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The Impact of Fishing Gear and Means of Fishing Site Access on Octopus *Octopus cyanea* (Gray, 1849) Catch Rate in Zanzibar

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Abstract:- The sustainability of octopus fisheries in Zanzibar is essential for local livelihoods and the broader economy. This study assessed the impact of different fishing gears and access methods on the catch rates (CPUE) of Octopus cyanea in Zanzibar, conducted over a year at Matemwe and Michamvi on Unguja Island. The research employed random sampling and quantitative analysis to explore variations in CPUE influenced by gear type and fishing site access. Spearfishing showed the highest variability in CPUE, recording 4.96 kg/fisher/day at Matemwe and 3.01 kg/fisher/day at Michamvi, indicating a strong dependency on the fisher's skill and local conditions. In contrast, metal hooks and sticks showed more consistent CPUEs across both sites, with Matemwe fishers using metal hooks and sticks achieving CPUEs of 2.79 kg and 2.97 kg per fisher per day, respectively. These gears are suggested as more sustainable due to their consistent performance and reduced ecological impact. Significant differences were also observed based on the methods of site access. At Michamvi, paddling fishers yielded a higher CPUE of 2.95 kg/fisher/day compared to 2.54 kg/fisher/day for boat fishers. Conversely, at Matemwe, fishing boats were more effective, achieving a CPUE of 4.63 kg/fisher/day against 2.56 kg for paddling. This illustrates the varying impacts of access strategies on sustainability and efficiency between sites. The findings insist on the need for detailed fishery management that accounts for gear types and access methods, essential for promoting ecological balance and economic growth within Zanzibar's blue economy. This research offers valuable insights for other fisheries, highlighting the importance of tailored management practices adapted to specific local conditions.

Keywords:- *Fishing Gear, Means of Fishing Site Access, Octopus Cyanea, Catch Rate, Zanzibar.*

I. INTRODUCTION

The big blue octopus (*Octopus cyanea*) fishery represents a critical socio-economic activity for coastal communities in Zanzibar, significantly contributing to livelihoods through food security and income generation. This species is among the most commercially valuable cephalopods in the Western Indian Ocean, supporting local subsistence needs and broader market demands (1,2). Octopus fishing in this region is predominantly artisanal, utilizing traditional and locally constructed methods such as gleaning on intertidal reef flats with metal and wooden sticks, metal hooks, and skin diving complemented by spearfishing in subtidal zones (3). While these artisanal gears are economically accessible, their use exerts direct and indirect pressures on coral reef ecosystems. It yields variable catches, often marked by uncertainty and declining reliability over time. The increasing demand for octopus in Zanzibar is closely tied to the rapid growth of the tourism industry, population expansion, and enhanced market access, both locally and internationally. These factors have collectively escalated harvesting intensity, frequently surpassing the natural recruitment capacities of octopus populations (4). The heightened fishing effort is reflected in extended fishing distances and durations, reduced average catch sizes, and an overall decline in catch volumes. Such trends compromise the reproductive potential and population sustainability of *O. cyanea*, directly threatening the livelihoods of coastal communities reliant on these fisheries. Furthermore, this challenges Zanzibar's aspirations for a sustainable blue economy, particularly concerning its fisheries and tourism sectors (5,6). Additional stressors exacerbating these challenges include the impacts of climate change, widespread non-compliance with fishing regulations, limited integration of ecological and fisheries data, and sub-optimal management practices (4,7).

The dynamics of catch rates within Zanzibar's *O. cyanea* fisheries are influenced by various operational factors, most notably the type of fishing gear employed and the strategies used to access fishing sites. The effectiveness of octopus harvesting is affected by the choice of gear, while the accessibility of productive fishing sites is determined by the means and distribution of fishing effort (8,9). Prolonged and intensified fishing pressure has resulted in substantial spatial and temporal variations in catch rates, highlighting the limitations of current practices (10). Despite these observations, there is a paucity of robust assessments that integrate these factors to forecast future catch trends and inform sustainable management strategies (11). This knowledge gap underlines the urgency of comprehensive evaluations of *O. cyanea* fisheries to identify and promote resilient harvesting measures.

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This study aimed to systematically analyze the effects of fishing gear type and fishing site access strategies on the catch rates within Zanzibar's artisanal *O. cyanea* fisheries. By investigating these variables, the study expects to provide insights into sustainable harvesting practices that can safeguard ecosystem health while enhancing the socio-economic resilience of coastal communities. The findings will contribute to developing evidence-based management frameworks that balance ecological sustainability with economic imperatives, ensuring the long-term viability of Zanzibar's octopus fisheries within the broader context of its blue economy aspirations.

II. MATERIALS AND METHODS

➢ *Study Sites*

The study was conducted in Matemwe (5°53′S, 39°20′E) and Michamvi (6°09′S, 39°29′E) on Unguja Island, Zanzibar (Fig. 1), the largest island in the Zanzibar archipelago with alternating South-east and North-east monsoon winds. Matemwe, with a population of 3,749, hosts regular fishery auctions, whereas Michamvi, with 3,465 residents, has a more developed tourism sector but lacks auction infrastructure (12). Both villages are bordered by fringing reefs that provide ideal habitats for octopus populations, and the nearby Chwaka creeks, contribute to a local richness of biodiversity (13). In Matemwe, most fishing activities are carried out near the Mnemba Atoll Marine Protected Area and offshore reefs, while in Michamvi mostly, fishing processes are within or in proximity to a lagoon, where octopus fishing closures have been implemented to support stock recovery (14). Generally, the two study sites were chosen based on the communities' reliance on octopus fishing, emphasizing the need to assess octopus stock for sustainable benefits.

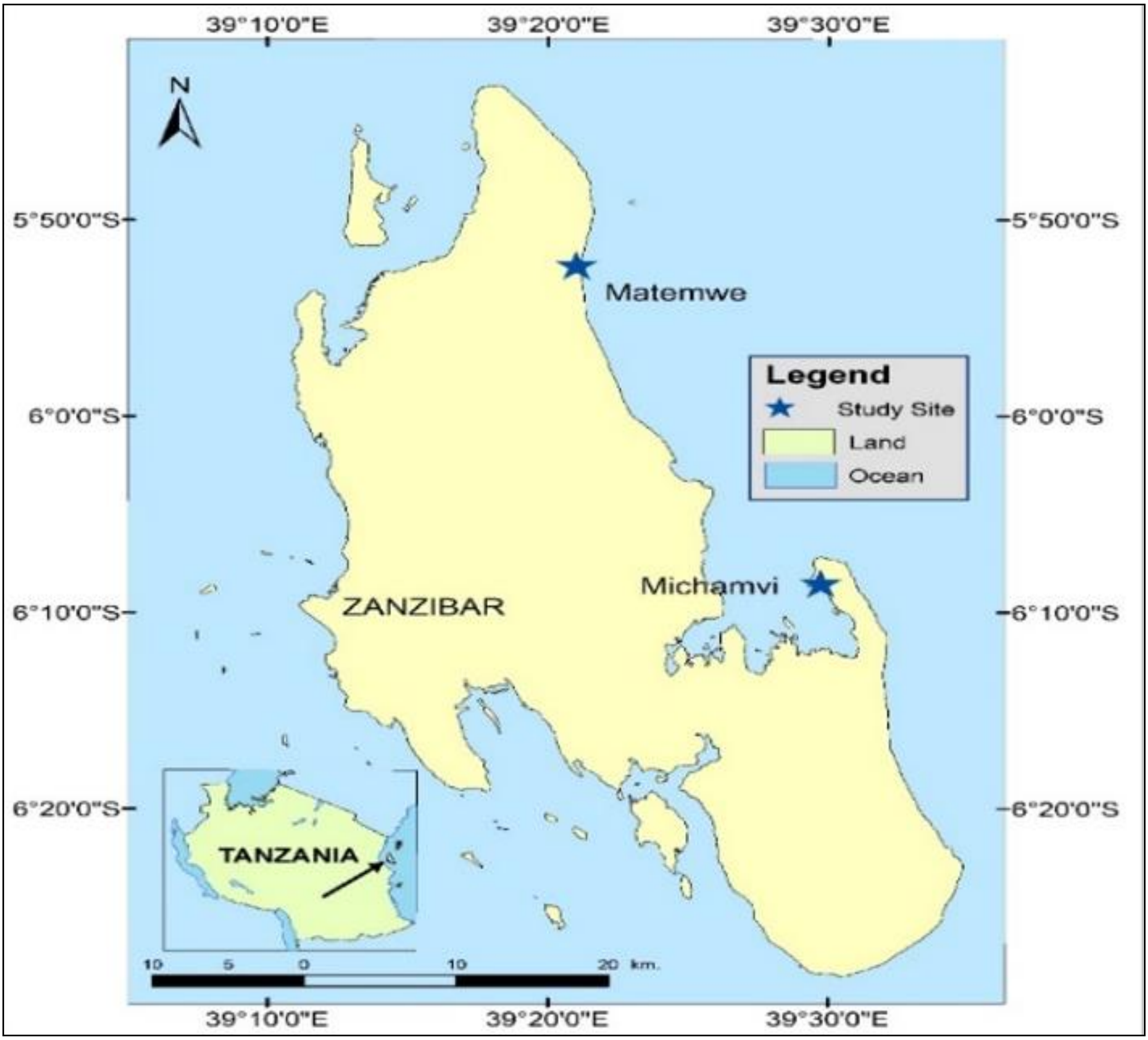

Fig 1 A Map of Unguja Island showing the Study Sites.

Fishers access the fishing grounds at their respective sites by using two approaches; the use of a fiber boat, which was termed a **"**fishing boat,**"** and on-foot, which was termed "paddling". Common fishing gears used by the fishers involved speargun (locally named *mshare/bunduki*), Metal hooks (locally named *umangu/njoro*), metal sticks (locally named *uchokoo*, a tool made by iron stick), and wooden sticks (locally named *uchokoo*, a tool made by wooden stick).

- *Data Collection*

The octopus catch data of O. *cyanea* were collected randomly from gleaners and skin divers who were landing their catches at the respective landing sites from September 2020 to October 2021. A total of 477 fishers were involved in this study for Matemwe and 455 fishers for Michamvi. In each study site, sampling was conducted four times monthly, two days from each tide, and it was synchronized with low spring tides, between the 13^{th} to 17^{th} days and the 25^{th} to 29^{th} days of the lunar cycle, respectively, for the full-moon and half-moon phases. These days were systematically the days fishers went out for artisanal octopus fishery in Zanzibar (*Pers. obs*). The landed catches were supplemented with extra observation to collect the key information, which included the fishing time, fishing gear, the means to access the reef site, and the number of landed octopuses with their respective catch weight.

- *Determination of Catch Rates (Catch Per Unit Effort - CPUE)*

The catch rate was calculated as catch per unit effort (CPUE), computed by dividing the kilograms with fishing gear, with the anglers using the fishing boat and paddling. As adopted by [3],[8], the CPUE was computed as;

$$CPUE = \frac{Total\ catch\ in\ weight\ (kg)}{Unit\ of\ effort\ (fisher\ hours\ per\ day)}$$

Where CPUE = Catch per Unit Effort

The catch size was determined using the number of octopuses and overall weight in kilograms harvested by the fisherman per day. The total catch weight was recorded in kilograms (kg).

- *Data Analysis*

Levene's test for homogeneity of variances was used to determine the suitability of CPUE data for parametric analysis. The one-way ANOVA test was used to compare the mean CPUE across fishing gears at Michamvi. Likewise, the Kruskall-Wallis test was used to compare the CPUE among fishing gears for the Matemwe site. Additionally, the Mann-Whitney U test was used to compare the mean CPUE between types of means of access to fishing sites at Matemwe and Michamvi.

III. RESULTS AND DISCUSSION

- *Catch Rate (CPUE) based on Gear Type*

The average CPUE varied slightly among the different gear types within sites (**Fig. 2**), suggesting differences in gear efficiency. Speargun recorded the highest mean catches, with a mean CPUE of 3.01 kg/fisher/day, with a SE of 0.071 in Michanvi, and a mean CPUE of 4.96 kg/fisher/day with a standard error of 0.265, indicating high variability, possibly due to the skill-dependent nature of this method. Metal hook and Metal stick showed the most stable performance with moderate variability in the catch efficiency among fishers using these gears. At Michamvi, the Metal hook showed an average CPUE of 2.59 kg/fisher/day with a standard error (SE) of 0.094. In contrast, Metal sticks reported a comparable mean CPUE of 2.61 kg/fisher/day but with a slightly higher variability (SE = 0.167). At Matemwe, Metal Hook and Metal Stick Gears showed mean CPUEs of 2.79 kg/fisher/day and 2.97 kg/fisher/day, respectively, but with more consistency, as evidenced by lower standard errors of 0.127 and 0.387, respectively. Wooden stick gear recorded the highest mean CPUE among non-speargun gears at both sites: CPUE of 2.80 kg/fisher/day and 4.10 kg/fisher/day for Michamvi and Matemwe, respectively. However, a large standard error, 0.339 for Michamvi and 2.707 for Matemwe reflects the low sample size (N=3 for Michamvi and N=3 for Matemwe) and hence implies less reliable estimates. When the effectiveness of octopus fishing gears was compared within sites, there was no significant variability in CPUE among gears at Michamvi (ANOVA, $p = 0.115$). Conversely, a Speargun at Matemwe had significantly higher CPUE than all other gears (The Kruskal-Wallis H test, $p < 0.001$).

The results indicate that spearfishing and traditional stick methods can yield high catches. Still, their effectiveness may be highly variable and influenced by external factors such as fisher skills and specific local conditions. In contrast, although metal-based gears yield lower catches on average, they offer more consistent performance and may represent more reliable tools for sustainable fishing practices.

By analyzing the catch rates, these findings on the impact of different fishing gears on Octopus fisheries in Zanzibar highlight significant variations in the efficiency of different fishing gears. Spearfishing and traditional stick methods, while capable of achieving high CPUEs, exhibit considerable variability in performance. This inconsistency can be attributed to the skill and experience of the fisherman, as well as varying environmental conditions, which are known to influence the success rates of these more artisanal methods (9). Our results are consistent with those found by (12), who reported that spearfishing yields higher catch rates but can be highly dependent on fisher proficiency and local ecological conditions.

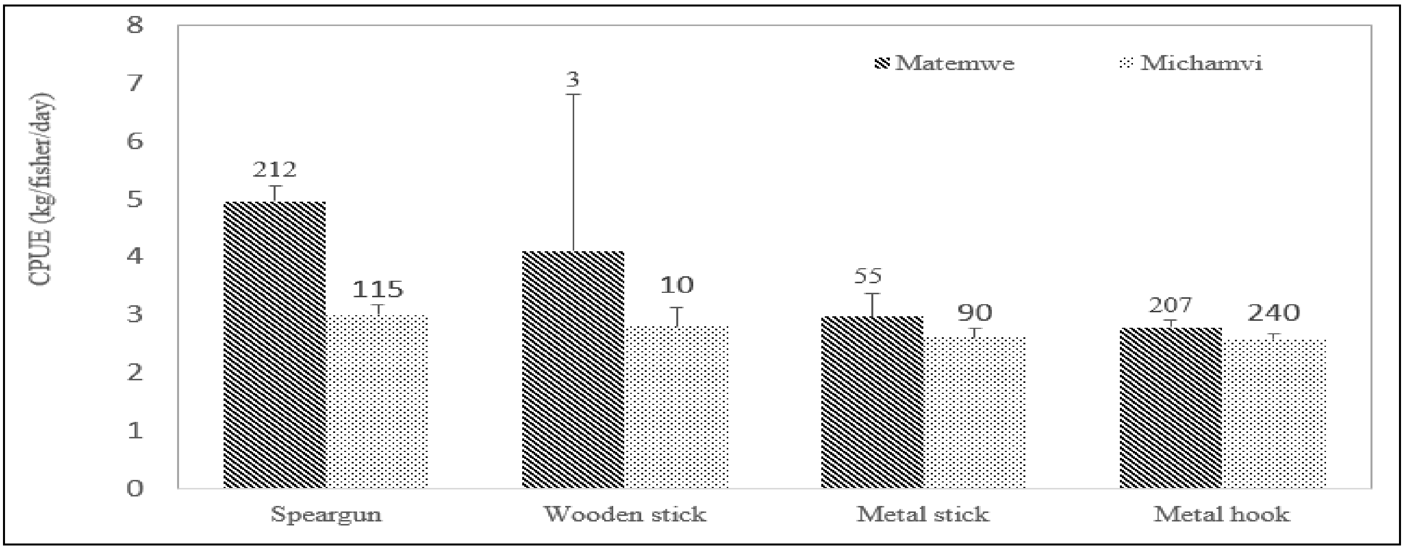

Fig 2 Comparison of the mean ± SE CPUE among types of fishing gears between Matemwe and Michamvi sites. The error bars represent the standard error of the mean (SE) as a measure of variability. The numbers above each bar are the sample size (N) for additional context. SE represents Standard Error, and CPUE represents Catch per Unit Effort.

In contrast, the metal hook and metal-stick gears demonstrated lower but more consistent CPUEs. This suggests a lower dependency on individual skill and potentially higher suitability for sustainable fishing practices, as these gears may exert less pressure on specific fish populations. This aligns with findings from (13), who observed that standardized gear types provide more reliable catch rates and are easier to manage from a regulatory perspective.

The findings of this study also align with the broader literature on fishing gear efficiency and its ecological implications. For instance, (15 and 16) emphasized the importance of gear choice in balancing fishery yields and conservation goals. They argued that gears with high variability in CPUE, like spearfishing and sticks, might target specific species, thereby increasing the risk of overexploitation. Therefore, understanding the characteristics of each gear type can inform better management decisions that align with economic and ecological sustainability goals.

Moreover, the methodological approach adopted in this study, quantitative analysis of gear-specific CPUE, builds upon the framework proposed by (8 and 9), who highlighted the need for empirical assessments of fishing gear performance to support evidence-based fisheries management.

- *Catch Rate (CPUE) based on the Means used to access the Fishing Site*

The mean CPUE between types of vessels used to access the fishing sites for octopus fisheries showed variabilities within sites (Fig.3). For Michamvi, the mean CPUE was significantly higher for fishers who used Paddling (2.95±0.12 kg per fisher per day) than fishing boats (2.54±0.09 kg per fisher per day), (Mann-Whitney U test, $p = 0.007$).

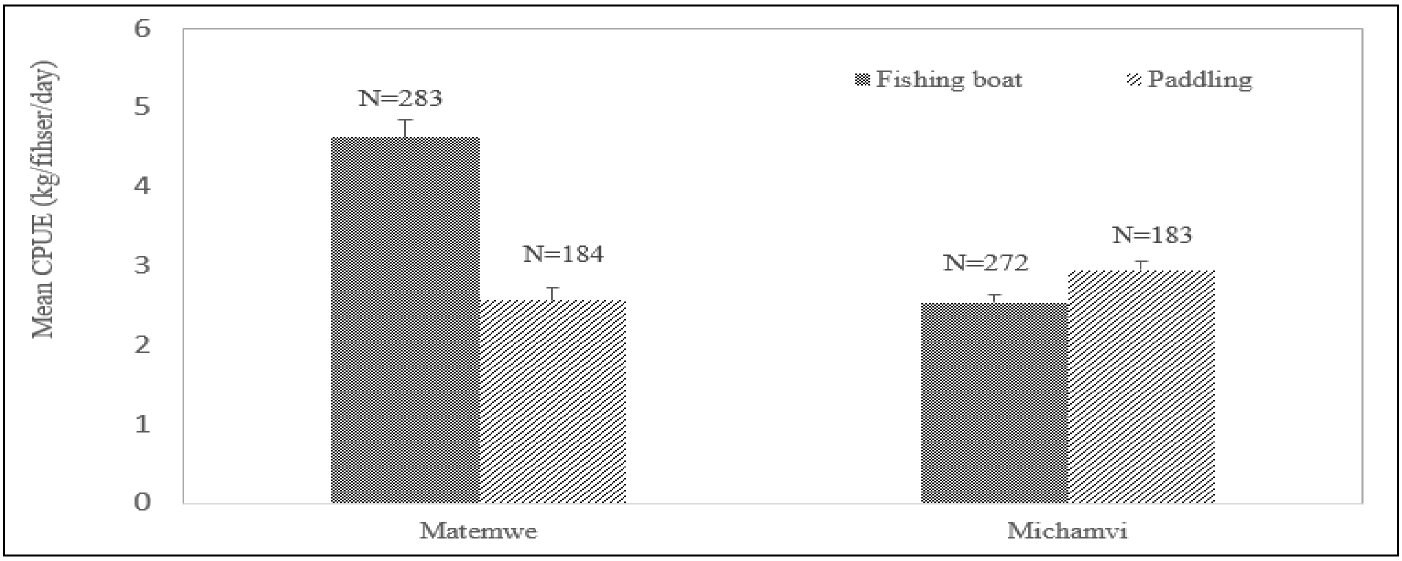

Fig 3 Comparison of the mean ± SE CPUE between types of vessels used to access the fishing sites for octopus fisheries between Matemwe and Michamvi sites. The error bars represent the standard error of the mean (SE) as a measure of variability. The numbers above each bar are the sample size (N) for additional context. SE represents Standard Error, and CPUE represents Catch per Unit Effort.

When considering the amount of error for fishing boats and paddling, the smaller standard error for fishing boats could reflect the precision of the mean estimate given the sample size of 272 observations relative to 183 observations for paddling. Thus, the higher CPUE for paddling was due to a slightly less precise estimate. However, the smaller p-value of the test statistic justifies the validity of higher mean CPUE in fishing boats than in paddling.

The assessment results for CPUE analysis by vessel type in Matemwe showed the opposite trend from Michamvi. Fishing boats exhibited relatively higher mean CPUE (4.63±0.21 kg per fisher per day) than paddling (2.56±0.16 kg per fisher per day) (Mann-Whitney U test, p <0.0001). The higher standard error in fishing boats, despite the larger sample size relative to paddling, 283 and 194, respectively, implies that there are diverse sets of fishing operations and possibly varying success rates depending on specific fishing grounds or techniques used. The higher mean CPUE in fishing boats reflects the enhanced capability of motorized boats to access a broader range of fishing areas and possibly exploit deeper waters or more distant fishing grounds that are less accessible to paddling. The lower CPUE and variability for paddling indicates a more consistent but reduced catch capability, likely due to the spatial and physical limitations inherent in paddling vessels.

The disparity in CPUE between fishing boats and paddling vessels within sites highlights the impact of vessel type on fishing efficiency, the nature of the fishing site, and potential fish stock exploitation. These findings further indicate that the vessel type significantly influences resource exploitation efficiency, suggesting that vessel-specific strategies might be required to optimize catch rates and ensure sustainable fishery management practices. The higher CPUE associated with paddling vessels in Michamvi might reflect more effective or selective fishing techniques suited to the local marine ecosystem or indicate areas with higher fish abundance accessible only to smaller, more maneuverable craft.

➢ *Management Implications*

In conclusion, our findings on the impact of fishing gear on octopus catch rate in Zanzibar indicated that spearfishing, although producing higher CPUE, shows significant variability that could be linked to this method's selective and skill-dependent nature. This variability in spearfishing efficiency could have implications for octopus populations, as highly efficient, selective catch methods may lead to overexploitation of specific age or size classes, potentially disrupting the reproductive cycles of the octopus. These results align with those found by (17), who noted that targeted fishing methods, while efficient, can adversely affect octopus population dynamics if not properly managed. Likewise, the results highlight the lower but more consistent CPUE associated with metal hook and metal stick gears. Using these gears may represent a more sustainable approach to octopus fishing, as they likely reduce the risk of selective overfishing. Consistency in catch rates may help maintain stable octopus populations, as suggested by (16,17), who argued for adopting less selective gear to enhance the sustainability of octopus fisheries in tropical regions. The findings also contribute to the ongoing discussion on the ecological impact of fishing gear on marine life. According to studies by (12), gear-specific assessments are crucial for developing management strategies that balance fishery yield and species conservation. This is particularly relevant for octopus fisheries, where gear type and fishing intensity can significantly influence population health and resilience.

The findings on the impact of means of fishing site access on octopus catch rate in Zanzibar suggest that differentiated management strategies could be beneficial. For instance, imposing stricter catch limits or operational zones for fishing boats might alleviate pressure on vulnerable fish stocks. Simultaneously, encouraging low-impact fishing methods, such as paddling, could be promoted as part of a broader strategy to conserve nearshore ecosystems and support the livelihoods of small-scale fishers. The results further underscore the need for tailored approaches to octopus fishery management that consider different fishing vessels' specific ecological impacts and operational capacities.

Given the socio-economic importance of octopus fishing in Zanzibar, these insights could guide policy adjustments, promoting gears that balance efficiency and sustainability. Implementing gear restrictions or modifications based on empirical CPUE data could help manage octopus stocks more effectively and boost the blue economy policy. By fostering an understanding of how vessel type influences CPUE, fisheries managers can better design interventions that balance economic efficiency with ecological sustainability, thus contributing to the long-term health and productivity of marine ecosystems.

➢ *Authorship Contribution Statement*

- **Abdalla Y. Kombo:** Conceptualization, Methodology, Investigation, and Writing – original draft.
- **Ali M. Ussi:** Supervision, Methodology, Formal analysis, Writing – review and editing.

➢ *Animal Ethics*

Research permission was obtained from the office of the Second Vice-President office of the revolutionary government of Zanzibar. The Department of Fisheries was informed about the collection of fisheries data.

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➢ *Declaration of Interest*

I, **Abdalla Y. Kombo**, declare that the authors have no conflict of interest regarding this manuscript or any part. The authors decide jointly and conclude publishing this article.

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