Effects of Excessive Fishing on Coral Reef Ecosystems and Biodiversity

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Abstract: Coral reef ecosystems and biodiversity (CRE&B) are vital for humid and semi-tropical coastal populations, small-island emerging economies, and native people since they offer essential ecological services, including food supply, economic possibilities, carbon storage, and storm shelter. Excessive fishing may significantly destabilize CRE&B globally while gathering at acceptable levels can enhance fish yields without harming CRE. The dispersion capabilities of CRE organisms result in densely interconnected CRE&B of reef fisheries relying on geographically explicit mechanisms, including the ripple effect and illegal fishing inside ocean-safeguarded zones. Nevertheless, a significant portion of the work about CRE&B preservation and governance has mostly focused on excessive fishing at a regional level, neglecting the impact of varying geographical trends in fishing intensity on reef ecology at territorial and local scales. A linked human-ecology framework has been developed to assess the responses of CRE and vegetarian reef-associated fish to excessive aquaculture at various geographical scales. Coral and reef-associated species exhibit contrasting responses to habitat destruction caused by excessive fishing, and a possible spillover impact from marine protection zones into excessively fished regions benefits coral species far less than it does for reef fish.

Keywords: Coral Reef; Biodiversity; Excessive Fishing; Ecosystem; Human-Ecology; Geography.

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I. Introduction

CRE are ecological hotspots that offer millions of individuals environmental services, including food supply, employment possibilities, retention of carbon, and protection against severe climatic occurrences. The ability of CRE to offer these advantages might vary over cyclical timeframes owing to inherent ecological oscillations or over decadal periods due to human stresses, including excessive fishing, damage to habitat, and global warming (Foo et al., 2021).

Comprehending the effects of these tensions on the water's capacity to deliver ecological benefits is crucial for advancing towards an economically viable blue economy, setting recovery objectives, fulfilling the UN's Sustainable Development Goals goals (SDGs), and predicting the implications of upcoming communities under various economic and social and carbon emission instances (Sarker, Rahman, & Wahab, 2023). Approximately 7 million individuals engage in CRE fishing globally, with CRE fisheries evaluated at 6.5 billion USD.

Coastal native people have vital historical ties with CRE&B, and their seafood intake is 16 times greater than that of outsider groups. Fish is a crucial nutritional resource for small-island emerging economies (SIEEs) populations, constituting 55%–92% of nutritional animal-based protein in various nations and regions (Eddy et al., 2021). In these areas, fish provide a significant supply of vitamins and minerals, including zinc, copper, and omega-3 fats. There is heightened acknowledgment and the desire to interpret endeavors and obstacles in safeguarding and rehabilitating tropical aquatic environments, particularly CRE.

Recent investigations have included worldwide examinations of native-led efforts aimed at promoting independence and environmental protection within customary regions, as well as a broader acknowledgment of the fundamental contributions of Small Island Developing States (SIDS) in redefining SDG strategies within a blue economy framework (Nama et al., 2023). The international community recognizes the significance of ecological services rendered by CRE, as evidenced by its dedication to fulfilling the objectives linked to SDG2 (eradicating starvation, attaining adequate sustenance, enhancing nutrition, and fostering environmentally friendly agriculture). The amount of coral coverage on humid reefs has significantly diminished during the previous 45 years (Sobha, Vibija, & Fahima, 2023).

Human-induced oceanic warming has precipitated widespread disintegration and outbreaks of diseases, significantly diminishing coral diversity over virtually all humid CRE globally. Regional variables such as contamination and excessive fishing are believed to contribute to CRE degradation in some areas; however, assessing, measuring, and quantifying these impacts has proven challenging (El-Naggar, 2020). The cumulative effects of these regional patterns on the worldwide ability of CRE to deliver ecological benefits for the millions dependent on them remain uncertain. This document presents a comprehensive worldwide study of changes in live coral cover, corresponding fisheries catches and efforts, the equilibrium of fishing within the food chain, CRE&B, and seafood intake among coastal native populations.

Effects of Excessive Fishing on CRE&B

The framework posits that aquatic herbivores consume algae and phytoplankton according to an operational reaction, theoretically expressed as a Hill curve characterized by a maximum development rate rH and a half-saturation parameter kH. The fish breed at a pace proportional to their consumption of algae and phytoplankton, perish from natural processes at an elevation of mH, and are collected at an independent rate. CRE and algae replicate by the spread of insects and seedlings, resulting in a distant rate of development. Coral embryos are produced in every region at a rate of rC. This remains consistent, although it has opted for a periodic variation since CRE production occurs at specified intervals throughout the year, facilitating a method for algae and phytoplankton to develop into coral. Algae propagation is produced in every area at a rate contingent upon the supply of nutrients, determined by an absorption value characterized by the maximum rate of development rM and a saturation variable kM.

At every phase, the newly spawned CRE larvae and algae propagation are allocated across regions based on their location from the originating area. The spreading of fresh larvae and propagation from every area is regulated by a Gaussian dispersion kernel centered on the separated area. The inherent development rate for CRE or algae and phytoplankton within an area is the aggregate of larvae or propagation produced elsewhere that spreads into that area. The frequency is diminished to reflect their mutual load capacity. CRE perish from environmental factors at an amount mC, but algae succumb to ecological factors at a rate mM and are consumed by fish as previously described. The debris is generated by creatures that perish from biological events at a ratio of 1 to 1 and decompose into micronutrients. Chemicals are generated from debris consistently, adjusted by a transformation factor, and assimilated by algae and phytoplankton, as previously indicated. Vital nutrients join the ecosystem through artificial mechanisms (e.g., river discharges) and exit it via sea currents. The operations are shown in a simplified illustration of the design's regional dynamics (Figure 1).

Alongside regional interactions, fish, debris, and micronutrients are expected to experience passive spread among patches. The dispersion rates for these organisms are regulated by Gaussian dispersion kernels, analogous to the propagation of coral and algae. It is presumed that mature CRE do not exhibit mobility. This indicates a significant capacity for aquatic life, coral larvae, and algae propagation to disseminate outside their native habitats. The variances in averages for debris and minerals are identical to those for fish; CRE propagates since dispersion in the latter categories is contingent upon physical variables such as waves and water currents, which similarly influence dissemination in the former categories. A Gaussian dispersion kernel quantifies the duration of shipping vessels from any specific area allocated to each area within the framework, indicating the impact of excessive fishing in each area.

The natural element of the framework has been enhanced by including the state parameter y that encompasses regional financial methods with a style similar to that previously utilized for assessing assistance with preservation. This work specifically examined two socioeconomic methods: excessive fishing and ecological tourism, designating yi as the fraction of the economic actors in area i participating in ecological tourism. In the approach, y varies based on the comparative usefulness of both options. y escalates with a substantial presence of CRE&B, hence enhancing the profitability of ecological tourism, and diminishes when significant amounts of fish are accessible for collection. The metrics $kT \text{ and } kF$ are used to quantify the extent to which funding levels for eco-tourism and fishing, respectively, are influenced by the fundamental ecological circumstances, whereas cy denotes the extent to which one approach is more lucrative than the other owing to external variables.

Furthermore, y fluctuates owing to social constraints via reproductive behavior, predicated on the premise that economic actors within a locality are more inclined to adopt a certain approach if their neighbors are concurrently using it and reaping benefits. It has been defined κ as the baseline rate at which financial players may alter their tactics. Variable y is reintegrated into the framework via the changing and excessive fishing rate since it is presumed that only those entities participating in fishing operate at the elevated economic rate.

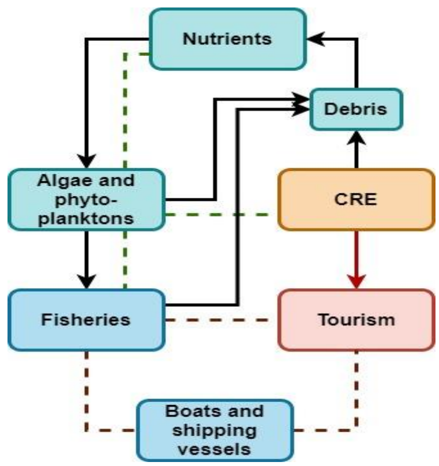

Figure 1: Regional Relationships among Design Elements

Figure 1 illustrates regional relationships among design elements. Brown lines denote economic relationships; green lines indicate feeding and antagonistic relationships and black lines signify resource recycling.

Overfishing significantly adversely affects CRE&B. The excessive extraction of essential species, especially herbivorous fish, disturbs the fragile equilibrium of coral-algae dynamics, resulting in algal proliferation that may suffocate corals and impede reef recovery. Eliminating apex predators modifies trophic dynamics, diminishing the ecosystem's tolerance to external stresses like climate change and pollution. Moreover, harmful fishing techniques such as blast and cyanide fishing directly harm reef structures, exacerbating habitat degradation and diminishing refuge for marine organisms. The reduction in biodiversity significantly undermines the ecological services offered by coral reefs, including coastal protection, fisheries production, and tourism, jeopardizing marine health and human livelihoods.

II. Conclusion

Coral reef ecosystems and biodiversity (CRE&B) are crucial for humid and coastal populations, growing economies of tiny islands, and indigenous communities since they provide key ecological services such as food provision, economic opportunities, carbon storage, and storm protection. Excessive fishing may considerably destabilize CRE&B worldwide while harvesting at sustainable levels might improve fish production without jeopardizing CRE. The dispersion capacities of CRE creatures lead to densely linked CRE&B of reef fisheries, which depend on geographically specific processes, such as the ripple effect and illicit fishing inside protected marine areas. Nonetheless, a considerable amount of research on CRE&B preservation and governance has been concentrated on overfishing at a regional level, overlooking the influence of diverse spatial patterns in fishing intensity on reef ecology at territorial and local scales. A connected human-ecology paradigm has been created to evaluate the effects of CRE and algal reef-associated fish on excessive farming across different geographical scales. Coral and reef-associated species have divergent reactions to habitat degradation resulting from overfishing, while a potential spillover effect from marine protected areas into heavily fished zones advantages coral and algal species to a lesser extent than reef fish.

References

[1] Foo, S. A., Walsh, W. J., Lecky, J., Marcoux, S., & Asner, G. P. (2021). Impacts of pollution, fishing pressure, and reef rugosity on resource fish biomass in West Hawaii. *Ecological Applications, 31*(1), e2213. https://doi.org/10.1002/eap.2213

[2] Sarker, S., Rahman, M. J., & Wahab, M. A. (2023). Modelling the role of marine protected area in biodiversity conservation. *Journal of Sea Research, 196*, 102457. https://doi.org/10.1016/j.seares.2023.102457

[3] Eddy, T. D., Lam, V. W., Reygondeau, G., Cisneros-Montemayor, A. M., Greer, K., Palomares, M. L. D., ... & Cheung, W. W. (2021). Global decline in capacity of coral reefs to provide ecosystem services. *One Earth, 4*(9), 1278-1285.

[4] Nama, S., Shanmughan, A., Nayak, B. B., Bhushan, S., & Ramteke, K. (2023). Impacts of marine debris on coral reef ecosystem: A review for conservation and ecological monitoring of the coral reef ecosystem. *Marine Pollution Bulletin, 189*, 114755. https://doi.org/10.1016/j.marpolbul.2023.114755

[5] Sobha, T. R., Vibija, C. P., & Fahima, P. (2023). Coral reef: A hot spot of marine biodiversity. *In Conservation and sustainable utilization of bioresources* (pp. 171-194). Singapore: Springer Nature Singapore.

[6] El-Naggar, H. A. (2020). Human impacts on coral reef ecosystem. *In Natural resources management and biological sciences*. IntechOpen.http://dx.doi.org/10.5772/intechopen.88841