to scientists and managers on both sides of the border, enabling rapid, coordinated responses to emerging threats. This real-time sharing of information exemplifies how transboundary coral reef conservation can be strengthened by open science, as stakeholders jointly track reef conditions and intervene quickly when warning signs appear.

Expanding such open-access initiatives across Red Sea nations could further enhance regional cooperation and reinforce science-based conservation strategies.

The growing world-wide practices of sharing data openly, coupled with the Red Sea's unique reef resilience can increase the commitment and participation of international researchers, which can complement regional efforts with additional expertise and funding

Toward a Joint World Heritage Site—"Reef Refuge of The Red Sea"

One of the propositions that can cement transboundary cooperation in the GoA is the establishment of a UNESCO World Heritage Site (WHS) that spans the marine territories of Jordan, Israel, Egypt, and Saudi Arabia. World Heritage designation is prestigious – it recognizes sites of Outstanding Universal Value – and comes with expectations (and support) for rigorous conservation. A transboundary World Heritage marine site in the GoA could serve multiple purposes: it would provide a unifying conservation framework, attract international resources, and politically bind the four nations to collaborate despite other differences. Notably, at ICRI's 38th General Meeting in 2024 hosted by Saudi Arabia, the global significance of the Red Sea's reefs was underscored, and a resolution was adopted calling for enhanced regional collaboration and even exploring "designation of particularly resilient reefs for World Heritage recognition" (ICRI, 2024). This indicates high-level openness to the idea. Jordan and Saudi Arabia (UNESCO, 2024) have already applied to UNESCO to obtain a WHS status of reefs in their territory but a transboundary WHS will secure reefs in the entire GoA and beyond.

There are several benefits of a World Heritage designation. World Heritage listing would enshrine the GoA's reefs as a global treasure, which in turn pressures the bordering nations to uphold high protection standards. It brings international legal frameworks and monitoring, for instance, UNESCO requires periodic reporting on site condition and can intervene (through recommendations or missions) if a site is threatened. A transboundary WHS virtually mandates cooperation – a joint management committee or authority would likely be formed, comprising officials and experts from all four countries, to oversee the site. Regular communication and coordination would become routine through this body. This is particularly powerful in the GoA where currently, for instance, Egypt and Saudi Arabia manage their coral reefs largely independently with minimal coordination with Israel and Jordan. Under a World Heritage framework, all parties would have to come to the table. The designation would put a spotlight on the GoA as a "reef refuge" – a last opportunity for coral ecosystems in a warming world. This narrative can attract substantial international funding and scientific interest. Already, initiatives like the Global Fund for Coral Reefs (GFCR) are looking to invest in climate-resilient reef areas; a World Heritage label would strengthen the case for the Gulf to receive such support. It could also boost sustainable eco-tourism; drawing visitors interested in experiencing a World Heritage coral reef, which can provide economic incentives for local communities to support reef protection. A properly managed WHS could be a boon for local communities in Aqaba, Eilat, Sinai, and northwest Saudi towns. It

would promote sustainable tourism and possibly limit harmful industrial activities, ensuring that local employment (dive tourism, park rangers, research assistants) grows while destructive jobs (unsustainable fishing, pollution-intensive industries) are curtailed.

Of course, achieving this is not trivial. It requires agreement among governments that are not all on formal speaking terms. However, there are signs of warming: Saudi Arabia and Israel have engaged quietly via U.S.-brokered talks in recent years, and both Saudi Arabia and Egypt have cooperated with Jordan on Red Sea conservation training via regional bodies. A neutral champion (perhaps UNESCO or IUCN) would likely be needed to mediate and assist the four countries in preparing a dossier nomination.

Next steps towards a WHS include consolidation of research on the GoA's coral reefs. Such data includes species diversity, resilience to warming, and ecological importance to demonstrate Outstanding Universal Value (OUV). Informal scientific cooperation can discuss the boundaries of key reef areas and compile the existing data. There is a wealth of scientific literature (e.g., Fine et al., 2013; Osman et al., 2018) and data from ongoing monitoring. Compiling this into a comprehensive dossier that demonstrates the Gulf's global importance and unique values is crucial. This scientific case would underpin the World Heritage nomination and guide what specific areas to include (likely the coral reef tracts fringing the Gulf from the Sinai Peninsula, past Aqaba and Eilat, to the Saudi coast). In parallel, diplomats and environmental authorities from Jordan, Israel, Egypt, and Saudi Arabia would need to reach a preliminary agreement in principle. This could be facilitated by a series of workshops and confidence-building measures such as renewing and broadening the 2005 Israel-Jordan MoU or signing a letter of intent at a regional summit. Once consensus is reached, a formal nomination to UNESCO would be prepared. This involves delineating the site boundaries, describing its Outstanding Universal Value, detailing the legal protection status in each country, and outlining a joint management plan. The management plan is a critical element that should specify how the four countries will coordinate.

The nomination would be submitted and evaluated by UNESCO advisory bodies. The World Heritage Committee could inscribe the site on the World Heritage List at one of its annual meetings. The very act of preparing and submitting the nomination would itself be a milestone of cooperation since it is a public commitment to work together. Countries can frame their cooperation in terms of fulfilling international obligations and pride, which might be more palatable domestically than bilateral concessions.

A World Heritage listing is not a panacea. It does not automatically solve enforcement or eliminate all tensions. However, it creates a durable framework and reference point. If one party lapses (e.g., a country considers an unsustainable development in its section), UNESCO can apply pressure via the threat of "in danger" listing, and the other partners can leverage the joint commitment to dissuade

such actions. The site's prestige also means any damage would be an international reputational issue, which governments usually seek to avoid. In essence, it elevates the stewardship of the Gulf's reefs from a national issue to a shared international responsibility.

Open science and a potential WHS are complementary. Open science ensures the knowledge flow and inclusive participation, while World Heritage provides the formal cooperative conservation framework. In fact, a joint World Heritage marine site in the GoA could explicitly incorporate an open science mandate: the four countries could agree to pool their monitoring data for the site and make it publicly available, as part of demonstrating transparency to UNESCO (this would align with World Heritage reporting requirements and the ICRI recommendations for the Red Sea. The process of managing the World Heritage site can be informed by the latest science coming from that open data collaboration.

Furthermore, these efforts dovetail with broader international initiatives focusing on reef refugia. The global community is increasingly recognizing that certain reef areas (like the Red Sea, parts of the Coral Triangle, etc.) may survive climate change longer and thus are priorities for protection and potential sources for reef restoration. The Global Fund for Coral Reefs (GFCR), mentioned earlier, is investing in resilient reefs and dependent communities. The Red Sea – with its 28 million coastal residents and significant Blue Economy – is a candidate for such investment. A cohesive regional approach backed by open science and World Heritage status would make it easier to channel funds from entities like GFCR, the Green Climate Fund, or private philanthropic initiatives into effective projects (e.g., sustainable tourism infrastructure, wastewater treatment upgrades to protect reefs, reef restoration pilots) across the GoA.

CONCLUSION

The Gulf of Aqaba's coral reefs are among the last refuges in a world facing widespread reef collapse, yet their resilience to rising temperatures does not make them immune to destruction. Climate change, coupled with intensifying coastal development, threatens to push these ecosystems past their tipping points. There is an urgent need for immediate action to prevent irreversible loss. Strengthening open science and data-sharing frameworks can facilitate collaborative conservation, ensuring that scientific knowledge remains accessible even amid political instability. Transparency and shared datasets will allow for coordinated responses, enhancing the region's ability to protect its marine ecosystems before degradation becomes irreversible.

A UNESCO World Heritage Site designation for the Gulf of Aqaba's reefs offers a long-term safeguard that transcends political cycles and national agendas. A jointly managed conservation framework between Israel, Jordan, Egypt, and Saudi Arabia

would not only protect marine biodiversity but also strengthen environmental security and foster diplomatic engagement through shared ecological stewardship. Additionally, a Red Sea Environmental Security Forum could provide a platform for strategic regional coordination, addressing immediate threats while developing long-term climate adaptation strategies. The time for action is now—without decisive transboundary governance, the Red Sea's coral reefs, along with the economic and ecological stability they provide, may not withstand the accelerating pressures of the 21st century.

POSTSCRIPT

This manuscript was completed prior to the escalation of the 2025–2026 regional war in the Middle East. Since then, geopolitical conditions in the Red Sea and Gulf of Aqaba (GoA) region have shifted significantly, with important implications for transboundary environmental cooperation (TEC) and coral reef conservation.

The ongoing conflict has further constrained formal diplomatic channels and disrupted several mechanisms of regional cooperation described above, including bilateral frameworks, multilateral initiatives, and externally funded programs. Reductions in international funding flows and the reallocation of governmental priorities toward security concerns have limited the operational capacity of joint environmental monitoring, research, and management efforts. These developments reinforce one of the central arguments of this study: TEC in the Red Sea is highly sensitive to geopolitical instability and external political dynamics.

Concurrently, the current crisis underscores the continued relevance and urgency of alternative cooperation pathways highlighted in this article. Informal, science-based collaborations, open data platforms, and internationally mediated initiatives have proven more resilient under conditions of political fragmentation. These mechanisms may now represent the primary viable channels for maintaining continuity in reef monitoring and conservation across national boundaries.

Importantly, the ecological stakes remain unchanged and may in fact be heightened. The coral reefs of the GoA continue to represent a globally significant climate refuge, but their long-term persistence is contingent on effective management of local stressors. Reduced enforcement capacity increased maritime risks, and potential environmental hazards associated with regional instability (e.g., pollution events, infrastructure damage) may elevate pressures on these ecosystems in the near term.

In this context, the strategic frameworks proposed in this paper, particularly the expansion of open science infrastructures and the potential designation of a transboundary UNESCO World Heritage Site, gain additional significance. Such approaches may provide rare avenues for sustained cooperation, even in the absence of stable political relations, by embedding environmental stewardship within international and scientific structures that transcend national conflicts.

Ultimately, the current geopolitical reality reinforces a central conclusion of this work: that safeguarding the Red Sea's coral reef refuge is inseparable from the development of robust, flexible, and multi-layered cooperation mechanisms capable of operating under conditions of uncertainty and conflict.

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