

Fisheries of the Red Sea and the Arabian Gulf: A Comparative Assessment

Priya Ranjan Mishra¹, Adil Sidahmed Omer Ahmed^{1,2}

¹Sustainable Technology Solutions, Ajman, UAE

²Institute of Marine Research, Red Sea University, Port Sudan, Sudan

Email: ranjan@sustecsol.com

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Abstract

The Red Sea and the Arabian Gulf are ecologically distinct yet socio-economically vital marine systems, where fisheries underpin food security, livelihoods, and coastal economies in the Middle East. This review presents a comparative assessment of fisheries status, exploitation patterns, drivers of illegal, unreported, and unregulated (IUU) fishing, and governance capacity in both regions, synthesizing peer-reviewed studies, regional assessments, and institutional data. Results indicate that 60% - 75% of stocks in the Red Sea and 70% - 85% in the Arabian Gulf are fully exploited or overexploited, with declining catch-per-unit-effort (CPUE) and reduced mean trophic levels, reflecting “fishing down the food web”. Despite shared pressures, the regions differ markedly in ecological and institutional context. The Red Sea’s high biodiversity and complex reef habitats support predominantly artisanal, multi-species fisheries, offering some ecological resilience but leaving high-value demersal species vulnerable to targeted exploitation. In contrast, the Arabian Gulf’s lower biodiversity, extreme environmental conditions, and mechanized, species-focused fisheries heighten susceptibility to overfishing. IUU fishing is a significant driver of unsustainable exploitation in both regions, influenced primarily by socio-economic pressures (35% - 40%), governance gaps (25% - 30%), environmental stressors (15% - 20%), and technological or market incentives (15% - 20%). Regional differences, such as weak monitoring and limited compliance in the Red Sea versus fleet overcapacity in the Arabian Gulf, create reinforcing feedback loops of declining biomass, reduced CPUE, and escalating fishing pressure. The study highlights the urgent need for ecosystem-based, region-specific fisheries management that integrates ecological complexity, socio-economic dependence, and governance capacity. Strengthening monitoring, surveillance, fleet regulation, data integration, and regional cooperation is essential to break the overfishing-IUU cycle and ensure long-term sustainability and resilience of these marine ecosystems.

Keywords

Red Sea, Arabian Gulf, Marine Fisheries, Fisheries Governance, Ecosystem-Based Management, Sustainability

1. Introduction

Marine fisheries play a critical role in food security, employment, and economic development throughout the Middle East. Among the region's marine systems, the Red Sea and the Arabian Gulf are particularly significant, both ecologically and socio-economically, yet they exhibit strikingly different physical and environmental characteristics that influence fisheries structure and management challenges [1].

Figure 1 presents a satellite view of the Red Sea [2], illustrating its long, narrow basin flanked by arid coastlines. This semi-isolated sea features extensive coral reef systems, high biodiversity, and relatively stable salinity and temperature gradients, providing the environmental foundation for predominantly artisanal and small-scale fisheries along the coasts of Sudan, Saudi Arabia, Eritrea, and Yemen [3].

In contrast, **Figure 2** shows a satellite image of the Arabian Gulf [4], a shallow, semi-enclosed basin situated between the Arabian Peninsula and Iran. The Gulf is subject to extreme environmental conditions, including elevated temperatures, hypersalinity, and pronounced seasonal variability. These natural constraints, combined with intense anthropogenic pressures from coastal development, industrial activities, and maritime traffic, shape fisheries dynamics and resource availability [5] [6].

Despite these contrasting contexts, both regions face pervasive threats to marine resources, including overexploitation, habitat degradation, climate change, limited data availability, and governance constraints. The interactions between ecological conditions, fishing pressure, and institutional capacity, however, vary substantially, resulting in region-specific fisheries outcomes.

Aim and Scope of the Review

This paper presents a comparative assessment of fisheries in the Red Sea and Arabian Gulf, focusing on:

- 1) reviewing the ecological and environmental characteristics of shaping fisheries in both regions;
- 2) comparing fisheries resources, production systems, and exploitation patterns;
- 3) examining governance structures, management approaches, and data availability; and
- 4) identifying key challenges, knowledge gaps, and opportunities for sustainable fisheries management.

The review synthesizes peer-reviewed literature, FAO and UNEP reports, regional assessments, and national fisheries data, aiming to inform research, policy

development, and ecosystem-based management initiatives.



Figure 1. Satellite photo of the Red Sea [2].

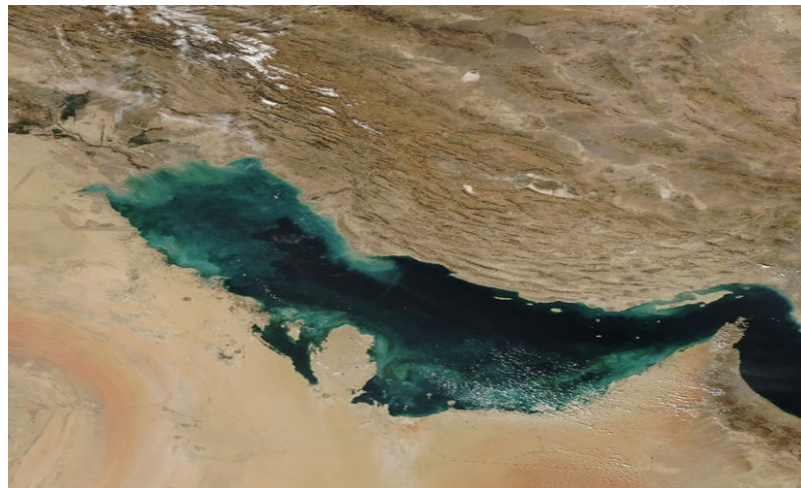


Figure 2. Satellite photo for the Arabian Gulf [4].

2. Methodology

This study adopts a narrative comparative review approach to synthesize and contrast fisheries status, production patterns, governance structures, and drivers of illegal, unreported, and unregulated (IUU) fishing in the Red Sea and the Arabian Gulf. The review integrates peer-reviewed literature, regional assessments, institutional reports, and national fisheries statistics to identify convergent patterns and region-specific dynamics.

Literature selection was guided by relevance to fisheries production, stock status, ecological trends, governance frameworks, and IUU fishing drivers in the two regions. Sources were screened to ensure geographic relevance, analytical credibility, and consistency with the comparative scope of the study. Rather than aiming for exhaustive coverage, the review prioritizes studies that provide empirical evidence, regional syntheses, or authoritative assessments.

The quantitative ranges presented for major IUU fishing drivers in **Table 2** and **Table 3** (e.g., 35% - 40%) are semi-quantitative estimates derived through cross-comparison of multiple sources. Where numerical indicators were available (e.g., fleet capacity, enforcement coverage, proportion of unreported catch), reported values were compared across studies. In cases where drivers were described qualitatively (e.g., high, moderate, or low influence), qualitative assessments were translated into approximate numeric ranges to facilitate structured regional comparison. These values represent relative influence rather than precise statistical measurements.

Comparative analysis focuses on identifying consistent trends across ecological conditions, fishery structures, and governance capacity. Limitations related to data gaps, underreporting, and uneven monitoring are explicitly acknowledged, and conclusions are framed to reflect relative patterns and policy-relevant insights rather than exact quantitative estimates.

3. Environmental and Ecological Context

3.1. Red Sea

Red Sea fisheries operate within a structurally complex coral reef ecosystem characterized by high biodiversity, habitat heterogeneity, and strong trophic stratification [7]-[10]. Reef-associated and pelagic assemblages support multi-species exploitation patterns dominated by groupers, snappers, emperors, sardines, and shrimp [11] [12].

Although aggregate landings remain moderate relative to global tropical systems, the ecological structure distributes fishing mortality across numerous taxa. However, slow-growing, late-maturing predators remain disproportionately sensitive to sustained effort, particularly under uneven enforcement and limited stock-specific monitoring [12]-[14].

3.2. Arabian Gulf

In contrast, the Arabian Gulf represents an environmentally extreme marine system shaped by hypersalinity, shallow bathymetry, high temperature variability, and chronic coastal modification [15]-[18].

Fisheries production is concentrated on fewer commercially dominant taxa, primarily shrimp and demersal finfish, resulting in reduced ecological redundancy. Combined with higher fleet mechanization and historical catch expansion, this structure increases vulnerability to stock fluctuations and environmental shocks [19]-[21].

3.3. Comparative Ecological Overview

3.3.1. Ecological Contrasts and Fisheries Structure

The Red Sea and Arabian Gulf represent two markedly contrasting marine ecosystems. The Red Sea is characterized by high biodiversity and extensive coral reef systems, complemented by seagrass meadows and mangrove habitats that support diverse reef-associated and pelagic species [22]-[24].

Structural complexity enhances ecosystem stability and buffers fisheries against

localized disturbances [24]. However, multi-species fisheries complicate stock assessment and management due to species-specific variation in growth, exploitation rates, and population dynamics [25].

By contrast, the Arabian Gulf is shaped by extreme environmental conditions that limit biodiversity and favor environmentally tolerant species. Anthropogenic pressures such as coastal reclamation, industrial development, shipping, and hydrocarbon exploitation further amplify ecological stress. Consequently, Gulf fisheries rely on a narrower ecological base and fewer commercially important species, increasing vulnerability to fishing pressure and environmental change.

3.3.2. Socio-Ecological Signals from Fisheries Landings

Fisheries landings reflect these ecological contrasts. In the Red Sea, multi-species landings dominated by reef-associated taxa indicate close links between fisheries and habitat diversity. High-value predators and long-lived reef fish remain vulnerable to concentrated fishing effort, particularly under weak enforcement [25] [26].

In the Arabian Gulf, landings are dominated by fewer commercial species, including demersal finfish and shrimp. This concentration increases susceptibility to overfishing, while declining CPUE and shifts toward lower trophic levels reflect ecological constraints [27].

Maintaining ecosystem integrity, particularly coral reefs and associated coastal habitats, is central to sustaining fisheries productivity in the Red Sea [27] [28]. In the Arabian Gulf, lower ecological buffering capacity necessitates precautionary exploitation limits, adaptive management, and strengthened monitoring [29] [30].

4. Fisheries Production Patterns

4.1. Red Sea Fisheries

Red Sea fisheries are predominantly artisanal and multi-species. Total landings are modest, but species diversity is exceptionally high due to complex coral reef systems [1] [2]. Fishing pressure is distributed across taxa, conferring ecological resilience. However, high-value predators remain vulnerable due to slow growth and late maturity [3]-[5].

4.2. Arabian Gulf Fisheries

Fisheries in the Arabian Gulf operate under constrained environmental conditions and are dominated by artisanal and semi-industrial fleets with higher mechanization and efficiency [6] [7]. Targeted resources include demersal finfish, small pelagics, shrimp, and crabs, with shrimp fisheries being economically significant [8] [9].

Shrimp stocks show strong spatial and temporal variability due to intensive exploitation, habitat degradation, and environmental stressors [8]-[10]. Low species diversity amplifies vulnerability, emphasizing the need for precautionary management [11] [12].

4.3. Comparative Production Patterns

Production dynamics in the Red Sea and the Arabian Gulf reflect fundamental

differences in ecological structure, fleet composition, and exploitation intensity.

In the Red Sea, fisheries are characterized by multi-species artisanal systems closely linked to coral reef ecosystems. Although total reported landings are moderate compared to other regional seas, species diversity is exceptionally high, and fishing effort is distributed across multiple reef-associated and pelagic taxa (**Table 1, Figure 3**) [12]-[14]. This diversity can provide a degree of ecological buffering by spreading fishing pressure across functional groups. However, it also complicates stock-specific monitoring and enforcement, particularly for high-value demersal predators that are more vulnerable to selective targeting [15] [16].

In contrast, the Arabian Gulf exhibits more concentrated production patterns. Fisheries rely on a narrower suite of commercially valuable species, particularly shrimp and demersal finfish, supported by semi-industrialized and mechanized fleets (**Table 1, Figure 3**) [17]-[19]. This structural concentration increases stock sensitivity to fluctuations in recruitment, environmental stress, and fishing effort. Combined with extreme environmental conditions and habitat modification, such production dynamics reduce ecological redundancy and heighten vulnerability to overexploitation [20] [21].

Across both regions, persistent constraints, including limited long-term standardized datasets, uneven control of fishing effort, and incomplete reporting, reduce the precision of stock assessments and management responses [22] [23] [30]. These structural and institutional differences underscore the need for region-specific, ecosystem-based management strategies that integrate production patterns, fleet characteristics, and ecological resilience.



Figure 3. Multi-species catch at Abu Dhabi's primary fish landing site during early morning operations, prior to auction [9].

5. Results: Comparative Fisheries Assessment

5.1. Stock Status and Exploitation

Red Sea stocks are predominantly fully exploited or overexploited, with 60% - 75% of assessed stocks in these categories [24]-[26]. CPUE declines are particularly evident among reef-associated demersal species, including groupers (Serranidae),

snappers (Lutjanidae), and emperors (Lethrinidae) [24]. High-value predators show sharper declines, while smaller, fast-growing reef fish and pelagic species remain comparatively stable.

Fisheries are mainly artisanal and semi-industrial. Artisanal fishers use gillnets, handlines, and traps targeting multiple species per trip, while semi-industrial vessels exert additional pressure in nearshore reefs and lagoons. Shrimp fisheries contribute significantly but generate high bycatch and habitat impacts, highlighting the need for selective gear and effort regulation [25].

Arabian Gulf stocks are also largely fully exploited or overexploited, with 70% - 85% of stocks in these categories [26]. CPUE declines are most evident for shrimp, groupers, and rabbitfish (Siganidae), key species for domestic and export markets [27] [28]. Fisheries combine artisanal and industrial fleets, with mechanized trawlers, gillnets, and purse-seiners intensifying pressure in shallow coastal habitats. Overcapacity and environmental stressors increase vulnerability despite relatively stronger governance [28].

Table 1. Stock status indicators for the Red Sea and Arabian Gulf fisheries.

Indicator	Red Sea	Arabian Gulf	Key Sources
% stocks fully or overexploited	60% - 75%	70% - 85%	[24]-[26]
CPUE trend	Declining	Declining	[27] [28]
Dominant fishing fleets	Artisanal, semi-industrial	Artisanal, industrial	[25] [28]
IUU fishing prevalence	Moderate-high	Moderate	[6] [13]
Enforcement capacity	Uneven	Relatively strong but strained	[3] [8]

5.2. Drivers of IUU Fishing

Illegal, unreported, and unregulated (IUU) fishing in the Red Sea and Arabian Gulf is closely linked to the socio-economic dependence of coastal communities on fisheries. **Table 2** highlights the estimated contribution of socio-economic pressures (35% - 40%) as a key driver of IUU activity.

5.2.1. Fisher Dependence and Income

a. Red Sea: Approximately 70% - 75% of coastal households rely on artisanal fishing as a primary or secondary livelihood. Average annual income per fisher ranges between \$3500 - \$4000 USD. Overexploitation and declining catch-per-unit-effort (CPUE) reduce income by 15% - 20% annually, heightening the incentive for IUU fishing [28].

b. Arabian Gulf: Around 60% of small-scale fishers depend on shrimp and demersal finfish for income, often supplemented by mechanized fleet work. Average annual earnings are higher (~\$5000 - \$6000 USD), but narrow species targeting and intensive exploitation increase vulnerability to stock fluctuations and economic losses [27] [28].

5.2.2. Fleet Size and Structure

a. Red Sea:

The majority of fishing activity is conducted by artisanal vessels with limited mechanization, resulting in a distributed effort across multiple species and fishing grounds [27] [28]. This artisanal emphasis provides some ecological buffering but can also mask unreported effort in areas with limited monitoring.

b. Arabian Gulf:

The regional fleet comprises a mix of artisanal and mechanized vessels, with mechanization and fleet capacity identified as significant contributors to fishing pressure and IUU activity [27] [28]. The presence of more efficient gear and higher vessel capacity increases the risk of overexploitation and complicates management.

5.2.3. Economic Pressures and IUU Incentives

Declining CPUE, income uncertainty, and high dependence on fisheries reinforce the feedback loop described in **Figure 4**, where economic pressures drive increased IUU fishing, further reducing stock biomass and ecosystem resilience. Quantitative socio-economic data underscore that IUU fishing is not merely a regulatory issue but also a survival strategy for many coastal communities.

5.2.4. Socio-Economic Drivers

IUU fishing is largely driven by poverty, high dependence on fisheries for livelihoods, and fluctuating market demand. In the Red Sea, artisanal fishers rely on fishing for income and subsistence, with limited alternative employment. Rising domestic and export demand incentivizes fishing beyond quotas, in restricted areas, or of protected species [29].

In the Arabian Gulf, small-scale and semi-industrial fleets sometimes bypass regulations to maintain profitability under high operational costs, fuel expenses, and market competition [30]. High-value species, groupers, emperors, snappers, and shrimp are disproportionately targeted, with shrimp trawl fisheries in Saudi waters exhibiting significant underreporting and discarding [29] [30].

5.2.5. Regulatory and Governance Gaps

Weak enforcement, limited monitoring, and legal gaps exacerbate IUU fishing. In parts of the Red Sea (Sudan, Yemen), restricted patrol coverage, vessel tracking, and compliance monitoring allow illegal catches to enter markets undetected.

In the Arabian Gulf, governance is stronger but challenged by fleet mobility, intensive fishing, and transboundary exploitation. Migrant labour and unregistered vessels further complicate regulation. Harmonized protocols, such as the SFISH Regional Protocol of Action on IUU Fishing, are critical for improving compliance and monitoring.

5.2.6. Environmental and Ecological Factors

Environmental variability, habitat degradation, and climate-related stressors indirectly drive IUU fishing. In both regions, hypersalinity, rising sea temperatures, and declining reef productivity reduce target species availability, prompting illegal fishing to maintain catches [30]. Shrimp and demersal finfish fisheries are particularly sensitive to habitat disturbances from trawling and coastal development, with unreg-

ulated effort increasing when management fails to adapt to ecological changes.

5.2.7. Technological and Market Drivers

Modern fishing technologies, GPS-equipped vessels, mechanized trawlers, and efficient gillnets expand fishing reach and efficiency, but also facilitate illegal operations. Improved transport and cold storage allow illegally caught fish to reach distant markets, obscuring true exploitation levels. Strong market demand for high-value species, especially from GCC and international buyers, further incentivizes bypassing quotas and regulations.

5.2.8. Quantifying Drivers

Based on regional reports and literature, key drivers of IUU fishing in the Red Sea and Arabian Gulf can be roughly apportioned as follows:

- **Socio-economic pressures** (35% - 40%), including dependence on small-scale fisheries and limited alternative livelihoods [1] [2].
- **Regulatory and governance gaps** (25% - 30%), such as fleet overcapacity, weak enforcement, and fragmented management [3] [4].
- **Environmental and ecological stressors** (15% - 20%), including hypersalinity, habitat degradation, and extreme temperatures [4] [5].
- **Technological and market incentives** (15% - 20%), such as mechanized fleets and high-value species demand [6] [7].

Table 2. Estimated contributions of key drivers to IUU fishing in the Red Sea and Arabian Gulf.

Driver	Approx. Contribution (%)	Key References
Socio-economic pressures	35 - 40	[1] [2]
Regulatory and governance gaps	25 - 30	[3] [4]
Environmental and ecological stressors	15 - 20	[4] [5]
Technological and market incentives	15 - 20	[6] [7]

Table 3. Prevalence of IUU drivers by region.

Driver	Red Sea (%)	Arabian Gulf (%)
Weak monitoring & surveillance	80	50
Fleet overcapacity	50	80
Transboundary fishing	80	80
Limited compliance	80	50
Economic dependence on fisheries	80	50

Table 2 and **Table 3** illustrate both the approximate contributions of major IUU drivers and their prevalence across regions. In the Red Sea, weak monitoring, transboundary fishing, limited compliance, and economic dependence affect roughly 80% of operations, while fleet overcapacity contributes moderately (~50%). In the Arabian Gulf, transboundary fishing and fleet overcapacity dominate (~80%), while weak monitoring, limited compliance, and economic dependence are moderately influential (~50%). These patterns reflect regional variation in ecological condi-

tions, fleet structure, and governance capacity, informing targeted management and regulatory interventions [8]-[11].

5.3. Ecological and Trophic Trends

Analyses of fisheries in both the Red Sea and the Arabian Gulf reveal a consistent pattern of “fishing down the food web”, characterized by declines in high-trophic-level predators such as groupers (Serranidae), snappers (Lutjanidae), and emperors (Lethrinidae), alongside increasing dominance of smaller, fast-growing species including sardines, rabbitfish (Siganidae), and other small pelagics [10] [16]. These shifts in catch composition and trophic structure indicate progressive simplification of food webs and reduced ecosystem resilience.

Spatial comparisons of offshore reef systems further highlight the influence of fishing pressure on trophic dynamics. Predator biomass on offshore reefs in Sudan has been reported to be nearly three times higher than that observed on comparable reefs along the Saudi Red Sea coast, reflecting lower exploitation intensity and reduced accessibility of fishing grounds in southern Sudan [11]. In some remote Sudanese reefs, predator biomass approaches levels documented for globally recognized low-impact or near-pristine reef systems, underscoring the strong top-down effects of fishing on reef ecosystems where exploitation is intense [11].

Trophic declines are most pronounced for demersal reef predators in the Red Sea, while in the Arabian Gulf, the strongest signals are observed for shrimp and rabbitfish stocks. These patterns reflect the combined effects of targeted exploitation, habitat sensitivity, and environmental stressors such as hypersalinity, elevated temperatures, and coastal habitat modification [12]-[14].

Figure 4 synthesizes these ecological and socio-economic interactions into a conceptual feedback loop. Increased fishing effort drives overexploitation and declining stock biomass, leading to reduced catch per unit effort and heightened economic pressure on fishers. These pressures, in turn, intensify IUU fishing, reinforcing ecosystem degradation and undermining fisheries management effectiveness.

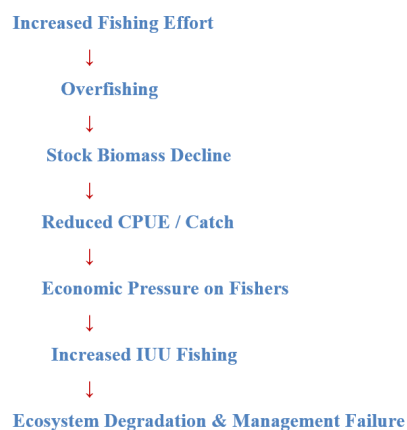


Figure 4. Conceptual feedback loop illustrating the interactions between fishing effort, overfishing, declining stock biomass, reduced catch-per-unit-effort (CPUE), economic pressure on fishers, increased IUU fishing, and the resulting ecosystem degradation and management failure.

5.4. Fisheries Production Patterns

Red Sea fisheries are dominated by artisanal, multi-species operations, targeting reef-associated and pelagic species, including groupers, snappers, sardines, and shrimp. Total landings in some areas remain below estimated biological potential, but the high species diversity distributes fishing pressure across multiple taxa, providing ecological resilience against environmental fluctuations and localized overexploitation.

In the Arabian Gulf, fisheries are more semi-industrialized, relying on mechanized fleets that primarily target fewer, high-value species, particularly shrimp and demersal finfish. These fisheries are highly sensitive to stock fluctuations due to intensive exploitation and environmental stressors, including hypersalinity, elevated temperatures, and habitat alteration. The narrow species focus, combined with higher mechanization, amplifies vulnerability to overfishing and ecosystem instability compared with the Red Sea.

Overall, Red Sea multi-species fisheries support ecological buffering and resilience, while Arabian Gulf fisheries, with limited target species, face higher ecological and economic risk.

5.5. Comparative Governance and Management

Governance and management structures differ between regions. In the Red Sea, management is fragmented, with uneven enforcement and limited infrastructure. Licensing, gear restrictions, and seasonal closures exist but vary across countries, limiting overall effectiveness. Transboundary fishing and high economic dependence on artisanal fisheries further complicate management.

The Arabian Gulf benefits from more centralized monitoring and stronger enforcement, but challenges remain. Fleet overcapacity, coastal development, competing maritime uses, and environmental stressors reduce management efficiency. Both regions lack long-term, comprehensive datasets, limiting adaptive management and accurate stock assessments.

Effective governance requires ecosystem-based approaches, enhanced monitoring, regional cooperation, and integration of socio-economic factors. Initiatives such as blue economy projects and mangrove conservation demonstrate opportunities to align sustainable fisheries management with broader environmental strategies.

5.6. Fisheries Production Patterns and Governance

5.6.1. Fisheries Production Patterns

a. Red Sea: Fisheries production reflects a predominantly artisanal, multi-species system strongly linked to coral reef habitats (Table 1, Figure 5). While high biodiversity distributes fishing pressure and may enhance ecological buffering, the absence of consistent effort control and long-term monitoring limits the realization of full biological potential. In several areas, reported landings remain below estimated productive capacity, suggesting either localized depletion or underreporting [15] [16].

b. Arabian Gulf: Production in the Arabian Gulf is characterized by higher

mechanization and concentration on fewer commercially valuable taxa, particularly shrimp and demersal finfish (**Table 1, Figure 5**). This structural concentration, combined with extreme environmental conditions and chronic habitat alteration, amplifies stock sensitivity to fishing pressure and reduces ecological redundancy [17]-[20].

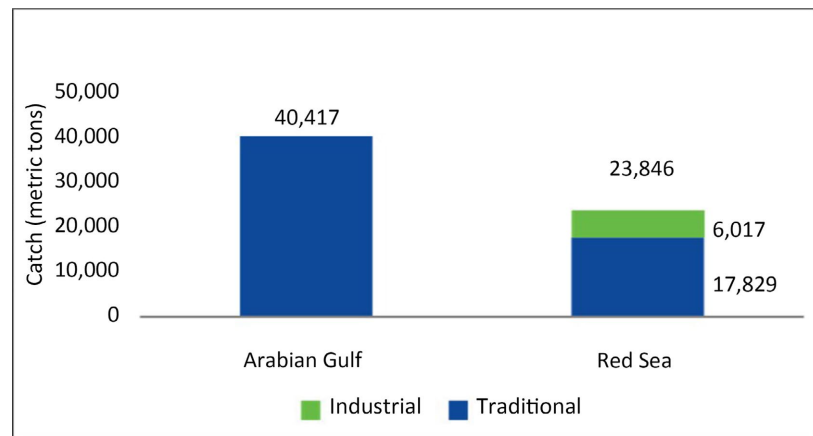


Figure 5. Marine fisheries catch from Saudi Arabia in 2022 (metric ton), according to the General Authority for Statistics, Kingdom of Saudi Arabia (2023).

5.6.2. Governance and Management

a. Red Sea: Governance is fragmented, with uneven enforcement and limited infrastructure. Licensing, gear restrictions, and seasonal closures exist but vary across countries, reducing overall effectiveness. Transboundary fishing and high dependence on artisanal fisheries further complicate management (**Table 2 and Table 3**) [20].

b. Arabian Gulf: Governance is more centralized, with stronger monitoring and enforcement. However, fleet overcapacity, competing maritime uses, and environmental stressors limit efficiency. Both regions lack long-term, comprehensive datasets, constraining adaptive management and precise stock assessments (**Table 2 and Table 3**) [21] [22].

5.6.3. Region-Specific Management Priorities

a. Red Sea: Expand monitoring and data collection, enforce licensing and seasonal measures, promote regional cooperation, and integrate socio-economic considerations (**Figure 4**) [23].

b. Arabian Gulf: Regulate fleet and fishing effort, strengthen monitoring, control, and surveillance, adopt ecosystem-based management approaches, and address socio-economic drivers of IUU fishing (**Figure 4**).

5.7. Comparative Governance and Management

Red Sea governance is fragmented, with uneven enforcement and limited infrastructure. Licensing, gear restrictions, and seasonal closures vary by country, reducing overall effectiveness. Transboundary fishing and high dependence on artisanal fisheries further complicate management.

The Arabian Gulf benefits from stronger enforcement and centralized monitoring,

Table 4. A concise comparison of fisheries structure, ecological risks, governance effectiveness, and management priorities for the Red Sea and Arabian Gulf.

Aspect	Red Sea	Arabian Gulf
Fisheries Structure	Predominantly artisanal, multi-species; reef-associated and pelagic species; high biodiversity	Semi-industrialized, mechanized; fewer high-value species (shrimp, demersal finfish)
Ecological Risks	Distributed fishing pressure supports resilience, but high-value predators vulnerable; localized overexploitation	Narrow species focus increases vulnerability; intensive exploitation and environmental stressors (hypersalinity, habitat alteration)
Governance Effectiveness	Fragmented management; uneven enforcement; limited infrastructure; variable regulations across countries	Centralized monitoring; stronger enforcement, but fleet overcapacity and competing uses reduce efficiency
Management Priorities	Expand monitoring and data collection; enforce licensing, gear, and seasonal measures; promote regional cooperation; integrate socio-economic considerations	Regulate fleet and fishing effort; strengthen monitoring, control, and surveillance; adopt ecosystem-based approaches; address socio-economic drivers of IUU fishing

but challenges remain. Fleet overcapacity, coastal development, competing maritime uses, and environmental stressors reduce management efficiency.

To synthesize these regional differences, a concise comparison of fisheries structure, ecological risks, governance effectiveness, and management priorities is presented in **Table 4**. As shown in **Table 4**, the Red Sea's predominantly artisanal, multi-species fisheries contrast with the Arabian Gulf's more mechanized and species-focused production systems. The table further highlights how differences in ecological buffering capacity and governance structures shape region-specific vulnerabilities and management priorities.

6. Discussion and Comparative Analysis

6.1. Socio-Ecological Expression of Environmental Differences

Environmental and ecological characteristics interact with socio-economic factors to shape fishing pressure in the two regions:

- **Red Sea:** High species diversity in reef ecosystems distributes fishing pressure and provides ecological buffering. Despite this, high-value predators remain vulnerable, and localized overexploitation occurs in areas of concentrated effort. With ~2500 artisanal vessels and 70% - 75% of coastal households dependent on fisheries, socio-economic pressure is a key driver of IUU activity, particularly where enforcement is weak [16].
- **Arabian Gulf:** The semi-industrialized fleet targets a narrower set of high-value species. Fleet overcapacity (~1200 mechanized vessels) and concentrated effort in shrimp and demersal finfish fisheries, combined with 60% fisher dependence, result in high economic vulnerability. Underreporting of catches and intensive exploitation exacerbate ecological risks, reinforcing the socio-ecological feedback loop [11].
- **Integration with IUU Drivers:** **Table 3** shows regional prevalence of IUU drivers, linking socio-economic dependence to limited compliance, transbound-

ary fishing, and fleet overcapacity. Quantitative socio-economic metrics clarify why IUU fishing remains persistent and indicate areas where alternative livelihood programs, gear buy-back schemes, and co-management approaches could mitigate both ecological and economic risks.

6.2. Stock Status and Exploitation Patterns

In the Red Sea, reef fisheries, despite their high species diversity, exhibit clear signs of overexploitation. Market surveys at key landing sites in the central Red Sea show that high-value serranids (e.g., *Plectropomus* spp. and *Variola louti*) dominate landings in terms of biomass and revenue, yet many individuals are below sexual maturity, reflecting intense harvesting pressure and reduced stock resilience [24] [25]. Population dynamics analyses of 55 commercially important species in the Egyptian Red Sea indicate that most stocks are overexploited, with exploitation rates exceeding sustainable thresholds across multiple taxa [26].

Current stock assessments cover only a fraction of total landings, with many southern and central fishing grounds lacking standardized evaluations. This limits the precision of status indicators and highlights the need for systematic monitoring expansion [26]. Overall, these findings suggest that sustained fishing pressure is affecting reef fish assemblages, likely driving shifts in catch composition and trophic structure.

In the Arabian Gulf, reconstructed fisheries catch from 1950 to 2010 indicates that officially reported statistics substantially underestimate total removals, likely by a factor of two [27]. Artisanal and discard components account for the majority of unreported catch, highlighting limitations in traditional monitoring systems and suggesting historically higher fishing pressure on demersal and commercially important species. High-trophic species, including groupers, snappers, shrimp, and rays, have experienced prolonged exploitation, intensifying their vulnerability to overfishing [27].

6.3. IUU Fishing and Data Gaps

Across both regions, IUU fishing and gaps in surveillance and reporting further complicate stock assessments and sustainable management. Small-scale and informal fisheries are often underrepresented in datasets, obscuring true fishing effort and total removals, which hampers adaptive management. In the Arabian Gulf, unreported sectors contribute substantially to total catches, reflecting governance limitations and incomplete statistical coverage [27].

6.4. Ecosystem-Based Management Implications

Despite these shared pressures, the two regions differ markedly in fishery structure and ecological context. The Red Sea supports a highly diverse, multi-species artisanal fishery, with numerous reef-associated taxa contributing to landings and market biomass [26] [27]. Such diversity can distribute fishing pressure and confer some ecological resilience, although high-value predators and long-lived species remain vulnerable under weak or inconsistent enforcement.

In contrast, Arabian Gulf fisheries are concentrated on a narrower set of commercially important taxa, particularly demersal finfish and shrimp. Historical catch reconstructions and stock assessments indicate that these stocks have endured decades of intensive exploitation by both industrial and artisanal sectors. Underreporting of actual catches further complicates management and increases the vulnerability of key stocks.

These comparative insights underscore the need for ecosystem-based management approaches that consider multi-species interactions, habitat dependencies, and trophic dynamics rather than focusing solely on single-species regulations [28]. Strengthening monitoring, control, and surveillance systems, including comprehensive collection of fishing effort and catch composition data, is critical for addressing IUU fishing and improving stock assessment reliability [29] [30]. Management strategies must also account for socio-economic realities, supporting adaptive co-management frameworks involving local fishers and stakeholders [30].

7. Conclusions

Fisheries in the Red Sea and Arabian Gulf face increasing pressure, with most stocks fully exploited or overexploited, declining catch per unit effort, and evidence of “fishing down the food web”. The Red Sea’s high biodiversity and complex reef habitats provide some ecological buffering, yet high-value species remain vulnerable. In contrast, the Arabian Gulf’s lower biodiversity and mechanized, species-focused fisheries heighten sensitivity to overfishing and environmental stressors.

IUU fishing, driven by socio-economic dependence, fleet overcapacity, transboundary activity, and governance gaps, reinforces a feedback loop of declining stocks and escalating exploitation. This underscores that ecological management alone is insufficient without addressing underlying social and institutional drivers.

Ecosystem-based management (EBM) is urgently needed, including:

- Maintenance of trophic diversity and protection of high-trophic predators.
- Regulation of fishing effort through spatial and temporal closures.
- Socio-economic incentives to reduce IUU fishing and promote compliance.

For example, gear buy-back programs could help reduce fleet overcapacity, while alternative livelihood subsidies (e.g., support for aquaculture, eco-tourism, or coastal handicraft initiatives) can provide viable income sources for fishers, lowering dependence on overexploited stocks.

Sustainable fisheries in both regions require region-specific EBM that integrates habitat protection, multi-species interactions, and socio-economic realities. Strengthening monitoring, surveillance, data integration, fleet regulation, and regional cooperation is essential to break the overfishing-IUU cycle and safeguard long-term productivity, resilience, and livelihoods dependent on these marine ecosystems.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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