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Research Article

The Response to Fishing Decisions and Changes in Fishing Income during Extreme Weather: A Behavioural Economy Study of Small-Scale Coastal Fisher Households

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Abstract

Extreme weather, attributed to global climate change, has altered the economic behaviour of small-scale fishing households in coastal areas. This study aims to analyse the economic behaviour of fishermen by investigating their fishing decisions using a logistic regression model using the maximum likelihood estimation method and their fishing business income through a normalized profit function. The research employed a quantitative research method with a survey approach conducted in the western coastal region of Barru Regency, Indonesia. The research sample consisted of 209 fishing households. The findings reveal that fishermen fish during extreme weather conditions to meet their household's economic needs, even though their earnings are diminished. Various factors, including the power of the boat engine, fishermen's age and education level, and the potential income from fishing, influence the decision to fish during extreme weather. Additionally, engine fuel prices, education levels, and the number of dependents in the family also impact fishers' income during extreme weather. The most important factor influencing the decision to fish in extreme weather conditions is formal education. Another factor that has the greatest impact on fishermen's income, both in the fishing season and during extreme weather, is the price of engine fuel. Fishermen can adapt to events triggered by extreme weather by implementing specific strategies. For instance, diversifying income by aquaculture production can be an alternative to sea fishing. Diversifying the types of fishing gear to accommodate different weather conditions is equally crucial. Fishing periods and locations can be adjusted to align with prevailing weather conditions. The contribution and significance of this research is to provide insight and understanding of the impact of extreme weather on fishing decisions and changes in the income of capture fishermen. This condition is the economic behaviour of small-scale fishing households in coastal areas when faced with extreme weather events.

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1. Introduction

Extreme weather events, increasingly influenced by global climate change, provide substansial risks to the livelihoods of small-scale fishers, particularly in coastal regions (Ilarri *et al.,* 2022) Communities in Barru Regency, Indonesia, a coastal region bordering the Sulawesi Strait, are vulnerable to rising sea levels and tidal inundation, disrupting fishing activities and threatening coastal ecosystems. These events have led to significant reductions in fishing opportunities, severely impacting the economic stability of local fishermen (Uddin *et al.,* 2021). Small-scale fishing communities are particularly vulnerable to extreme weather events due to their limited operational capacity and range in open waters (Selvaraj *et al.,* 2023). Extreme weather conditions limit fishers' opportunities to catch fish (Erauskin-Extramiana *et al.,* 2023) with large ocean waves significantly impact fishing activities (Maltby *et al.,* 2021), decreasing the quality and quantity of catches (Shaffril *et al.,* 2019). Nevertheless, small-scale fishers in the study area persist in conducting fishing operations to meet their household economic needs despite the inherent safety risks. Fishing activities predominantly occur near land or coastal areas, involving short-duration fishing operations. This pattern represents the dynamic behaviour of fishermen in coastal regions. The survival of small-scale fishers is highly dependent on catches and profit margins (Ruiz-Jarabo *et al.,* 2022). Fishers' decision-making can provide opportunities to adapt and prepare for future shocks (Lopez-Ercilla *et al.,* 2021).

Extreme weather phenomena are also observed in various countries with marine waters, including the marine waters of the Pacific Islands (Hanich *et al.,* 2018), the East Coast of Peninsular Malaysia (Samah *et al.,* 2019a), the Sea Waters of Ghana (Mabe and Asase, 2020), the Coastal and Marine Areas of China (Cai *et al.,* 2021), and the Sea of Portugal (Ilarri *et al.,* 2022).

The research area of Barru Regency in Indonesia, situated along the western coast and bordering the Sulawesi Strait, is directly impacted by extreme weather patterns attributed to global climate change. According to the Barru District fisheries or Barru (2022) in the past two years, the region has encountered tidal flooding resulting from rising seawater levels, leading to occurrences of flooding 2-3 times per year. The rise of sea level in the study area directly and indirectly impacts coastal communities. The direct impacts are a reduction in land area due to seawater inundation and tidal flooding. Indirect impacts include loss of livelihoods of coastal communities, reduction of rice fields near the coast, and disruption of inter-island transport. This will pose a globally significant economic, social, and environmental threat to coastal countries (Muringai *et al.,* 2022). The Intergovernmental Panel on Climate Change (IPCC) reports that global sea levels are rising at a rate of 3.2 mm per year (Shaffril *et al.,* 2017). This rise has repercussions on wave heights and sea breeze speeds. According to Meteorology, Climatology and Geophysics Agency or MCGA (2022) has also reported sea breeze speeds ranging from 5 to 25 knots, typically moving from North-Northeast to Southwest-Northwest at 8 to 20 knots. The report further notes that wave heights in the Sulawesi Sea can reach 4-6 meters. Through the Directorate General of Indonesian Fisheries, the Ministry of Maritime Affairs and Fisheries or MMAF (2022) has urged fishermen and fishing vessel owners to remain vigilant against extreme weather conditions. They have even issued directives to refrain from sailing until weather conditions return to normal due to the significant risks posed to maritime safety.

This study underscores the pressing necessity to mitigate the effects of harsh weather on small-scale fishers, especially in Barru Regency, Indonesia. The study elucidates local fishermen's constrains and adaptive tactics, offering critical insights to enhance fisheries' resilience and foster sustainable practices under climate change (Rogers-Bennett *et al.,* 2022). Small-scale fishers, whose livelihoods depend on capture fisheries, are especially susceptible to the impacts of climate change (Mabe and Asase, 2020). Most maritime nations are projected to witness a decline in fisheries income and livelihoods due to extreme weather (Cheung *et al.,* 2021). Extreme weather, a consequence of global climate change (Ilarri *et al.,* 2022), can exert significant effects on marine ecosystems (Servino *et al.,* 2018) and coastal regions (Selvaraj *et al.,* 2022), notably on the economic behavior of small-scale fishing households.

The economic behaviour of fishermen entails changes in their attitudes or actions, resulting in alterations in work or business productivity (output) (Mukherjee, 2021). Extreme weather disrupts the socio-economic equilibrium, affecting aspects such as fishing activities (Savo *et al.,* 2017), the prices of fresh marine fish, and fishermen's income from fishing. Globally, fisher behaviour is widely recognized as essential for effective fisheries management (Li *et al.,* 2021), particularly as fishing industries expand worldwide (Harper *et al.,* 2013). Extreme weather is a global phenomenon characterized by unusual weather events or climate conditions that can potentially disrupt human life and natural ecosystems. Such events manifest as heavy rains, high-speed winds, frequent tidal waves, tsunamis, and elevated sea surface temperatures (Shaffril *et al.,* 2017). Erratic rainfall, abrupt temperature fluctuations, and extreme climatic occurrences are anticipated (Siddique *et al.,* 2022). Indonesia frequently experiences extreme weather due to the Asian Monsoon, driven by winds blowing from the Asian continent towards the Australian continent. Indications of extreme weather include high waves in coastal areas, heavy rainfall accompanied by lightning, and swift cloud formation, often with Cumulonimbus clouds during transitional seasons. Climate change significantly affects marine ecosystems and fisheries, directly impacting fishing communities, fisheries management, economies, and the prospects of fishing endeavors for humanity (Erauskin-Extramiana *et al.,* 2023). These challenges hinder the achievement of sustainable ocean development in coastal countries (Daly *et al.,* 2021).

Extreme weather is a critical topic in the present and the future (Gallicchio, 2017). Understanding the vulnerability of Indonesia's coastal areas to natural disasters, including extreme weather, is paramount for research and consideration. The vulnerability of these coastal regions to extreme weather can lead to population vulnerability, which, in turn, may impede the progress of social and economic development (Rahman and Rahman, 2015). This global concern has found its way into economic development policies (Mbaye *et al.,* 2023) and fisheries climate adaptation policies (Szmkowiak and Steinkruger, 2023). It aligns with the first Sustainable Development Goal (SDG) to address poverty. The overarching objective is effectively incorporating climate change adaptation into global fisheries development planning for long-term sustainability.

Numerous researchers in various countries have explored fisher behaviour in response to extreme weather caused by climate change. These studies have investigated the economic vulnerability of fishing households to climate change in the Tumaco region of the South Pacific coast of Colombia (Selvaraj *et al.,* 2022), adaptation strategies employed by fishers in the context of climate change in Malaysia (Shaffril *et al.,* 2017) and Asia (Shaffril *et al.,* 2019), factors influencing fisher adaptation in Malaysia (Samah *et al.,* 2019b), the impacts of climate change adaptation on the catchability of artisanal fishers in the Volta Basin in Ghana (Mabe and Asase, 2020), fishermen's adaptation measures and climate change mitigation in support of small-scale fisheries in the Pacific Islands Region (Hanich *et al.,* 2018), the social construction of climate change and adaptation strategies among artisanal fishers in Senegal (Mbaye *et al.,* 2023), and fishers' perceptions of risk in adapting to climate change in the UK (Maltby *et al.,* 2021). However, to our knowledge, research on household economic behaviour during extreme weather has not been conducted before. This study aims to investigate the economic behaviour of small-scale fishing households, explicitly focusing on the drivers behind fishers' decision to go to sea during extreme weather and its impact on changes in fishing income. Probability response of fishermen's decision to go to sea during extreme weather by analyzing the Logistic regression model with the Maximum Likelihood Estimation (MLE) method (Pampel, 2000). The impact of changes in fishing revenues with a normalized profit function (Ge *et al.,* 2023).

The implications of this research are expected to provide policymakers with new insights and information on the dynamics of the economic behaviour of small-scale fishing households in coastal areas in the face of future global extreme weather events.

2. Materials and Methods

2.1 Materials

The materials used in this study was HVS A3 -70 GSM paper measuring 297 x 420 mm with the brand SiDU. This material was used to record research data in the sample area through questionnaires.

The tools used in this study was the Statistical Package for the Social Sciences or Statistical Product and Service Solutions (SPSS) software. The software brand used is IBM SPSS Statistics version 21. This software brand was created in 2017 in New York, United States. SPSS software was used to process and analysis quantitative data for the purposes of this study.

2.1.1 Ethical approval

This study does not require ethical approval because it does not use experimental animals.

2.2 Methods

2.2.1 Study area

The research was conducted in the western coastal area of Barru Regency, which is adjacent to the Sulawesi Strait. Data collection took place from July 2023 to August 2023. The selected sample district was the Mallusettasi sub-district, chosen through purposive sampling due to its having the most significant number of small-scale fisher households compared to other sub-districts (Tanete Rilau, Barru, Soppeng Riaja, and Balusu), all of which are also situated along the coastal area of Barru district (CBS, 2022). In the Mallusetasi sub-district, purposive sampling was used to select areas directly affected by extreme weather events due to climate change, namely the villages of Palanro, Mallawa, and Kupa (Barru, 2022). Fishermen in the area have been experiencing tidal flooding caused by rising sea levels inland for the past two years, which occurs 2-3 times a year.

The data utilized in this research were cross-sectional data. The population of fishermen in the sample sub-district was 439 households, 76 fishermen from Palanro, 132 fishermen from Mallawa, and 231 fishermen from Kupa (CBS, 2022). Based on this proportion, a regional sample was taken using the Slovin formula with an error rate of 5% (according to equation 1), resulting in 209 fisher households, each represented by Palanro 36 fishermen, Mallawa 63 fishermen, and Kupa 110 fishermen.

$$n = \frac{N}{1+Ne^2} = \frac{439}{1+439\,(5\%)^2} = 209 \qquad (1)$$

Where, n is the number of samples. N is the population size. 1 is the constant. e^2 is the estimated error rate (5%).

2.3 Analysis Data

2.3.1 Response analysis of fishing decisions

The hypothesis of this research objective is to analyze the decision to go to sea to catch fish during extreme weather (equation 3) with Analysis: Logistic regression model using MLE method (Pampel, 2000) as follows:

$$P_i = F(Z_i) = (\beta_0 + \beta_0 X_i) = \frac{1}{1+e^{-Zi}} = \frac{1}{1+e^{-(\beta_0+\beta_1 X_i)}} \quad (2)$$

Where, e (Euler's constant) is the base of the natural logarithm, with a value of 2.718. P_i is the probability (with a value between 0 and 1). Z is the lies between - ∞ and + ∞.

The equation above can be manipulated by multiplying $1 + e^{-Zi}$ on both sides, giving the following equation:

$$(1 + e^{-Zi})Pi = 1 \quad \text{......(3)}$$

The above equation will result in the following equation:

$$\frac{e^{-Zi}\,Pi}{(1-Pi)/Pi} \quad \text{......(4)}$$

The equation above can be transformed into a natural logarithmic model, so the equation becomes:

$$Z_i = Ln\left(\frac{Pi}{1-Pi}\right) = \beta_0 + \beta_i LnX_i \quad \text{......(5)}$$

$$KNMICEx = Ln\frac{Pi}{1-Pi} = \beta_0 + \beta_1 Ln\pi UTN + \beta_2 LnUkMT + \beta_3 LnUmrN + \beta_4 LnPndN + \beta_5 LnPnglM + \beta_6 LnTgKl + \delta_1 AkInt\ \mu_1 \quad \text{......(6)}$$

Where, P_iP_i is the probability with a value between 0 and 1. KNMICEks is the decision of fishermen to fish during extreme weather (1, to fish; and 0, other). πUTNCEks is capturing business income during extreme weather. β_0 is the intercept. $\beta_1, \ldots, \beta_6$ are regression coefficients of independent variables. δ_1 is the regression coefficient of the dummy variable. πUTN is the fishing business income (IDR). UkMT is the outboard engine size (PK). UmrN is the fisher's age (years). PndN is the fisher's formal education (years). PnglM is fishing experience (years). TgKl is family dependents (people). Internet access dummy, AkInt is the 1, using mobile phones, and 0, for others. μ_1 is the confounding error.

2.3.2 Analysis of factors affecting fishing income

The hypothesized research objectives of factors affecting fishing income during the fishing season (equation 10) and extreme weather (equation 11) were proxied by the normalized profit function first developed by Yotopoulos and Nugent in 1976 (Ge *et al.*, 2023) using multiple regression analysis. Maximum profit is achieved when the marginal product value equals the input price. About the inputs used, we denote the short-run profit function as follows:

$$\pi = pf(X_1, \ldots, X_m; Z_j, \ldots, Z_m) - \sum_{i=1}^{m} ci' X_i \quad \text{......(7)}$$

Where: $\pi\pi$ is the short-term profit. pp is the input price. $cici$ is the price of the variable input. Z_jZ_j is the fixed input. X_iX_i is the variable input. Furthermore, Ge *et al.* (2023) stated that the Cobb-Douglas profit function is a price function of variable inputs normalized by output prices that can cope with slight price variations. If we assume the relationship between production factors using the Cobb-Douglas production function, the profit function can be normalized in the following way:

$$\pi^* = A\,\Pi(C_i^*)^{\alpha i}\,\Pi\,(Z_j)^{\beta i} \quad \text{......(8)}$$

Equation (8) can be written :

$$Ln\,\pi^* = Ln\,A^* + \sum_{i=1}^{m} \alpha_i^* LnC_i^* + \sum_{i=1}^{m} \beta_j^*\,Ln\,Z_j \quad \text{....(9)}$$

Where: $\pi^*$is the profit normalized to the output price. A^* is the intercept. α_i^* is the variable input price coefficient. β_j^* is the fixed input coefficient. C_i^* is the variable input price normalized by the output price. Z_j is the fixed input.

Referring to equation (9), the determinants of small-scale fishermen's income during the fishing season and extreme weather conditions are as follows:

$$\pi UTNMs* = \beta_9 + \beta_7 HBBMT* + \beta_8 LMlt + \beta_9 UkMT + \beta_{10} UmrN + \beta_{11} PndN + \beta_{12} PnglM + \beta_{13} TgKl + \delta_2 AkInt + \mu_2 \quad \text{......(10)}$$

$$\pi UTNMCEx* = \beta_{14} + \beta_{15} HBBMT* + \beta_{16} LMlt + \beta_{17} UkMT + \beta_{18} UmrN + \beta_{19} PndN + \beta_{20} PnglM + \beta_{21} TgKl + \delta_3 AkInt + \mu_3 \quad \text{......(11)}$$

Where: π^* is the normalized profit (input price divided by output price). A^* is the intercept. α_i^* is the variable input price coefficient. β_j^* is the fixed input coefficient. C_i^* is the variable input price normalized by the output price. Z_j is the fixed input. πUTNMs* is the normalized fishing season income (income divided by the selling price of fish). πUTNCEks* is the normalized fishing revenue during extreme weather (income divided by the selling price of fish). β_9, β_{14} is the intercepts. $\beta_7, \ldots, \beta_{13}$; $\beta_{15}, \ldots, \beta_{21}$ is the regression coefficient of independent variables. HBBMT* is the normalized outboard engine fuel price (fuel price divided by fish selling price). LMlt is the length of time at sea (hours). δ_2 and δ_3 are regression coefficients of dummy variables. μ_2, μ_3 are confounding errors.

3. Results and Discussion

3.1 Results

3.1.1 Socioeconomic conditions

The social conditions of small-scale fishing households in the study area influence fishing decisions and changes in fishing income during extreme weather conditions. Social conditions include fishermen's age, formal education, fishing experience, and number of family dependents (Table 1). Of the 209 fishermen sampled, the oldest was 67 or 32.06%, aged between 47 and 57, while the youngest fishermen were 27 fishermen (12.92%) aged between 25 and 35. The highest formal education of the fishermen is junior high school (JHS) graduates, as many as 78 fishermen (37.32%), and the lowest is one fisherman (0.48%). However, some did not graduate from elementary school (ES), as many as 29 fishermen 13.88%. The lowest fishing experience was seven fishermen (3.35%), and the highest was 52 (24.89%). The highest number of family dependents of fishermen is 3 - 4 or 45.93% of people in their households.

Another case is the economic condition of fishing households, which can be compared with fishing business income during both the fishing season and extreme weather conditions. During extreme weather conditions, fishing income per trip, week, and month decreases (Table 2). The comparison of fishing business income per trip during the fishing season of IDR 130 thousand is lower than during the fishing season of IDR 2 million. In terms of fishing operations at sea, during extreme weather conditions, 3 - 8 hours per trip is less than during the fishing season, which is 9 - 14 hours per trip. The power of the outboard engine used by the fishermen to reach the fishing ground is 20 power knots (PK) with 37 fishermen, while the lowest is 5.5 PK with 12 fishermen (Table 3). Fishing operations, fishing time, and outboard engine power are determinants of fishermen's fishing decisions and changes in fishermen's income.

3.1.2 Response to fishers' fishing decisions and comparative changes in fishing income

The probability of fishermen's decision response to fish at sea during extreme weather conditions is influenced by the variables that influence it (Table 4). Formal education of fishermen is the variable that provides the highest probability of catching fish during extreme weather conditions with an Exp. (βi) of 1.116, followed by the value of Exp. (βi) of outboard engine power, age of fishermen, and fishing income of 1.009, 1.005, and 1.000, respectively. This condition can be seen from the parameters, namely if the value of Exp. (βi) > 1, the probability of the decision is greater. Conversely, if the value of Exp. (βi) < 1, the chances are smaller, such as the variables of fishing experience, number of family members covered, and Internet access (0.998; 0.968; and 0.728). Analysis of the logistic model is usually done by examining the regression coefficients (βi) and the corresponding significance level or confidence level values. The odds ratio (Exp. (βi)) can then be used to explain the probability or likelihood of going to sea and fishing during extreme weather. The value of this finding is that it provides insight into how extreme weather events caused by global climate change may affect fishing practices.

Table 1. Social conditions of small-scale fishers in coastal areas.

Variable	Description	Frequency	Percent (%)
Fishers age (year)	25 – 35	27	12.92
	36 – 46	49	23.45
	47 – 57	67	32.06
	58 – 68	54	25.83
	> 69	12	5,74
Total		**209**	**100.00**
Formal education of fishers (Year)	Not completed school	29	13.88
	Elementary school (ES)	65	31.10
	Junior high school (JHS)	78	37.32
	Senior high school (SHS)	36	17.22
	Bachelor's degree (S1)	1	0.48
Total		**209**	**100.00**
Experience at sea (year)	< 5	7	3.35
	5 – 15	33	15.79
	16 – 26	42	20.10
	27 – 37	52	24.89
	38 – 48	48	22.96
	> 48	27	12.91
Total		**209**	**100.00**
Family dependents (people)	1 – 2	77	36.85
	3 – 4	96	45.93
	5 – 6	36	17.22
Total		**209**	**100.00**

Comparing the factors affecting fishermen's fishing income during extreme weather, the price of fuel (pertalite) for outboard motors and formal education of fishermen have a significant positive effect at the 1% (99% confidence level) and 5% (95% confidence level) error rates, respectively. Similarly, the number of family members has a negative effect at the 5% level. In contrast, during the fishing season, fishing income is negatively affected by the price of fuel oil and positively affected by the fishing season (Table 5). The price of pertalite fuel as input is the variable that has the greatest impact on changes in fishermen's fishing business income, both during the fishing season and during extreme weather events. 2020). Social conditions and factors can be considered as social information (de Oliveira Estevo *et al.*, 2021) since they pertain to the behavior of individuals who make risk-related decisions in the lives of fishermen.

Social characteristics significantly contribute to determining fishermen's income levels (Al-Jabri *et al.*, 2013) during both the fishing season and periods of extreme weather. As Marín-Monroy and Ojeda-Ruiz de la Peña (2016) noted that income, fishing experience, and education indicate economic diversification strategies for fishermen's livelihoods. The importance of fishermen's economic diversification strategy can reduce dependence and provide added value to improve the community's economy. Processing catches such as shredded fish, fish nuggets, and so on can provide added value to the economy of small-scale fishing households in coastal areas during extreme weather. Consequently, social and economic factors play a crucial role in poverty alleviation (Islam *et al.*, 2011) and have a substantial impact on determining the welfare level of fisher households (Al-Jabri *et al.*, 2013).

Table 2. Economic conditions of small-scale fishers during catching season and extreme weather in coastal areas.

Description	Capture Business Income			Income	Income
	Revenue (IDR/trip)	Cost (IDR/trip)	Income (IDR/trip)	(IDR/week)	(IDR/month)
Catching season	568.720	2.040.732	340.122	2.040.732	8.161.728
Extreme weather	241.556	392.415	130.805	392.415	1.569.663

Capture Business Income (IDR/trip)	Description	Catching season		Extreme weather	
		Frequency	Percent (%)	Frequency	Percent (%)
	0 - 99.000	-	-	66	31.57
	100.000 - 199.000	13	6.22	131	62.67
	200.000 - 299.000	62	29.67	12	5.74
	300.000 - 399.000	73	34.92	-	-
	400.000 - 499.000	48	22.97	-	-
	500.000 - 599.000	12	5.74	-	-
	> 600.000	1	0.48	-	-
Total		**209**	**100.00**	**209**	**100.00**

3.2 Discussion

3.2.1 Socioeconomic conditions and catch operations

The impact of climate change-induced extreme weather has adverse effects on the socio-economic status of fishers. This study aims to identify the socio-economic variables that influence the decision-making process of small-scale fishers while fishing, including factors such as age, education level, experience, and the presence of family dependents among fishers, fishing income, and the fishing technology employed, such as the outboard engine power of fishing boats. Research suggests that social and economic factors, including income, influence fishers' fishing behavior (Eliasen *et al.*, 2014). In addition to socio-economic factors, cultural norms also play a pivotal role in the decision-making process of fishers (Bisack and Clay,

The economic wellbeing of small scale fishermen is significantly influenced by their catch business income per trip during the fishing season. However, extreme weather conditions have a comparatively lower impact on their household economy. Changes in fishermen's catches cause changes in income. Extreme weather conditions result in reduced catches compared to the fishing season. Seasonal changes such as extreme weather lead to an extreme pattern of shifting

Table 3. Fishing operations and catching technology of small-scale fishers in the coastal areas.

Variable	Description	Catching season		Extreme weather	
		Frequency	Percent (%)	Frequency	Percent (%)
Time at sea (hour)	3 - 5	-	-	83	39.72
	6 - 8	-	-	126	60.28
	9 - 11	112	53.59	-	-
	12 - 14	97	46.41	-	-
Total		**209**	**100.00**	**209**	**100.00**

Variable	Description	Frequency	Percent (%)
Outboard engine power (PK)	5.5	12	5.74
	6	9	4.30
	9	18	8.61
	13	43	20.57
	15	26	12.44
	16	64	30.62
	20	37	17.70
Total		**209**	**100.00**

Table 4. Analysis of factors influencing fisher's fishing decisions during extreme weather in coastal areas extreme weather in coastal areas.

Independent Variable	Coefficient	Standard Error	Wald-test	Sig.	Exp. (β_i)
Capture business income	0.000	0.000	1,119	0.290	1.000
Outboard engine power	0.009	0.016	0.289	0.591	1.009
Age of fishermen	0.005	0.030	0.023	0.880	1.005
Formal education of fishers	0.110	0.064	2.940	0.086	1.116
Fishing experience	-0.002	0.020	0.016	0.901	0.998
Family dependents	-0.032	0.134	0.058	0.810	0.968
Dummy of Internet access	-0.318	0.381	0.381	0.537	0.728
Intercept			-0.386		
Nagelkerke R^2			0.030		
-2 Log Likelihood			240.561		
n			209		

Note: If the value of Exp. (β_i) > 1, then the probability is getting bigger, otherwise if the value of Exp. (β_i) < 1, then the probability is getting smaller.

the fishing season into the lean season. This condition leads to uncertainty in the livelihood of fishermen in capture fisheries. On average, fishermen earn IDR 130 thousand per trip, with 131 fishermen (62.67%) reporting this income, as opposed to IDR 340 thousand per trip during the fishing season, with 73 fishermen (37.92%) earning this amount. The cost of fishing and the revenue generated also play vital roles in the household economy and non-capture business income (Rahim and Hastuti, 2018).

Low capture business income can indicate poverty within the marine fisheries sector (Teh *et al.*, 2020). Understanding fishing income is crucial for assessing the contribution of fisheries to fishers' livelihoods on a global and temporal scale (Purcell *et al.*, 2018). Additionally, fishing income can gauge fishers' decision-making (Bisack and Clay, 2020) and economic behavior and inform sustainable fisheries management decisions (Robotham *et al.*, 2019).

In addition to social and economic factors, fishing technology factors are also considered, as presented in Table 3. When fishermen venture out to sea to catch fish, their goal is to maximize their catch per trip, considering the time spent fishing. Fishing effort can be quantified by the number of trips fishermen make (Muallil *et al.,* 2013), even if the catch is relatively small. Fishermen can boost their income by traveling farther to fishing grounds, with more significant opportunities to secure larger catches. During extreme weather conditions, the average duration of fishing operations ranges from 6 to 8 hours per trip, whereas during the fishing season, it extends to between 12 and 14 hours.

Fishermen typically employ outboard engines ranging from 5.5 to 20 PK to navigate their small boats, locally known as 'katinting,' to access the fishing grounds. The fishing gear used is relatively simple, comprising long lines and gillnets. The duration of time spent at sea and the fishing technology employed can significantly influence fishermen's income, a factor exacerbated by the global climate change phenomenon (Shaffril *et al.,* 2017). Frequent extreme weather events can disrupt fishing operations or reduce the time spent at sea (Predragovic *et al.,* 2023), affecting the catch's price. Fish is a highly perishable product, and its price is determined by its freshness and texture, which can be affected by how quickly it is handled after being caught. Unfortunately, these events result in substantial economic losses in the fishing industry worldwide.

When examining the factors influencing fishers' decisions to venture out to sea during extreme weather conditions, several variables are typically considered. These factors include the fisherman's income from fishing, the power of their outboard engine, and various social factors such as age, education level, fishing experience, and family situation. Additionally, a dummy variable can be employed to represent internet access. These independent variables can be analyzed to assess their impact on a fisherman's decision to go fishing during extreme weather.

Income changes significantly impact fishers' fishing decisions and overall income during extreme weather. Despite declining catches, fishing typically takes place close to coastal areas or shallow ocean waters as fishermen strive to meet the economic needs of their households. According to Bisack and Clay, (2020) fishing decisions are indeed influenced by income derived from catches. Economic necessitiestake precedence during extreme weather, even though the catch is smaller than the fishing season. Furthermore, the selling value of the catch tends to be lower due to the less targeted nature of catches during extreme weather. In addition, the dependence of some small-scale fishers on lenders and marketers for financial support has led to indebtedness. There is a significant difference in net income between small-scale fishers and fish traders, with the net income of fishers being lower than that of fish traders (Jueseah *et al.,* 2020). On average, fishermen's catch per trip includes squid, priced between IDR 30,000 to IDR 35,000, mackerel, ranging from IDR 20,000 to IDR 25,000, and anchovies, with prices between IDR 10,000 to

Table 5. Comparison of factors affecting normalized capture business income during fishing season and extreme weather in coastal areas.

Independent Variable	ES	Catching season			Extreme weather		
		Coefficient (β_i)	t-test	Sig.	Coefficient (β_i)	t-test	Sig.
Normalized fuel price	-	-2.109**	-2.258	0.025	120.221***	10.665	0.000
Length of time at sea	+	0.008*	1.896	0.059	0.051	1.015	0.311
Outboard engine power	+	0.000	-0.303	0.762	-0.003	-0.311	0.756
Age of fisherman	-	0.000	0.172	0.863	-0.023	1.443	0.151
Fishers formal education	+	0.002	0.681	0.497	0.006**	1.972	0.050
Fishing experience	+	0.000	-0.188	0.851	-0.009	-0.827	0.409
Family dependents	+	-0.007	-1.277	0.203	-0.165**	-2.377	0.020
Internet access dummy	+	-0.009	-0.411	0.681	0.168	0.617	0.538
Intercept		0.600			-3.798		
Adjusted R^2		0.019			0.367		
F-test		1.503			16.086		
n		209			209		

*** is a level error significance of 1% (0.01) or confidence level 99%; ** is a level error significance of 5% (0.05) or confidence level 95%; * is a level error significance of 10% (0.10) or confidence level 90%; ns is not significant; and ES is an expectation sign.

3.2.2 Fishers' response to fishing decisions during extreme weather

IDR 15,000. During the fishing season, the selling value is relatively higher due to successful catches from deep-sea species such as skipjack (IDR 45,000 - IDR 50,000), tuna (IDR 20,000 - IDR 25,000), and red snapper (IDR 65,000 - IDR 75,000). Ghana has also witnessed a continuous decline in fisheries sector productivity, resulting in reduced economic benefits for fishers due to the impact of global climate change (Kwadzo *et al.,* 2022). This situation has led to poverty in small-scale fisheries worldwide, particularly in Asian countries, including Indonesia. Comparing fishers' incomes across countries and over time can challenge broader assumptions about poverty alleviation (Purcell *et al.,* 2018).

The age of fishermen also presents opportunities for fishing. Age structure is very important in identifying one's status and role in society and understanding certain issues (Ali *et al.,* 2023). The increasing age of fishermen will bring work experience and more work in fishing (Kim *et al.,* 2020). In the study area, the productive age of fishers ranged from 25 to 57 years old, while the non-productive age group included individuals aged 58 to 68 years old and even older than 68 years. Nevertheless, fishermen continue to choose to fish during extreme weather. With their extensive fishing experience, spanning 30 to 40 years, their chances of catching fish remain high. Similarly, in Malaysia, young and older fishermen exhibit strong adaptability (Samah *et al.,* 2019b). However, in the West Philippine Sea region of the Philippines, younger fishers engage in fishing more frequently than their older counterparts (Muallil *et al.,* 2013). Younger fishermen are more likely to achieve significant catches due to their higher productivity than older fishermen. Remarkably, despite their theoretically decreasing productivity with age in Taiwan, fishermen over 40 have substantially contributed to their household income from ocean fishing (Lu *et al.,* 2020). As heads of their families, fishermen are responsible for being the family's breadwinners. The profession of a fisherman entails rigorous physical demands when venturing out to sea. Working as a fisherman requires good physical fitness, so age is essential in choosing a career (Baruah and Hazarika, 2019). Therefore, the age of fishermen significantly influences their fishing decisions (Liao *et al.,* 2019) and their varying levels of adaptability to fishing knowledge.

The power of the outboard engine on fishing boats also plays a crucial role in influencing fishermen's decisions during extreme weather in the study area. On average, the most powerful outboard engine measures 16 PK, while the smallest is 5.5 PK, both used to reach the fishing grounds. According to interviews with fishermen, some remove the outboard engine from their boats during extreme weather conditions. In such cases, fishermen resort to rowing boats to conduct their fishing closer to the coastal waters, aiming to save on expenses. The strength of the outboard engine on a motorboat can significantly impact fishermen's fishing decisions (Rahim *et al.,* 2020). The power of the outboard engine greatly supports fishing activities and the time allocated for fishing operations. A boat with a larger engine tends to yield higher earnings from fishing efforts due to extended time spent on fishing operations (Islam *et al.,* 2014).

Typically, small-scale fishing in the study area occurs near the coastline during extreme weather conditions. These fishing operations have a shorter duration, ranging from 3 to 8 hours per trip, compared to 9 to 14 hours during the fishing season. On average, fishing activities commence in the morning at 05:00 and conclude at 14:00, resulting in less time spent at sea compared to the fishing season. Fishing operations involving multiple fishing trips are also called the ‚length of time at sea' (Muallil *et al.,* 2013), during which fishermen journey from the mainland to the sea and back to the mainland. During extreme weather, there are typically an average of three fishing trips per week, as opposed to six fishing trips per week during the fishing season. Fishermen primarily engage in fishing during extreme weather to meet the needs of their households, typically doing so close to the coast. The duration of fishing operations undoubtedly impacts the catch's quantity, quality, and prices. Furthermore, small-scale fishers often cannot target species with high commercial value while fishing at sea, resulting in non-commercial catches brought ashore for family consumption. It differs from European practices (Denmark, Greece, and the UK), where catches with no commercial value are often discarded back into the sea (Eliasen *et al.,* 2014).

Education is a crucial factor that significantly influences the decision-making process of fishermen. In particular, formal education is vital during climate change and extreme weather conditions. With the proper education and fishing experience, fishermen can quickly identify the best time and location to catch fish, even in shallow waters. In the study area, 37.32% (78 people) of fishermen have completed Junior High School, while only 0.48% (one person) have completed a Bachelor's degree. Among those with an undergraduate degree is the Head of Kupa Village, Mallusetasi District, Barru Regency, an economics graduate. It's a significant information source for the fishing community and multiple fishing groups in the research area. He regularly provides essential information, such as sea wind speed and sea wave height, which are crucial for conducting fishing activities, especially during extreme weather.

The low level of education among small-scale fishermen can be attributed to economic limitations, with children often following their parents into the fishing profession. Despite the Indonesian government's efforts, especially at the regional level (districts), which have provided accessible facilities and infrastructure to enhance the formal education level for all, starting from Elementary School, Junior High School, and Senior High School. Based on interviews with several coastal area fishermen, they mentioned that becoming a proficient fisherman may not necessarily require a high formal education but instead relies on fishing experience. The average fishing experience of fishermen tends to fall within the categories of 16-26 years, 27-37 years, and 38-48 years.

Since childhood, fishermen have been accompanying their parents to the sea to catch fish. Equipped with experience, they can catch fish along the coast, not too far from their homes, to meet the needs of their families. This finding differs from Olale and Henson's (2012) research in Western Kenya, with indicated that fishermen with higher levels of formal education are more inclined to make decisions. Such educated individuals can readily embrace and implement innovations and even devise new methods that influence the decision-making process of fishers, especially during adverse weather conditions. On the other hand, small-scale fishers in the study area tend to generate new ideas independently by leveraging the knowledge passed down by their parents, who often possess little or no formal education. Coastal communities in Asia often face disadvantages, with limited access to formal education for fishers, resulting in structural poverty. Small-scale fishers are frequently marginalized, belonging to one of the most economically disadvantaged groups in many countries.

Other determinants, such as fishing experience, the number of family dependents, and internet access, do not significantly influence fishermen's fishing decisions during extreme weather. Fishermen often rely on their fishing experience as a decisive factor for survival in their profession. Fishermen know natural signs such as sea breezes, seawater temperature, marine biota, and ocean currents and their experience determines the duration of fishing operations, both during the fishing season and in extreme weather conditions. Fishing experience is critical in determining fishermen's success in catching fish at sea (Macusi *et al.*, 2021)and serves as a foundation for resource management and poverty alleviation efforts (Njock and Westlund, 2010) while also providing valuable insights into the biodiversity of the fishing environment (Rosa *et al.*, 2014). Furthermore, it shapes fishing patterns, influencing the decision to target large or small fish species (Alexander *et al.*, 2020). Similarly, a more significant number of family dependents or family size can motivate fishers to continue fishing, especially during extreme weather. The highest average number of family dependents in the study area is 5-6 people, accounting for 17.22% of the population.

Regarding internet access, small-scale fishers in the research area utilize mobile phones as communication tools to access information about extreme weather conditions through electronic media, such as weather forecasts. The Ministry of Maritime Affairs and Fisheries is dedicated to enhancing the welfare of fishing communities through digital technology. Similarly, the Marine and Fisheries Human Resources Research Agency, in collaboration with the Ministry of Communication and Information, has introduced the "Go-Online Fishermen Program" or "Smart Fishermen" to cater to the needs of fishermen, providing information on various aspects such as weather conditions, port status, sea wave data, wind directions, and fish market prices. This application also offers critical information during emergencies, such as fuel shortages. This innovative fisher application is designed specifically for small-scale fishermen. However, many fishermen in the research location, particularly the older ones, are still in the process of familiarizing themselves with it and primarily rely on their 30-40 years of fishing experience. Moreover, the mobile phones they use often lack internet access. This explains why the variable of internet access does not significantly influence fishermen's decisions to venture to sea for fishing activities.

It has been previously mentioned that the coastal area, which serves as the sample area, often experiences varying extreme weather conditions. Despite these challenges, fishermen persist in their activities at sea to meet the economic needs of their households. The opinions and perceptions of fishermen regarding climate variability can differ significantly between countries, as seen in California, the third-biggest state in the United States (Zhang *et al.*, 2012). On average, productive fishermen between the ages of 25 and 57 utilize mobile phones with Android applications, while those aged 58 to 68 and even those above 69 years old tend to use mobile phones that are not Android-based. Android is currently one of the most widely used mobile operating systems. Mobile phones equipped with various high-end Android versions can efficiently track and monitor weather condition information. Accessing information through the internet is a component of digital literacy, providing individuals with the capability to comprehend and utilize information in various formats through digital devices.

3.2.3 Comparison of changes in fishing business income during the catching season and extreme weather

The study area reveals varying findings regarding changes in fishing income during the fishing season and extreme weather. During the fishing season, the price of engine fuel (pertalite) negatively impacts fishing business income. It suggests that as the input price, pertalite, increases, the income of the fishing business decreases. This finding can be interpreted as a consequence of targeted catches being less lucrative for fishermen compared to species like lemuru, which command a high selling value of IDR 75,000 - 80,000 per kg. On average, fishermen obtain IDR 47,000 per kg of tuna during the fishing season, skipjack for IDR 22,000 per kg, and red snapper for IDR 67,000 per kg. Fuel usage increases significantly, particularly during the fishing season when fishermen must reach distant fishing grounds to maximize their catch.

In contrast, during extreme weather, the price of pertalite positively influences fishing income. These estimations demonstrate that fishing income rises as the price of pertalite increases. Fishermen's income from fish prices and quantities is relatively robust during extreme weather conditions, especially for species such as octopus, mackerel, and anchovies. The average price of octopus is IDR 33,000 per kg, mackerel is IDR 23,000 per kg, and anchovies are IDR 12,000 per kg. These catches and their selling prices prove enticing enough to contribute to household economies amidst climate change challenges. All small-scale fishers in the study area procure boat engine fuel at public fuel filling stations (PFS), obtaining pertalite at IDR 10,000 per liter. Increased utilization of this pertalite for outboard engines on fishing boats results in extended fishing operations or longer time spent at sea to reach distant fishing grounds for increased catches. Understanding fishing income and costs is fundamental to managing fisheries to improve efficiency (Purcell *et al.,* 2018) operating costs affect fishers' income (Al-Jabri *et al.,* 2013). During the fishing season, the time spent at sea for fishing is more significant than during extreme weather conditions and elevated fuel prices can diminish fishermen's fishing income. Countries with high fishing dependency and substantial fish consumption are among the most affected by the impacts of climate change (Predragovic *et al.,* 2023).

The capital invested by the fishermen does not solely determine the average cost of fishing. They often rely on loans or debts from Pabalu Balle, a group of traders in the region, to cover their expenses. This dependency weakens the fishermen's bargaining position, as the traders purchase all their catches. Even during extreme weather conditions, fishermen must pay a 10% loan fee each time they sell their catch as part of a profit-sharing agreement. Unfortunately, some small-scale fishers have accrued significant debt due to their reliance on lenders and marketers for financial assistance. According to Jueseah *et al.* (2020), small-scale fishers earn considerably lower net income than fish traders. Many fishermen from the Barru District have experienced price discrepancies due to their contractual agreements with traders. Traders outside the district, such as Pare-Pare City, also buy the catches. Price fluctuations in the local, domestic, and global markets impact the income of small-scale fishers. These fluctuations make it challenging for fishermen to maintain stable income over time, threatening their livelihood (Outeiro *et al.,* 2018).

When it comes to the formal education of fishermen, it does not appear to impact their fishing income during the regular fishing season. However, it can positively affect their income during extreme weather conditions. This finding suggests that fishermen with higher levels of formal education tend to have higher fishing income during extreme weather. As discussed earlier, fishermen's decisions to go to sea during extreme weather can also be positively and significantly influenced by their formal education. It has been observed that changes in fishermen's capture business income are strongly linked to their level of education (Adili and Antonia, 2017). Fishermen with undergraduate education can often provide essential information, such as marketing strategies for their catches during extreme weather conditions. Education equips them with the knowledge to deal with extreme weather conditions safely and effectively, including accessing fishing area forecasts and planning their fishing operations more efficiently, which can help reduce costs. However, it is worth noting that catches during extreme weather conditions are typically less abundant than during the regular fishing season.

The number of family dependents determines the size of fisher households. However, extreme weather conditions can adversely affect fishing income. Fishermen with many family dependents often feel compelled to work harder to catch more fish, increasing their income to meet their family's needs. On average, a fisherman has 5-6 family dependents, accounting for 17-22% of the total household size. In addition to providing for their wives and children, fishermen, as heads of their households, also support their grandchildren as family members. Fishing is inherently dangerous, and extreme weather conditions only exacerbate these risks; however, fishermen work tirelessly to maximize their catch and income despite the associated risks. They use their earnings to meet their family's needs and pay off their debts. The substantial number of family members in a fisherman's household strongly motivates them to continue working as fishermen. In the short and long term, they often have no alternative employment opportunities besides fishing. Fishermen also typically owe significant debts to traders (fish buyers) during the fishing season. Even during extreme weather events, fishermen in the study area remain committed to fishing to provide for their families. As primary breadwinners, fishermen are relied upon to ensure food security for their households.

It was found that social factors such as the age and experience of fishermen, the length of time spent at sea, fishing technology (outboard engine power), and internet access do not have any impact on the income earned by fishermen when they catch fish in extreme weather conditions. However, factors like fuel use and the price of inputs, such as pertalite fuel, significantly affect fishing income, and they are directly related to the distance traveled by boat to reach the fishing grounds. The power of the outboard engine plays a significant role in determining the fuel capacity of the engine and, consequently, the distance that can be covered. Factors like mileage, capacity, and boat size with engine power (PK) also impact fishing activities and time. Typically, fishermen's outboard engine power ranges from 5.5 PK to 20 PK, with fishing times lasting between 3 and 14 hours. This finding is consistent with similar research on fishermen in Fiji's marine waters, where varying engine powers were used for their fishing technology to reach the fishing grounds (Purcell *et al.,* 2018). Having sustainable and efficient fishing technology is crucial for safeguarding marine fisheries resources. Adequate engine power and longer fishing times can lead to larger catches, particularly during the fishing season. However, when severe weather conditions occur, catch sizes reduce, and their selling values drop, resulting in decreased income for the fishing business. During such weather, fishermen typically catch fish in shallow waters close to the coastal area.

Concerning internet access through mobile phones as a communication tool used by small-scale fishers, they know market information provided by traders, who act as their business partners. Fishermen's catches can be directly distributed to the market through intermediary traders, especially during the fishing season, for high-value fish species like skipjack, tuna, and red snapper. However, during extreme weather, the catch is primarily consumed directly by fishermen rather than sold, such as octopus, mackerel, and anchovies. Various fish collectors come from the study area (Mallusetasi sub-district, Barru district) and other areas such as Pare-pare City. Fish collectors from the research area go directly to the fishermen, while fish collectors from Pare-Pare City wait for the catch to be delivered directly. Mallusetasi Sub-district is a border area between Barru District and Pare-pare City. The average distance from the study area is only 20 km and can be accessed in 28 minutes. Fishermen who already have mobile phones with Android applications use them to access market information. The Smart Fishermen Program can also help break the intermediaries' market chain by providing marketplace information and a list of fish prices.

With the help of mobile phones and Internet access, small-scale fishers can stay informed about market information provided by traders who act as business partners. These traders can directly distribute the fishermen's catches to the market, especially high-value fish species like skipjack, tuna, and red snapper during the fishing season. However, during extreme weather, the catch is mainly consumed by the fishermen rather than sold, especially species like octopus, mackerel, and anchovies. Fish collectors come from various areas, including the study area of Mallesetasi sub-district, Barru district, and Pare-pare City. While fish collectors from the study area go directly to the fishermen, those from Pare-Pare City wait for the catch to be delivered. Mallusetasi Sub-district, located in the border area between Barru District and Pare-pare City, can be accessed in 28 minutes and is only 20 km from the study area. Fishermen who have mobile phones with Android applications can use them to access market information. The Smart Fishermen Program can also help eliminate intermediaries in the market chain by providing marketplace information and a list of fish prices.

The implication of this research is to understand the impact of fishing decisions on changes in capture fishermen's income during extreme weather events, namely the economic behavior of small-scale fishing households in coastal areas. The findings can contribute valuable insights and solutions for policymakers, especially small-scale fishers, to use practical strategies to adapt to extreme weather conditions. The aim is to achieve the Sustainable Development Goals (SDGs) in overcoming poverty, which is the foundation of the Blue Economy (Schutter *et al.,* 2024) and sustainable marine economic development (Croft *et al.,* 2024). Achieving these goals can improve the well-being of people in coastal countries (Daly *et al.,* 2021). Global climate change is driving management strategies and practices (Sultan, 2020), influencing economic development policies (Mbaye *et al.,* 2023) and fisheries climate adaptation policies (Szmkowiak and Steinkruger, 2023). Small-scale fishers also produce fishery products that support the food supply (Marín-Monroy and Ojeda-Ruiz de la Peña, 2016), global production systems for food security (Limuwa *et al.,* 2018) or food security in communities around the world (Hastuti *et al.,* 2022; Cañete et al., 2022). Moreover, small-scale fisheries are increasingly part of national and international market chains whose livelihoods depend on marine fisheries (Steenbergen *et al.,* 2019). They are, therefore, closely linked to employment (Marín-Monroy and Ojeda-Ruiz de la Peña, 2016). This condition significantly impacts economic development worldwide, including in developing countries such as Indonesia (Nguyen and See, 2023).

4. Conclusion

Fishermen still decide to go to sea to catch fish during extreme weather to meet the economic needs of their households. Fishing is conducted near the coast in coastal areas. However, the income from the fishing business is smaller during extreme weather than during the fishing season. Factors influencing fishermen's fishing decisions during extreme weather include capture business income, outboard engine power, age, and formal education level. During extreme weather, changes in capture business income are influenced by the price of engine fuel and the length of time spent at sea. In contrast, during the fishing season, fishing income is influenced by the price of engine fuel, the level of education of fishermen, and the number of family members they are responsible for. The first recommendation that can be made to fishermen in the face of extreme weather conditions is adaptation strategies that will affect the economy of fishing households in coastal areas. These strategies include income diversification (aquaculture production) and gear diversification (based on weather conditions). The second recommendation is to provide policymakers with an understanding of how to ensure their economic stability during this period, such as establishing a social security fund through insurance and credit. This recommendation can help fishermen to maintain their purchasing power and avoid becoming indebted to capital owners. Other research recommendations that need to be explored in the continuation of this study are fishermen's adaptation strategies in the face of extreme weather that can be done by minimizing its impact. Adaptation strategies can be tailored to the needs, capabilities, and interests of small-scale fishers in coastal areas, such as environmental adaptation, optimizing various government support programs, and improving patron-client relationships and interaction patterns. These adaptation strategies are necessary to meet the challenges and opportunities posed by the adverse impacts of environmental change in coastal areas.

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Authors' Contributions

The contribution of each author is as follows: Rahim conducted the research and wrote the articles (Introduction, Materials and Methods, Results and Discussion, Conclusion); Malik translated the articles and proofread; Hastuti conducted the research and data analysis.

Conflict of Interest

The authors declare that this research was conducted without any potential conflicts of interest.

Declaration of Artificial Intelligence (AI)

The author acknowledges using an AI such as Grammarly to improve all grammar in this article, from the Abstract, Introduction, Materials and Methods, Results, and Discussion to a Conclusion. All AI-generated content was rigorously reviewed, edited, and validated to ensure accuracy and authenticity. Turnitin is also used to reduce high plagiarism rates. Full responsibility for the final content of the manuscript rests with the authors. A comprehensive description of the tool's application was tailored to the publisher's ethical guidelines to ensure transparency and support the review process.

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