Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(4): 629 – 642 (2025)
www.ejabf.journals.ekb.eg

Dual-Model Assessment of Sustainable Yield Benchmarks for Egyptian Red Sea Invertebrate Fisheries

Basma Nassary Hamed[1] , Mostafa A. Khaled[2] ، Mohsen Y. Omer[3], Khaled Y. AbouelFadl[1*]
[1]Fisheries Department, Faculty of Fish and Fisheries Technology, Aswan University, Egypt
[2]Marine Science Department, National Authority for Remote Sensing & Space Sciences (NARSS), Egypt
[3]National Institute of Oceanography and Fisheries (NIOF), Red Sea Branch, Egypt

[*]**Corresponding Author: Khaledabouelfadl@aswu.edu.eg**

ARTICLE INFO

Article History:
Received: May 29, 2025
Accepted: July 6, 2025
Online: July 12, 2025

Keywords:
Marine invertebrates,
Sustainable yield,
Schaefer model,
TLP,
Overfishing,
Egyptian Red Sea

ABSTRACT

Invertebrate fishing in the Egyptian Red Sea holds significant economic value as a source of livelihood. Analysis of annual production data from 2002 to 2021 revealed substantial fluctuations in shrimp, cuttlefish, and crab yields, along with a pronounced declining trend. Catch and effort data were assessed using the Schaefer surplus production model and the Total Latent Productivity (TLP) method to evaluate sustainable exploitation levels. According to the Schaefer model, the maximum sustainable yield (MSY) for total invertebrates was estimated at 1,326 tons, requiring a fishing effort of 816 boats (FMSY). For cuttlefish and crab specifically, the MSY values were 499 and 265 tons, respectively, with corresponding FMSY estimates of 606 and 578 boats. Accounting for natural population variability, the TLP method set a total sustainable catch benchmark of 1,218 tons, with species-specific TLPs of 665.8 tons for shrimp, 245.0 tons for cuttlefish, 97.6 tons for crab, 186.7 tons for squid, and 13.6 tons for lobster. Both modeling approaches clearly indicate that current fishing pressure exceeds sustainable limits, with actual catches significantly surpassing both MSY and TLP reference points. These findings highlight the urgent need for robust fisheries management strategies that integrate both equilibrium-based and variability-responsive frameworks to ensure the long-term sustainability and resilience of invertebrate fisheries in the Red Sea.

INTRODUCTION

Fisheries of invertebrates from the Egyptian Red Sea have always been important for the economic stability and ecological balance of the region due to their contribution to food security, employment, and biodiversity. However, these fisheries face unprecedented challenges today, with sharp and disproportionate declines across various metrics over the past few years. Total invertebrate landings reached 558 tons in 2021, representing a drop of nearly 45% from 2020 **(GAFRD, 2021)**. This occurred despite a modest decrease in fishing effort from 985 to 858 boats. This decline, in addition to the well-known issue of overfishing, highlights other underlying problems such as habitat destruction, pollution, illegal fishing, and the growing pressure of climate change **(Agwa**

***et al*., 2013; Porter *et al*., 2013; Yanik & Aslan, 2018; GAFRD, 2021; Khaled *et al*., 2023a)**.

The Red Sea is an outstanding example of the world's marine biodiversity hotspots, harboring over 1,200 species of fish and more than 200 species of corals. It also supports more than 1,000 invertebrate species, including commercially and ecologically important groups such as molluscs and arthropods **(Vandepitte *et al*., 2018; FAO & GEF, 2023)**. Invertebrates such as shrimp and crabs are also vital to local economies and food systems, having historically dominated landings **(Piatkowski *et al*., 2001; FAO, 2018)**. The dramatic decline in productivity, as well as the shifting composition of catches—such as the boom-and-bust cycles seen in high-value species like sea cucumber—provides further evidence of insufficient management and over-exploitation **(GAFRD, 2021)**.

An examination of production patterns from 2002–2021 shows that shrimp, cuttlefish, and crab have traditionally dominated landings but have all experienced significant interannual variability and chronic declines. The weak, and often negative, relationship between fishing effort and total catch, along with a steady decline in catch per unit effort (CPUE), indicates that current management strategies are insufficient for sustaining stock productivity and resilience **(Maiyza *et al*., 2020)**. Moreover, the semi-enclosed nature of the Red Sea, combined with high salinity and extreme temperatures, creates a specialized yet fragile ecosystem **(FAO & GEF, 2023; Mohammed-Geba *et al*., 2024)**. The region's coral reefs, seagrass beds, and mangroves are increasingly under threat from rising sea surface temperatures, ocean acidification, and other human activities, leading to habitat destruction and reduced recruitment for many invertebrate stocks **(Khaled *et al*., 2019; Krueger *et al*., 2024)**.

The increase in invertebrate fisheries and the trend of "fishing down" marine food webs have shifted global management focus, highlighting the need for more adaptive, ecosystem-based methods **(White & Rogers-Bennett, 2014; FAO, 2024)**. In the Red Sea, the ecosystem faces additional stress from invasive species introduced through the Suez Canal and the consequences of climate change **(Krueger *et al*., 2024)**. Significant gaps persist, including the absence of coordinated regional stock assessments and the insufficient integration of habitat protection into fisheries management frameworks **(FAO & GEF, 2023)**.

To address these issues, accurate estimation of sustainable yield is essential. The Schaefer surplus production model **(Schaefer, 1954)** remains a cornerstone for estimating maximum sustainable yield (MSY) and the associated optimal fishing effort (FMSY) in data-sparse tropical fisheries **(Prager, 2004)**. However, the model's static equilibrium assumption often leads to overharvest in stocks with variable and unstable dynamics **(Poot-Salazar *et al*., 2024)**, which characterize many short-lived invertebrates, including cephalopods and crustaceans. Recent advances suggest the use of Total Latent Productivity (TLP), which averages sustainable yields over periods of positive and negative productivity, offering a more realistic standard for species with oscillating or irregular population cycles **(White & Rogers-Bennett, 2014; Poot-Salazar *et al.*, 2024)**. TLP is especially important for invertebrate fisheries, given the need to navigate environmental uncertainty and recruitment variability. Additionally, policies based solely on MSY principles may lead to overexploitation and potential stock collapse **(Ahmed, 2015; Poot-Salazar *et al.*, 2024)**. Integrating TLP with traditional surplus production models supports the development of sustainable benchmarks and adaptive management frameworks that are responsive to both equilibrium and fluctuating stock levels **(FAO & GEF, 2023; FAO, 2024)**.

This study aimed to assess the invertebrate fisheries of the Egyptian Red Sea from 2002 to 2021 using an integrated, rigorous, and sustainable data approach. Both the Schaefer surplus production model and the TLP approach were applied to the officially reported catch and effort data to estimate MSY, FMSY, and TLP for both total and species-specific stocks. This integrated methodology is intended to enhance invertebrate fisheries management in the Egyptian Red Sea based on the best available evidence, promote ecosystem resilience, and support long-term sustainability.

2. MATERIALS AND METHODS

1. Study area

The study was conducted along the eastern Egyptian Red Sea coast, covering seven major coastal cities from Ras Gharib in the North to Halayeb in the South (Fig. 1). This area comprises various marine habitats and represents a significant part of Egypt's invertebrate fisheries.

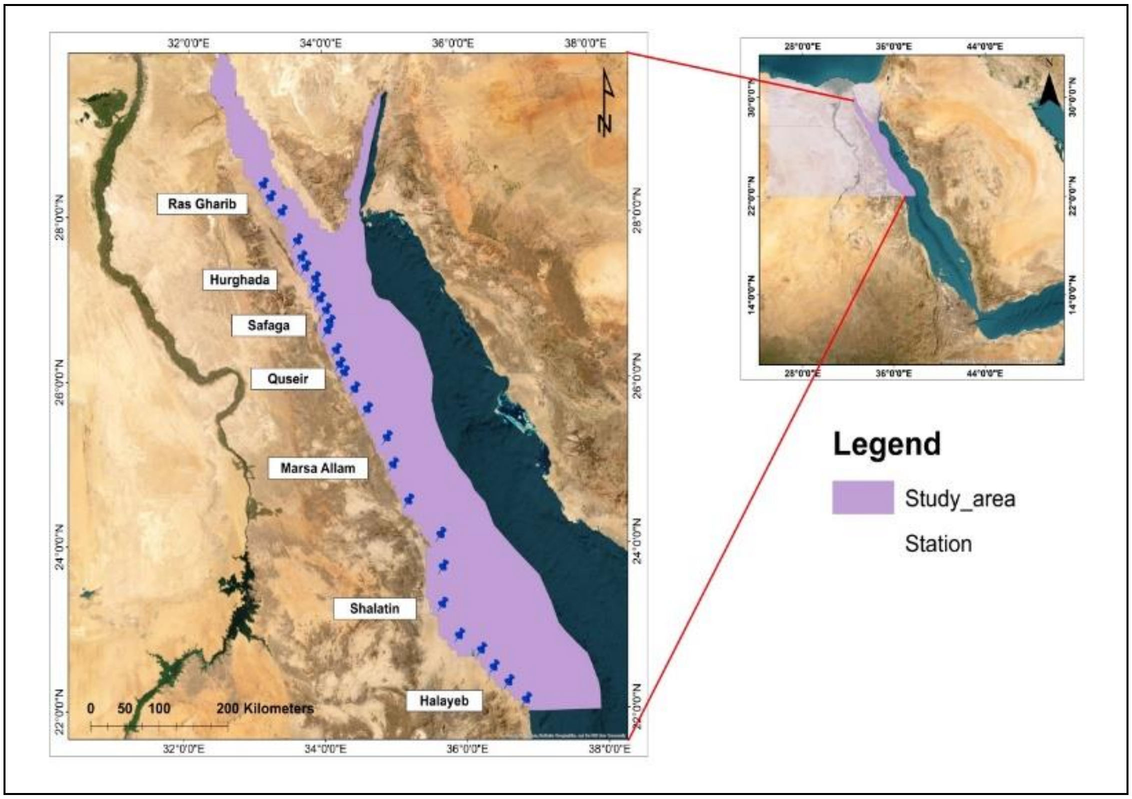

Fig. 1. Map of the study area along the eastern Egyptian Red Sea coast

2. Data collection

Annual records of marine invertebrate landings (tons) and fishing effort (number of boats) were collected from the General Authority for Fish Resources Development (GAFRD) for the years 2002–2021. Data were gathered for each city and the entire Red Sea region to complete spatial and temporal coverage. The dataset was validated against port landing records and previous regional assessments to ensure accuracy and reliability **(Maiyza *et al*., 2020; FAO & GEF, 2023)**.

3. Methods

Catch per unit effort (CPUE) was calculated as an indicator of fishery productivity. Two analytical approaches were applied: the Schaefer surplus production model and the Total Latent Productivity (TLP) method. The Schaefer model estimates maximum sustainable yield (MSY) and optimal fishing effort (FMSY) by regressing CPUE against effort using ordinary least squares (OLS) and deriving reference points from fitted parameters. In parallel, the TLP approach, which accounts for natural fluctuations in stock productivity, calculated sustainable yield as the product of mean CPUE and mean effort across the study period. Statistical analyses were performed using Microsoft Excel and R software.

3.1 Catch per unit effort

Catch per unit was calculated as:

$$CPUE = \frac{Total\ Catch\ (tons)}{Number\ of\ Boats} \qquad \textbf{(1)}$$

This metric served as a proxy for relative stock biomass and fishery productivity **(Cadrin & Dickey-Collas, 2015)**.

3.2 Surplus Production Model: Schaefer Model

To estimate the maximum sustainable yield (MSY) and the corresponding fishing effort (FMSY), the Schaefer surplus production model **(Schaefer, 1954)** was applied. The model assumes a linear relationship between CPUE and fishing effort, expressed in the form:

$$\frac{Y}{f} = a + bf \qquad (2)$$

Where, *Y* is the annual catch (tons); *f* is fishing effort (boats); *a* is the intercept; and *b* is the slope of the regression line. Parameters *a* and *b* were estimated by fitting the model to the observed time series of CPUE and effort using ordinary least squares (OLS) regression **(Schaefer, 1954; Prager, 2004; Elsaey *et al*., 2024)**.

The reference points were calculated as:

$$MSY = \frac{a^2}{4b} \qquad (3)$$

$$FMSY = \frac{a}{2b} \qquad \textbf{(4)}$$

A negative slope (*b*) indicates a decline in CPUE with increasing effort, consistent with stock depletion under higher fishing pressure **(Srinath, 2002)**.

3.3 Total latent productivity (TLP) analysis

Given the fluctuating dynamics of many invertebrate stocks, total latent productivity (TLP) was also estimated as a more precautionary and realistic benchmark for sustainable yield **(Poot-Salazar *et al*., 2024)**. TLP is defined as the product of the mean CPUE and mean effort over the study period:

$$TLP = \overline{CPUE} \times \overline{Effort} \qquad (5)$$

Where, $\overline{CPUE}$ is the average annual CPUE, and $\overline{Effort}$ is the average annual fishing effort (boats) for each species or the total fishery. This approach accounts for both positive and negative productivity periods and is particularly suited for stocks with non-equilibrium, oscillating population dynamics.

4. Statistical analysis

All data processing, statistical analyses, and model fitting were conducted using Microsoft Excel and R statistical software **(R Core Team, 2024)**. Excel was used for initial data organization, calculation of CPUE, and descriptive statistics, while R was employed for regression analysis, model fitting, and graphical visualization. Model diagnostics included examination of residuals, assessment of fit (R^2), and evaluation of parameter plausibility, following international standards for fisheries stock assessment **(Cadrin & Dickey-Collas, 2015; FAO & GEF, 2023)**.

RESULTS

1. Annual production trends and variability of key invertebrate species

Analysis of available data from 2002 to 2021 on the production of key invertebrate species in the Egyptian Red Sea reveals marked fluctuations alongside a progressively declining trend in recent years. Shrimp exhibited the highest mean annual production at 666.1 tons, followed by the cuttlefish (237.6 tons), squids (186.8 tons), and crabs (93.3 tons). Lobster production remained consistently low, averaging only 13.3 tons. Total annual catch peaked at 2,687 tons in 2003 but sharply declined to a minimum of 452 tons in 2012. In subsequent years, production remained stagnant and below historical averages. Time series plots clearly show that shrimp and the cuttlefish—the dominant contributors to total catch—not only experienced steady declines after 2014 but also exhibited significant year-to-year variability. This trend suggests increased fishing pressure along with other unquantified factors negatively affecting stock sustainability (Fig. 2 & Table 1).

Table 1. Descriptive statistics of annual invertebrate production and total catch in the Egyptian Red Sea (2002–2021)

Species	Mean (tons)	Std. Deviation (tons)	Min (tons)	Max (tons)
Shrimp	666.1	491.8	52	1654
Cuttlefish	237.6	319.8	4	1166
Crab	93.3	116.5	5	532
Squids	186.8	279.5	1	825
Lobster	13.3	13.5	1	41
Total Catch	1217.6	618.1	452	2687

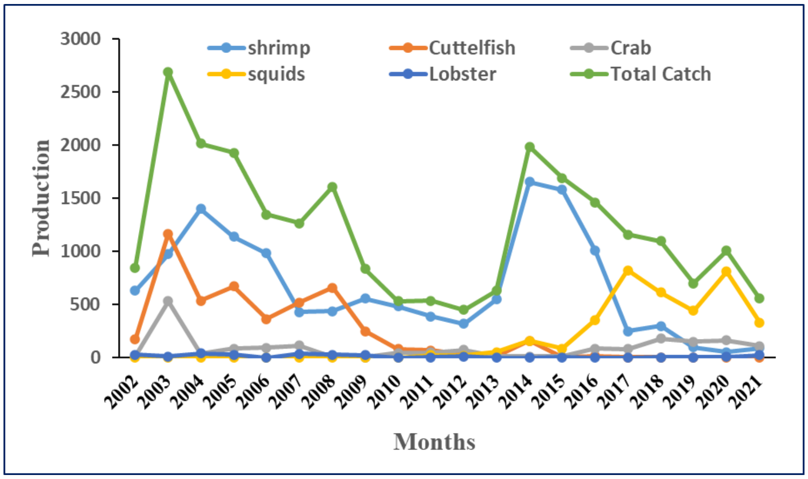

Fig. 2. Annual production trends of major invertebrate species (Shrimp, Cuttlefish, Crab) in the Egyptian Red Sea (2002–2021)

2. Effort–catch relationship and productivity decline

The annual catch in the Egyptian Red Sea invertebrate fisheries fluctuated significantly from 2002 to 2021, reaching a peak of 2,687 tons and dropping to 452 tons. Fishing effort, measured in terms of active boats, ranged from 871 to 1,124 per year. The total catch and fishing effort captured in the scatter plot and bar chart demonstrated a weak, negative relationship, supported by a Pearson correlation coefficient of r = -0.08. This suggests that there is virtually no relationship between the two variables. In contrast, the analysis of catch per unit effort (CPUE) demonstrated a clear and consistent decline throughout the study period, with notable high CPUE values above 3.0 in 2003 followed by a steady drop to sub 1.0 levels in the most recent years. These findings are further elucidated in the time series plots. The figures provide a visual representation of the decline in fishery productivity per unit of effort, reinforcing the marked disconnect between effort and catch (Figs. 3, 4).

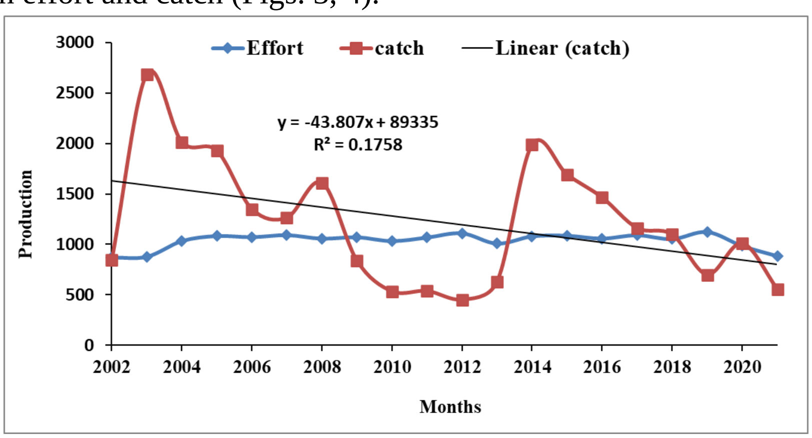

Fig. 3. The relationship between effort and yield of invertebrate in the Egyptian Red Sea (2002-2021)

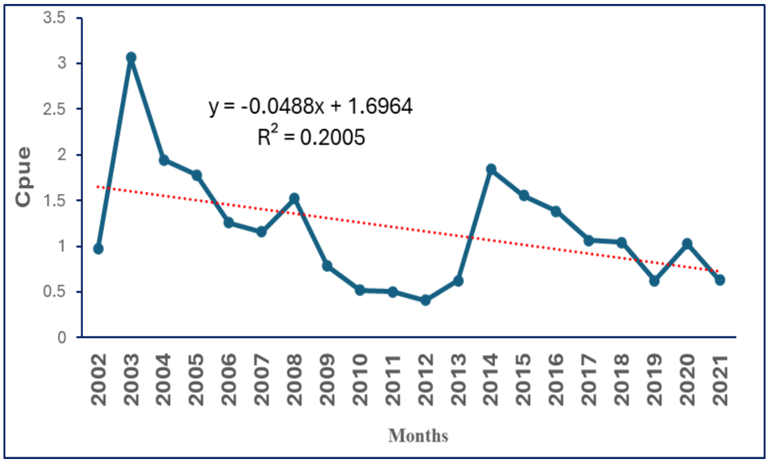

Fig. 4. Trend of annual catch per unit effort (CPUE) in the Egyptian Red Sea (2002–2021)

a. Regional production patterns in the Egyptian Red Sea

The invertebrate production spatial analysis from 2002 to 2021 shows distinct differences over time and an average yield among the three regions of the Egyptian Red Sea (Table 2 & Fig. 5). Marsa Allam had the highest mean annual production value of 893.25 tons, followed by Hurghada with 229.10 tons. Ras Gharib recorded the lowest average at 50.60 tons. The time series plots depicting each region's production showcased that Marsa Allam produced the largest share of total production, experienced the most dramatic shifts, and even had several years of extraordinarily high output. Hurghada had moderate production output, and Ras Ghareb was low and stable. Correlation analysis done between regional and total catch confirmed the production trends where Marsa Allam's production was most strongly aligned with overall trends (r = 0.89). Marsa Allam showed strong correlation, Hurghada moderate positive correlation (r = 0.54), and Ras Ghareb exhibited weak negative correlation (r = -0.36).

Table 2. Statistical summary and correlation of annual fish catch by location along the Egyptian Red Sea coast

Location	Mean (tons)	Std. Deviation (tons)	Min (tons)	Max (tons)	Correlation with Total Catch (r)
Ras Ghareb	50.6	55.91	1	179	-0.36
Hurghada	229.1	333.31	6	1100	0.54
Marsa Allam	893.25	503.84	285	1891	0.89

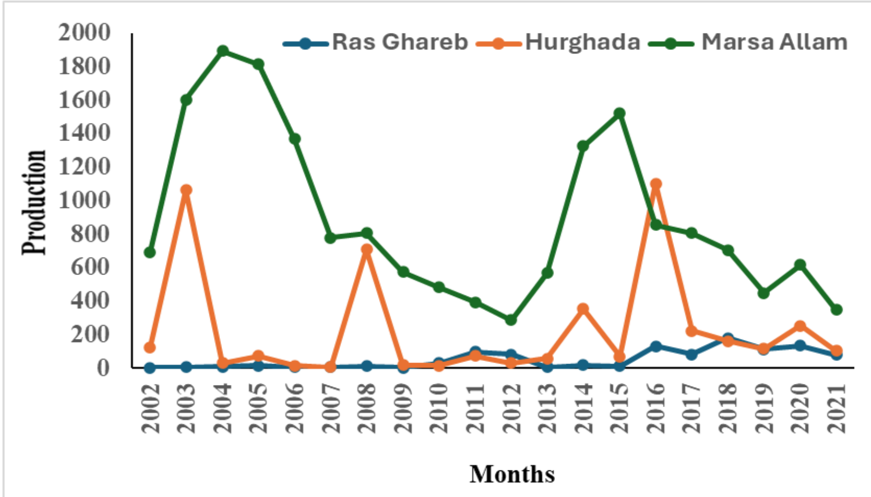

Fig. 5. Annual variation in fish landings (2002–2021) at Ras Gharib, Hurghada, and Marsa Allam along the Egyptian Red Sea Coast

b. Integrated sustainable yield benchmarks

Applying the dual-method quantitative evaluation using the Schaefer surplus production model alongside Total Latent Productivity (TLP) on invertebrate fisheries of the Egyptian Red Sea sets clear sustainability targets. The total catch maximum sustainable yield (MSY) estimated using the Schaefer model was 1,325 tons, which can be achieved at an optimal fishing effort of 817 boats (FMSY). For the cuttlefish, the MSY and FMSY were 499 tons and 606 boats, respectively. For crab, those values were 265 tons and 578 boats, and for lobster, 24 tons at 627 boats. Squid and shrimp both produced biologically unrealistic MSY/FMSY figures due to non-negative CPUE-effort relationships, suggesting sparse data or unusual stock recruitment patterns. The best fits for the models were found for crab (R^2 = 0.21), followed by lobster (R^2 = 0.12) and cuttlefish (R^2 = 0.09). Simultaneously, the TLP approach that considers natural fluctuations of biomass produced a total catch limit of 1,218 tons, with individual species TLP quotas set at 665.8 tons for shrimp, 245.0 tons for the cuttlefish, 97.6 tons for crab, 186.7 tons for squids, and 13.6 tons for lobster. Overall, these findings provide detailed reference points - actionable limits for total allowable catch (TAC) at both the species level and in aggregate which supports adaptive management of the red sea invertebrate fisheries through equilibrium (MSY/FMSY) and responsiveness to change (TLP) driven structures vital from ecological and economic perspectives (Table 3 & Fig. 6).

Table 3. Schaefer model and TLP estimates of MSY and FMSY for major invertebrates and total catch in the Egyptian Red Sea (2002–2021)

Species	MSY (tons)	FMSY (boats)	R^2	TLP
Shrimp	-	-	-	665.8
Cuttlefish	499	606	0.09	245
Crab	265	578	0.21	97.6
Lobster	24	627	0.12	13.6
Squid	-	-	-	186.7
Lobster	24	627	0.12	13.6
Total Catch	1,326	816	0.06	1228.5

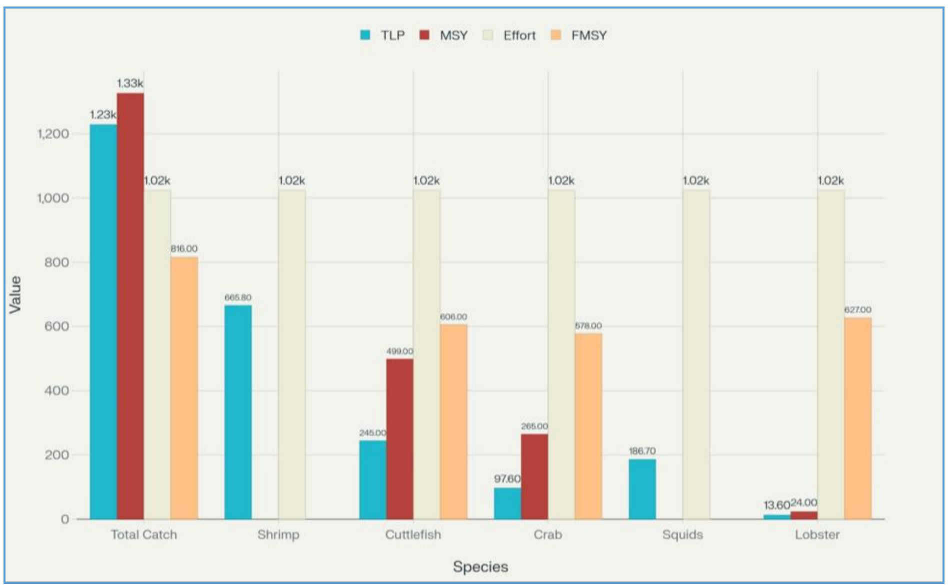

Fig. 6. TLP, MSY, effort and FMSY for major invertebrate species and total catch in the Egyptian Red Sea (2002–2021)

DISCUSSION

The findings of this study indicate a continual and worsening decline in the productivity of invertebrate fisheries in the Egyptian Red Sea over the past two decades. Total fisheries landings decreased by nearly 45% in 2021 compared to the previous year, despite only a slight reduction in fishing effort **(GAFRD, 2021)**. This significant drop points to mounting additional stressors, including marine ecosystem degradation, environmental pollution, illegal and unregulated fishing, and climate change **(Yanik & Aslan, 2018; Khaled *et al.*, 2023b; Krueger *et al.*, 2024; Said *et al.*, 2024)**. The global decline in invertebrate fishery stocks due to such factors is well documented, as rapidly changing environmental conditions and human interference contribute to swift population declines and dramatic shifts in species composition **(Anderson *et al.*, 2011)**.

Current management approaches appear insufficient to maintain stock productivity and resilience. This is evidenced by the weak—and often negative—relationship between fishing effort and total catch, reflected by a Pearson correlation coefficient of r = -0.08. These results align with previous regional and global studies, which have emphasized that simple effort controls are ineffective in systems characterized by complex, multifactorial dynamics **(El-Gammal & Mehanna, 2006; Maiyza *et al.*, 2020)**. The continued decline in catch per unit effort (CPUE) further supports the overexploitation hypothesis, suggesting a chronically overfished system that is more prone to collapse than recovery—a phenomenon frequently observed in global invertebrate fisheries **(Anderson *et al.*, 2011; Poot-Salazar *et al.*, 2024)**.

Spatial analysis revealed that Marsa Allam has consistently contributed the largest share of invertebrate production, yet it has also suffered the most extreme fluctuations. This suggests that localized environmental or anthropogenic factors are significantly disrupting productivity. Such spatial heterogeneity underscores the need for area-specific management strategies, as localized depletion patterns have similarly been reported in other Red Sea and Mediterranean fisheries **(FAO & GEF, 2023; Khaled *et al.*, 2023b; Khalfallah *et al.*, 2024; Shafai *et al.*, 2024)**. Among species, shrimp, the cuttlefish, and crab have historically dominated landings, but all exhibited marked interannual variability and long-term declines, consistent with the "boom-and-bust" cycles characteristic of high-value invertebrates worldwide **(Anderson *et al.*, 2011; Ahmed, 2015)**.

A major strength of this study is the use of a dual-method approach, incorporating both the Schaefer surplus production model (MSY) and the Total Latent Productivity (TLP) framework. The Schaefer model estimated the total catch MSY at 1,325 tons with an optimal fishing effort (FMSY) of 817 boats. In contrast, the TLP approach yielded a more conservative estimate of 1,218 tons. Notably, both methods indicate that current catches are well below sustainable thresholds. TLP, however, is particularly valuable for unstable or fluctuating stocks, as it accounts for productivity across both positive and negative phases and better reflects dynamic population responses **(Poot-Salazar *et al.*, 2024)**. For species with oscillating or unstable dynamics—such as short-lived invertebrates—MSY often proves overly generous and unreliable, whereas TLP offers a more realistic and precautionary management benchmark **(Poot-Salazar *et al.*, 2024)**. This has been empirically demonstrated in cephalopods and other invertebrates, where harvest levels based on TLP better align with stock resilience and mitigate the risk of collapse under fluctuating environmental conditions **(Poot-Salazar *et al.*, 2024)**.

The chronic decline in productivity, weak effort–catch correlation, and spatial heterogeneity in production patterns collectively indicate a system under severe ecological strain. It is likely that the compounded effects of climate change, pollution, habitat destruction, and overfishing are diminishing stock resilience and driving persistent declines **(FAO & GEF, 2023; Krueger *et al.*, 2024)**. The study's findings support a shift away from purely equilibrium-based management models (e.g., MSY/FMSY) toward approaches that integrate TLP and reflect environmental variability. This is particularly relevant for the Red Sea invertebrate fisheries, where high interannual variability and sensitivity to environmental change make TLP a more suitable and adaptive benchmark. Recent global fisheries science also advocates for the broader adoption of TLP in managing stocks with unstable or oscillating dynamics **(Poot-Salazar *et al.*, 2024)**.

These findings reinforce earlier assessments of Egyptian and regional fisheries, which have reported declining productivity, overexploitation, and an absence of effective management frameworks **(Mehanna & Amin, 2005; FAO, 2018; Khalfallah *et al.*, 2024)**. The use of TLP as a management benchmark offers a more flexible and adaptive strategy for setting sustainable harvest limits in overexploited fisheries **(Poot-Salazar *et al.*, 2024)**.

CONCLUSION

This study provides a comprehensive assessment of the status and sustainability of key invertebrate fisheries along the Egyptian Red Sea using a dual modeling approach. Over the past two decades, total invertebrate production has declined sharply, despite relatively stable fishing effort. Species such as shrimp, the cuttlefish, and crab historically dominant in the landings exhibited significant interannual variability and long-term downward trends, highlighting the vulnerability of these stocks. The lack of a strong correlation between fishing effort and yield, combined with the consistent decline in CPUE, strongly suggests chronic overexploitation and systemic ecological stress. Spatial analysis confirmed Marsa Allam as the primary production hub, yet also revealed high variability and probable localized stressors, emphasizing the need for region-specific management. The application of the Schaefer surplus production model and the Total Latent Productivity (TLP) method revealed that current catches are below sustainable limits. However, the TLP estimates offer more conservative and ecologically realistic benchmarks for setting harvest targets, especially under unstable stock dynamics common to invertebrate populations.

REFERENCES

Agwa, A.; Leheta, H.; Salem, A. and Sadiq, R. (2013). Fate of drilling waste discharges and ecological risk assessment in the Egyptian Red Sea: an aquivalence-based fuzzy analysis. Eighteenth International Water Technology Conference (IWTC18), Sharm ElSheikh, 12-14.

Ahmed, M. I. (2015). A decade of Sea Cucumber Fishing in Egypt, a Boom and Bust Case Study. Egyptian Journal of Environmental Sciences, 6(1): 81–90.

Anderson, S. C.; Flemming, J. M.; Watson, R. and Lotze, H. K. (2011). Rapid Global Expansion of Invertebrate Fisheries: Trends, Drivers, and Ecosystem Effects. PLOS ONE, 6(3): e14735.

Cadrin, S. X. and Dickey-Collas, M. (2015). Stock assessment methods for sustainable fisheries. ICES Journal of Marine Science, 72(1): 1–6.

El-Gammal, F. I. and Mehanna, S. F. (2006). Fisheries Management of Invertebrates in The Gulf of Suez, Red Sea. Agricultural and Marine Sciences, 11(1): 37–45.

Elsaey, S. E. F.; Adam, E. A. and AbouelFadl, K. Y. (2024). An Extended Bio-Economic Management Plan for Fisheries at Lake Nasser. Aquatic Science and Fish Resources, 5(1): 43–56.

FAO. (2018). The State of World Fisheries and Aquaculture 2018—Meeting the Sustainable Development Goals.

FAO. (2024). The State of World Fisheries and Aquaculture 2024: Blue Transformation in Action. Rome: FAO.

FAO and GEF. (2023). RedSeaFish Project: Promoting Sustainable Fisheries Management in the Red Sea Large Marine Ecosystem. FAO, Rome.

GAFRD. (2002–2021). The General Authority for Fish Resources Development: Year book of fishery statistics (2002–2021), Cairo, Egypt.

GAFRD. (2021). The General Authority for Fish Resources Development: Year book of fishery statistics (2002–2021), Cairo, Egypt.

Khaled, M. A.; Al-Jamali, F. H.; Said, R. E.; Mohammad, A. S.; Ahmed, M. H. and Ahmed, H. O. (2023b). Analysis of SST and Chl-a data from MODIS-Aqua in the Major Egyptian Fishing Zones of the Red Sea. Egyptian Journal of Aquatic Research, 49(4): 520–529.

Khaled, M. A.; Muller-Karger, F.; Obuid-Allah, A.; Ahmed, M. and El-Kafrawy, S. B. (2019). Using Landsat Data to Assess the Status of Coral Reefs Cover along the Red Sea Coast. Int. J. Ecotoxicol. Ecobiol., 4: 17–31.

Khaled, M.; Muller-Karger, F.; Obuid-Allah, A.; Ahmed, M. and El-Kafrawy, S. (2023a). Long-term detection of coral reef thermal stress events using daily satellite data in the Red Sea. In: International Conference of Remote Sensing and Space Sciences Applications (pp. 367–374). Cham: Springer Nature Switzerland.

Khaled, M. G.; Galal-Khallaf, A.; Hamza, W.; Al-Harby, A.; Schott, E. J. and Martínez-Rodríguez, G. (2024). Editorial: Current genetic diversity in the Red Sea and related aquatic environments. Frontiers in Marine Science, 11: 1450234.

Khalfallah, M.; Mahmoud, H. H.; Fahim, R. M. and Pauly, D. (2024). Once upon a century, the Egyptian Mediterranean fisheries (1920–2019), as affected by ‘fishing down’ and climate change. Ocean & Coastal Management, 245: 106831.

Krueger, T.; Berumen, M. L. and Voolstra, C. R. (2024). Differential spatio-temporal responses of Red Sea coral reef benthic communities to a mass bleaching event. Scientific Reports, 14(1): 24229.

Maiyza, S. I.; Mehanna, S. F. and El-Karyone, I. A. (2020). An evaluation for the exploitation level of Egyptian Marine Fisheries. Egyptian Journal of Aquatic Biology & Fisheries, 24(6): 447–456.

Mehanna, S. F. and Amin, A. M. (2005). Population dynamics of the cuttlefish Sepia dollfusi (Adam, 1941) from the Gulf of Suez, Egypt. Egyp. J. Aquat. Biol. Fish., 9(1): 1–14.

Piatkowski, U.; Pierce, G. J. and Morais da Cunha, M. (2001). Impact of cephalopods in the food chain and their interaction with the environment and fisheries: an overview. Fisheries Research, 52(1–2): 5–10.

Poot-Salazar, A.; Velázquez-Abunader, I.; Avendaño, O.; Barajas-Girón, P. and Rojas-González, R. I. (2024). Sustainable fishing harvest rates for fluctuating fish and invertebrate stocks. PLOS ONE, 19(9): e0307836.

Porter, E. M.; Bowman, W. D.; Clark, C. M.; Compton, J. E.; Pardo, L. H. and Soong, J. L. (2013). Interactive effects of anthropogenic nitrogen enrichment and climate change on terrestrial and aquatic biodiversity. Biogeochemistry, 114: 93–120.

Prager, M. H. (2004). User's manual for ASPIC: A stock–production model incorporating covariates (ver. 5) and auxiliary programs. Beaufort Laboratory Document BL-2004-01, National Marine Fisheries Service, NOAA, Beaufort, North Carolina, USA, 25 pp.

R Core Team. (2024). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Said, R. E.; Hasieb, H. E.; Khaled, M. A.; Mohammed-AbdAllah, E. and Osman, A. G. (2024). Regional variability in remotely sensed data with respect to the distribution of some snapper fishes (Family: Lutjanidae) between the Red Sea and the Arabian Gulf. Scientific African, 23: e02104.

Schaefer, M. B. (1954). Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. Inter-American Tropical Tuna Commission Bulletin, 1(2): 27–56.

Shafii, M. A. M.; Saad, Z. M. and Khaled, M. A. (2024). Assessment of fisheries production in the major Egyptian fishing ports of the Mediterranean Sea using remote sensing data. Egyp. J. Aquatic Biol. Fisher., 28(5): 1937–1960.

Srinath, M. (2002). Evaluation of Schaefer's production model. Indian Journal of Fisheries, 49(4): 361–368.

Vandepitte, L. (2018). A decade of the World Register of Marine Species–General insights and experiences from the Data Management Team: Where are we, what have we learned and how can we continue? PloS One, 13(4): e0194599.

White, J. W. and Rogers-Bennett, L. (2014). The rise of invertebrate fisheries and the fishing down of marine food webs in California. California Fish and Game, 100(2): 218–233.

Yanik, T. and Aslan, I. (2018). Impact of Global Warming on Aquatic Animals. Pakistan J. Zool., 50(1): 353–363.