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RESEARCH PAPER

Impact of Extreme Weather Events Due to Climate Change on Household Economic Change and Adaptation Decisions of Small-scale Fishers in Coastal Areas

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Abstract

Extreme weather events can influence the household economy and adaptation decisions of small-scale fishers in coastal regions. This study investigates the determinants affecting household income, consumption spending, and fisher adaptation strategies in reaction to unfavorable weather circumstances. The sample of respondents comprised 288 fisher households. We employed the ordinary least squares method as the analytical technique to ascertain household income and consumption expenditure. We assessed the adaptive choice responses of fishers using logistic model estimation. The findings indicate that regional dummy disparities among fishing communities during the fishing season and extreme weather events influence the income variability of fisher households. Conversely, household income is unaffected by the quantity of employed family members or the age of the household head. Conversely, regional disparities and household income influence the variability of household consumption spending during the fishing season, in contrast to instances where geographical variances solely account for extreme weather events. The fishermen's income, fishing experience, and formal education influence their capacity to adjust to adverse weather events. Economic, social, and environmental adaptation strategy measures can be implemented. Furthermore, government support initiatives include insurance, credit, and patron-client relationship dynamics.

Introduction

Severe and extreme weather incidents are becoming more frequent because of global climate change (Forster et al., 2022; Ilarri et al., 2022; Sreya et al., 2021). Fishermen operating on a small scale in coastal areas are some of the most susceptible to climate change. Climate variability may jeopardize small-scale fisheries, affecting fisheries resources, fishermen's livelihoods, fish stock variations, and production value per fisher (N'Souvi et al., 2024). Selvaraj et al. (2023) have constrained their range and operational capacity in open waters. Besides offering consistent revenue (Steenbergen et al., 2019a), marine fisheries are also closely linked to employment (Marín-Monroy & Ojeda-Ruiz de la Peña, 2016a). Extreme weather severely affects the food security of small-scale fishermen (Galappaththi et al., 2021).

Their survival highly depends on the catch and profit margins (Ruiz-Jarabo et al., 2022). Because of this, small-scale fishermen have limited options regarding where to fish in marine waters (Erauskin-Extramiana et al., 2023). Fishermen are scared to go to the sea because of high waves, more rainfall, and extremely high wind speeds (Maltby et al., 2021). Fish migration networks are altered by extreme weather events, which also decrease the number and quality of economically fished fish stocks (Diouf et al., 2020; Mozumder et al., 2023; Samah et al., 2019). The family economy will be impacted by changes in the catch and fisheries performance of both large-scale and small-scale sectors (Belhabib et al., 2018). Family economics, or household economics, refers to household income (Hastuti et al., 2022; Jones et al., 2022) and household consumption expenditure (Oladimeji et al., 2015).

Amidst inclement weather, small-scale fishing villages in Barru Regency, Indonesia, persist in coastal fishing activities. Nonetheless, it presents a significant threat to their safety. To sustain their households, fishermen in coastal areas continue participating in short-term fishing activities near the shore or on land. In specific locations, fishermen venture into the open sea to escape the moderate waves, which nearby tiny islands along the shore mitigate. Elevated sea levels result in tidal flooding in coastal regions despite the islands functioning as barriers that can reduce wave height.

The coastal region of the West Coast adjoins the waters of the Sulawesi Strait in Barru Regency, Indonesia, serving as a research area concentrated on global climate change, particularly extreme weather phenomena. We have observed extreme weather indicators; over the past three years, rising sea levels have caused tidal floods in the research region. Based on the Meteorology, Climatology, and Geophysics Agency (MCGA) or BMKG Makassar (2024)**,** this event is triggered by rising sea waves reaching heights of 1 to 2 meters, together with wind speeds of 4 to 5 knots, with winds blowing from the east to southeast and from southeast to southwest. This occurs in the Sulawesi Strait waters that directly adjoin Barru Regency's coastal region, specifically from June 2024 to August 2024**.** The Intergovernmental Panel on Climate Change (IPCC) reports that sea levels worldwide are increasing by 3.2 mm annually (Shaffril et al., 2017a). This occurrence is a global climate change that leads to severe weather conditions. This situation will significantly impact the economy, society, and environment (Muringai et al., 2022).

Globally, extreme weather also occurs in coastal areas directly adjacent to sea waters in various parts of the world, such as the West Arabian Sea of India (Koya et al., 2017), the Pacific Islands Sea (Hanich et al., 2018), the Ghana Sea (Mabe & Asase, 2020), the Portuguese Sea (Ilarri et al., 2022), the East Coast of Peninsular Malaysia (Samah et al., 2019) the Coastal Region of Bangladesh (Jakariya et al., 2020), the Coast of Senegal (Diouf et al., 2020), the Coast of South India (Sreya et al., 2021), and the Coastal and Marine Region of China (Cai et al., 2021), the Caribbean Coast of Dominica (Forster et al., 2022). Coastal areas are small spaces associated with significant human, economic, and environmental interests and multiple vulnerabilities to climate change (Lemée et al., 2019). Coastal areas offer various resources to diversify livelihoods, but climate change reduces these options (Savo et al., 2017).

Extreme weather events are a serious issue (Gallicchio, 2017). Extreme weather conditions affect household finances, fishermen's decisions, and their ability to adapt to coastal locations. To prepare for future shocks, fishermen's decision-making can offer chances for adaptation and implementing local remedies (Lopez-Ercilla et al., 2021). Small-scale fishermen must implement effective adaptation to deal with obstacles, seize opportunities, and combat the effects of climate change in coastal regions. One crucial tactic to lessen the adverse effects of climate change on the fishing industry is adaptation. Fishermen's adaptive behavior is impacted by climate change (Begum et al., 2022). The adverse effects of environmental change and appropriate action by seizing opportunities are two ways to define adaptation to climate change (Shaffril et al., 2019). According to 'Souvi et al. (2024), adaptation is a crucial tactic to lessen the detrimental effects of climate change on fisheries, while (Le Bras et al., 2024) suggest that adaptation is a survival strategy based on behavioral changes in response to environmental changes. Adaptation also involves deciding how to react to demands from environmental changes to lessen any future dangers. Resilience and vulnerability reduction are the objectives. Climate change adaptation can improve the food security of fishing households (Rahman et al., 2022)

For numerous years, scientists and politicians have prioritized adaptation to climate change as a significant global issue in economic development strategies (Mbaye et al., 2023a). Climate adaptation policies in the fishing industry (Szmkowiak & Steinkruger, 2023) can mitigate poverty (Kalikoski et al., 2018). Adaptation is crucial for small-scale coastal fishers to mitigate the adverse effects of climate change (Mozumder et al., 2023). Local fishermen need to implement practical adaptations to tackle challenges, take advantage of opportunities, and mitigate the effects of climate change in coastal regions. Consequently, small-scale fishermen in the research area have opted to adapt by fishing to sustain their households. The home economy consists of income from non-catch and catch sources and consumer expenditures on food and non-food products. The economic conduct of fishermen who produce work or business productivity through alterations in economic attitudes or actions is termed household economic modifications (Mukherjee, 2021). Small-scale fisheries require targeted support to fulfill their household financial obligations (Ali et al., 2023; Rahim et al., 2024; Rahim & Hastuti, 2023)

This research is vital due to the necessity of comprehending the impact of extreme weather events induced by global climate change on household economic transitions and the adaptation choices of small-scale fishers in coastal areas. The Sustainable Development Goals (SDGs) aim to enhance the welfare of coastal communities by eradicating poverty through sustainable marine economic development (Croft et al., 2024) and the Blue Economy (Schutter et al., 2024). Approximately 90% of small-scale fishers worldwide contribute to food security (Ayisi et al., 2023). In addition, small-scale fisheries are increasingly part of domestic and international market chains (Steenbergen et al., 2019b) (Steenbergen et al., 2019). They are closely linked to employment (Marín-Monroy & Ojeda-Ruiz de la Peña, 2016b). This will provide a future challenge for achieving sustainable marine development in coastal nations and can serve as a reference for policymakers in formulating scientific papers and international policies. The level of proficiency and confidence in managing hazards may provide critical insights into how individuals, mainly small-scale fishers, can adjust to the impacts of climate change in the future.

Several researchers in other countries have studied changes in the economic behavior of fishermen during extreme weather events caused by climate change, such as the vulnerability of coastal fishing households to climate change in India (Koya et al., 2017) and climate change adaptation carried out by fishermen in Asia (Shaffril et al., 2019), climate change adaptation strategies and fishing capacity of traditional fishermen along the Volta Basin in Ghana (Mabe & Asase, 2020), factors influencing fishermen's adaptation to extreme weather in Malaysia (Samah et al., 2019), assessment of marine climate drivers, risks and adaptation in coastal and marine zones of China (Cai et al., 2021), livelihood vulnerability of coastal fishing communities in Bangladesh (Jakariya et al., 2020), the economic vulnerability of fishermen's households to extreme weather events in South India (Sreya et al., 2021), social, economic and ecological adaptation strategies of small-scale Hilsa fishermen in coastal Bangladesh in response to climate change impacts (Mozumder et al., 2023), impacts of climate change on catches and adaptation practices of fishermen in coastal areas of Togo (N'Souvi et al., 2024), Transition and adaptation of fishermen in coastal areas of France (Le Bras et al., 2024)

However, to the best of the researcher's knowledge, research on the impact of extreme weather due to global climate change on household economic changes and adaptation decision responses of small-scale fishermen has never been conducted. This study aims to estimate the determinants of changes in fishermen's household income during extreme fishing seasons and weather conditions. Likewise, the second objective is to estimate the determinants of changes in household consumption expenditure, and the third is to assess how fishermen's adaptation decision responses are formed in extreme weather conditions.

Materials and Methods

The study was conducted in the western coastal area of Barru Regency, which borders the Sulawesi Strait directly. The data collection phase took place from July 2024 to October 2024. The selected sample area was Mallusettasi District, identified through purposive sampling because of its prominence in the number of small-scale fishing households compared to neighboring coastal districts, such as Tanete Rilau, Barru, Soppeng Riaja, and Balusu (BPS Kabupaten Barru, 2022). This study utilizes cross-sectional data. The sample size was comprised of 288 fishing families, determined using the Slovin formula with a margin of error of 5% (Equation 1). The sample was drawn from 1,024 fishing households (Barru, 2023). Among the 288 fishing households, 39 were located in Palanro Village, 50 in Cilelalng Village, 72 in Mallawa Village, and 127 in Kupa Village.

$$n= \frac{N}{1+Ne^2} = \frac{1024}{1+1024(5\%)^2} =288 \qquad (1)$$

Where n is the number of samples. N is the population size. 1 is a constant. e^2 is the estimated error rate (5%). The research data about the correlation between variables was processed and evaluated utilizing IBM's Statistical Package for the Social Sciences (SPSS) version 21.

Determinants of Small-scale Fishermen's Household Income

Utilizing the agricultural household model theory (Singh et al., 1986) to analyze fishing household income. For any production cycle, the household is assumed to maximize a utility function:

$$U=U(X_a, X_m, X_1,) \qquad (2)$$

Where the commodities are an agricultural staple (X_a), a market purchased good (X_m), and leisure (X_1). Utility is maximized subject to a cash income constraint:

$$p_m X_m=Y^*=P_a (Q-X_a)-w(L-F) \qquad (3)$$

Where p_m and P_a are the prices of the market-purchased commodity and the staple, respectively, Q is the household's production of the staple (so that $Q - X_a$, is its marketed surplus), w is the market wage, L is total labor input, and F is family labor input (so that $L - F$, if positive, is hired labor and, if negative, off-farm labor supply).

The household also faces a time constraint-it cannot allocate more time to leisure, on-farm production, or off-farm employment than the total time available to the household:

$$X_i+F=T \qquad (4)$$

Where T is the total stock of household time. It also faces a production constraint or production technology that depicts the relation between inputs and output:

$$Q=Q(L,A) \qquad (5)$$

Where A is the household's fixed quantity of land

The three constraints on household behavior can be collapsed into a single constraint. Substituting the production constraint into the cash income constraint for Q and substituting the time constraint into the cash income constraint for F yields a single constraint of the form.

$$p_m X_m = P_a X_a + wXj = wT + \pi \quad (6)$$

Where $\pi = P_a Q(L,A) - wL$ and is a measure of farm profits.

The agricultural household model hypothesis says that each household can maximize utility (Equation 2) within several constraints, such as income and commodity prices (Equation 3), production or production technology (Equation 5), and time (Equation 6). Small-scale fishing households can find the best way to maximize the utility function. However, they have to deal with several constraints or limitations, such as limited household income (from fishing and non-fishing businesses), time spent at sea, and the productivity of the catch or fishing technology.

The first research objective is to analyze the determinants of changes in household income of fishermen during the fishing season and extreme weather using the ordinary least square (OLS) method (Gujarati & Porter, 2009) as follows:

$$\pi HFFS = \beta_0 + \beta_1 AgHH + \beta_2 QFMW + \delta_1 dKpV + \delta_2 dCllngV + \delta_3 dPlnrV + \mu_1 \quad (7)$$

$$\pi HFEW = \beta_3 + \beta_4 AgHH + \beta_5 QFMW + \delta_4 DKpV + \delta_5 dCllngV + \delta_6 dMllwV + \mu_2 \quad (8)$$

Where $\pi RTNMPI$ is the income of small-scale fishing households during the fishing season (IDR). $\pi RTNCE$ is the income of small-scale fishing households during extreme weather conditions (IDR). β_0, β_3 are constants. $\beta_1, \beta_2, \beta_3, \beta_4$ are regression coefficients of independent variables. $\delta_1, \ldots, \delta_6$ are regression coefficients of dummy variables. $AgHH$ is the age of the household head (years). $QFMW$ Is the number of family members working (people). Regional difference dummy, $dKpV$ is 1 for the Kupa village fishing area and 0 for others. $dCllngV$ is 1 for the Cilellang village fishing area and 0 for others. $dPlnrV$ is 1 for the Palanro village fishing area and 0 for others. Mallawa village as a control variable during the fishing season and Cilellang village as a control variable during the fishing season μ_1, μ_2 are disturbance errors.

Determinants of Household Consumption Expenditure of Fishermen

Household consumption expenditure employs the consumption theory model (Keynes, 1936). Keynes posited that the propensity to consume denotes the correlation between the anticipated income of the community allocated for expenditure and consumption, contingent upon the psychological traits of the community. The propensity to spend is a functional connection between Yw (a certain income level in wage units) and Cw (consumption expenditure derived from that income level). Consequently, the consumption function can be articulated as follows:

$$Cw = (Yw) \text{ or } C = W(Yw) \quad (9)$$

The tendency to consume is a consistent function, indicating that the total consumption level is determined by the total income level (both quantified in wage units). The economy is presumed to be in a standard condition, with alterations in propensity seen as secondary influences on requirements.

Household consumption spending employs the consumption function methodology derived from life cycle theory (Dornbusch & Fischer, 1990), which can be expressed as follows:

$$C = aWR + bY \quad (10)$$

Where C is consumption, and a is the marginal consumption propensity of wealth. WR is real wealth. b is the marginal consumption propensity of labor income. Y is labor income.

Dornbusch and fisher contend that labor income differs from revenue generated by other production elements, such as rental income from land or profits derived from capital. The life cycle theory also offers a mechanism for equity markets to affect consumption patterns. The value of publicly traded equities constitutes a component of wealth and is incorporated in WR in Equation (10). When stock values are elevated, indicating a flourishing equities market, the high wealth ratio (WR) typically stimulates increased expenditure. The converse transpires when equities markets are subdued.

The consumption theory model states that total consumption is related to total labor income (equation 9). In the life cycle theory, marginal consumption expenditure is derived from labor income (equation 10). The economic behavior of small-scale fishing households, including household consumption expenditure on food and non-food items, is greatly influenced by income earned from fishing and non-fishing activities. The fishing industry earns income from fishing and non-fishing labor from wives and family members.

Concerning the second study objective, specifically the factors influencing household consumption expenditure of small-scale fishers, the ordinary least squares (OLS) approach (Gujarati & Porter, 2009) is employed as follows:

$$CExHFS = \beta_6 + \beta_7 \pi HFFS + \beta_8 WfEdu + \beta_9 QFCM + \delta_7 dKpV + \delta_8 dCllngV + \delta_9 dPlnrV + \mu_3 \quad (11)$$

$$CExHEW = \beta_{10} + \beta_{11} \pi HFEW + \beta_{12} WfEdu + \beta_{13} QFCM + \delta_{10} dKpV + \delta_{11} dCllngV + \delta_{12} dMllwV + \mu_4 \quad (12)$$

Where $CExHFS$ is the consumption expenditure of small-scale fishing households during the fishing season (IDR). $CExHEW$ is the consumption expenditure of small-scale fishing households during extreme weather conditions (IDR). β_6, β_{10} are intercepts/constants. $\beta_7, \ldots, \beta_9, \beta_{11}, \ldots, \beta_{13}$ are regression coefficients of independent variables. $\delta_9, \ldots, \delta_{12}$ are regression coefficients of dummy variables. WfEdu is the wife's education (year). QFCM is the number of family members covered (persons). μ_3, μ_4 are disturbance errors.

Adaptation Decision Responses of Small-scale Fishermen

The probability of adaptation decisions as small-scale fishermen is formed in extreme weather conditions using the Logistic regression model approach with the Maximum Likelihood Estimation (MLE) method (Pampel, 2000) as follows:

$$P_i=F(Z_i)=(\beta_0+\beta_0 X_i)=1/(1+e^{-Z_i})=1/(1+e^{-(\beta 0+\beta 1 X i)}) \quad (13)$$

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:

$$(1+ e^{-Zi})Pi=1 \quad (14)$$

The above equation will result in the following equation:

$$\frac{e^{-Zi}\,Pi}{(1-Pi)/Pi} \quad (15)$$

The above equation can be converted into the following equation model:

$$Z_i= \frac{Pi}{1-Pi} =\beta_0+\beta_i X_i \quad (16)$$

Equation (16) can be used to analyze the response of small-scale fishermen's adaptation decisions during extreme weather using the logistic distribution function analysis with the MLE method as the third research objective as follows:

$$AdptDcEW = P_i/(1- P_i) = \beta_{14}+\beta_{15}\pi FBEW + \beta_{16}FsExp + \beta_{17}FFEdu + \delta_{13}dKpV + \delta_{14}dCllngV + \delta_{15}dMllwV + \mu_5 \quad (17)$$

Where $AdptDcEW=P_i/(1- P_i)$ is the chance or probability of fishermen's adaptation decision during extreme weather (1 for adaptation and 0 for others). β_{14} is the intercept/ constant. β_{15}, β_{16} are the regression coefficients of the independent variables. $\delta_{14}, \ldots, \delta_{16}$ are the regression coefficients of the dummy variables. $\pi FBEW$ is fishing business income (IDR). FsExp is fishing experience (years). FFEdu is the fishermen's formal education (years). Palanro Village is a control variable. μ_5 is the disturbance error.

Result and Discussion

Socio-economic Conditions of Fishing Households

Small-scale fishing communities require socio-economic instruments to adjust to extreme weather resulting from climate change (Hanich et al., 2018). The socio-economic conditions of fishermen in the study region encompass the age of the family head, the formal education level of the fisherman's spouse, the number of employed family members, and the number of

Table 1. Social Conditions of Small-Scale Fishermen in Coastal Areas

Variable	Description	Frequency	Percent (%)
Age of Family Head	25 – 35	37	12.85
(year)	36 – 46	65	22.57
	47 – 57	96	33.33
	58 – 68	71	24.65
	> 69	19	6.60
Total		288	100.00
Fishermen's wife education	Not completed primary school	23	7.99
(year)	Elementary School (ES)	99	34.37
	Junior High School (JHS)	120	41.67
	Senior High School (SHS)	46	15.97
Total		288	100.00
Family members who work	None	112	38.89
(person)	1	87	30.28
	2	66	22.91
	3	23	7.92
Total		288	100.00
Family members covered	1 – 2	132	45.83
(person)	3 – 4	107	37.15
	5 – 6	49	17.02
Total		208	100.00

dependents supported by the family head (Table 1). Social and economic issues influence the economic behavior of individuals, particularly within the family economy of fishers. Social and economic aspects are crucial in poverty alleviation (Islam et al., 2011) and influence the welfare level of fishermen's households (Al-Jabri et al., 2013; Malik et al., 2024). Fishermen's economic diversification tactics as a livelihood are influenced by social elements, such as education and maritime experience, as well as economic aspects, including fishing income (Marín-Monroy & Ojeda-Ruiz de la Peña, 2016). Social and economic factors, including income, shape the conduct of fishermen (Eliasen et al., 2014). Fishing activities result in income levels (Al-Jabri et al., 2013) during the fishing season and severe weather conditions.

Global climate change affects the social dimensions of fishers (Shaffril et al., 2017). The social situation of fishermen, such as the age of the household head, the size of the family, and the level of education of the fisherman's spouse, can affect changes in the household economy, precisely income and spending, during the fishing season and extreme weather events. It can also affect the ways that fishermen adapt to these conditions.

The education level of fishermen's wives greatly impacts handling household finances for food and non-food expenses, particularly during adverse weather conditions. Additionally, due to the large size of the fishermen's families, the wife's skills are crucial in handling household finances, including income and expenses. Coastal fishermen in the examined region continue fishing to fulfill their household economic needs, participating in activities close to the beach and occasionally traveling deeper waters. The fisherman's age is a crucial determinant in adaptation decisions to harsh weather circumstances. Productive individuals will demonstrate enhanced decisiveness. This demography has considerable potential to clarify small-scale fishers' adaptability to the impacts of climate change.

The household economy comprises household income and household consumption spending. Income from fishing and non-fishing enterprises constitutes household income. Household consumption expenditure includes food and non-food consumption. The fishing industry and the household income of small-scale fishermen are significantly influenced by seasonal conditions, as is household consumer expenditure. Variations in catch production attributable to seasonal fluctuations would consequently affect fishing business revenue, household income, and household expenditures. Insufficient income from fishing enterprises may signify poverty within the marine fisheries industry (Teh et al., 2020). The income from the fishing industry is crucial for evaluating the contribution of fisheries to the livelihoods of fishermen worldwide and over time (Purcell et al., 2018). Revenue from the fishing sector can reflect fishermen's decision-making (Bisack & Clay, 2020) and sustainable fisheries management (Robotham et al., 2019).

In the sampled villages—Kupa, Mallawa, Cilellang, and Palanro—average income from fishing businesses, household income, and household consumption expenditure were elevated during the fishing season compared to periods of extreme weather events (Table 2). In Kupa and Cilellang, fishermen's enterprises and household incomes exceeded those in Mallawa and Palanro during the fishing season. Conversely, during severe weather, fishermen in Mallawa and Palanro saw more fishing business and household revenues than those in Kupa and Cilellang (Table 2). Extreme weather significantly affects the long-term income of people dependent on fishing as their main livelihood, as demonstrated by instances in Kenya (Thoya & Daw, 2019).

Table 2 demonstrates that Palanro and Mallawa Villages fishermen continue to fish despite adverse weather conditions to meet their household economic needs. The sea waves are often mild owing to *Dutungan* Island, a small landform that is a natural barrier against strong winds and currents. This island reduces wave height, yet the area still experiences tidal flooding from increased saltwater levels. Each year, all coastal areas adjacent to the west coast of Barru Regency or the Sulawesi Strait encounter tidal inundations.

The fishing season lasts from March to August. In adverse weather circumstances, fishermen from Kupa and Cilellang Villages, situated along the western shore of Barru Regency, halt fishing operations due to strong winds and increased wave heights. Fishermen report that the harsh weather period, known as the "lean

Table 2. Household economic conditions of small-scale fishers during fishing season and extreme weather events

Village	Fishing Season			Extreme Weather		
	Capture Business Income (IDR/trip)	Household Income (IDR/ month)	Household Consumption Expenditure (IDR/month)	Capture Business Income (IDR/trip)	Household Income (IDR/ month)	Household Consumption Expenditure (IDR/month)
Kupa	432,472.44	10,203,417.32	3,204,850.00	335,661.41	7,960,267.71	3,023,669.00
Mallawa	309,034.72	7,380,722.22	2,456,160.00	381,902.78	9,020,166.67	2,662,379.00
Cilellang	411,960.00	9,941,920.00	2,146,730.00	325,960.00	7,869,920.00	1,910,730.00
Palanro	313,346.15	8,257,282.05	2,338,462.00	397,961.53	10,329,076.92	2,530,769.00
Average	366,703.32	8,945,835.40	2,536,550.50	360,371.43	8,794,857.82	2,531,886.75

US$ 1 (IDR 16,350)

season" or "wet season," lasts from September to February. Similar conditions are observed among fishermen in Brixham, England (Maltby et al., 2021). Fishermen in Kupa and Mallawa Villages endure severe weather conditions for seven months, from October to April. Conversely, fishermen in Cilellang Village endure severe weather for six months (September–February), whereas those in Mallawa Village face it for four months (December–March). The main species caught during this time are yellowtail tuna and skipjack tuna, which have significant economic worth. The fishing apparatus comprises trolling rods (*ulur*) and trawls (*tasi' nets*).

Determinants of Household Income of Fishermen

The VIF (variance inflation factor) method tests for multicollinearity and examines the factors affecting small-scale fishers' household income. Multicollinearity denotes a correlation among independent variables inside the model (Gujarati & Porter, 2009). A VIF value below 10 indicates the absence of multicollinearity or multiple collinearity (Table 3). The R^2 statistic, also known as the "goodness of fit measure," shows how much of the variation in the dependent variable can be explained by the independent variables and how much can be explained by factors that have not been considered (Gujarati & Porter, 2009). This research shows that household income explains 70.2% of the changes in the independent variables (age of head of household, number of family members, and dummy differences in fishermen's residential locations) during the fishing season and 61.1% during lousy weather. The remaining 28.9% and 39.9% are attributable to parameters excluded from the model (Table 3).

Household income consists of both fishing and non-fishing earnings. Palanro Village exhibits the highest fishing household income during adverse weather events compared to Mallawa, Kupa, and Cilellang villages. The substantial income from fishing (Table 1) and supplementary earnings from family members, including fishermen's spouses, contribute to this. Moreover, during the fishing season, Kupa Village exhibits the most significant household income compared to other villages, including Cilellang, Palanro, and Mallawa. Family members, particularly the spouses of fishermen, augment non-fishing income. Regardless of the fishing season or adverse weather conditions, the income generated by wives through non-fishing activities, including small and medium enterprises (MSMEs), fish sales, motorcycle taxi services, or nursing at health centers, bolsters household economies.

The household income is affected by the dummy variable that shows differences in the locations of communities where small-scale fishermen live during the fishing season and extreme weather (Table 3). Dummy variables facilitate variations in slope and intercept among people in the regression estimation technique (Gujarati & Porter, 2009). The regional differences pertain to Kupa, Cilellang, and Palanro Villages. Mallawa Village functions as the independent variable in this research. The study uncovers regional variations in household income among the variables. Kupa, Cilellang, and Palanro Villages significantly enhance the income of fishermen's households throughout the fishing season. The Kupa and Cilellang Village dummies demonstrate an error rate of 1%, which aligns with a confidence level of 99%.

Statistically, a 1% variation in residential location for fishermen will influence the rise in household income by 0.340 in Kupa Village, 0.332 in Cilellang Village, and 0.412 in Palanro Village. Table 3 employs Mallawa Village as the control variable. The data indicates that the monthly average household income of fishermen's families in Cilellang Village is IDR 9.9 million, surpassing the income of fishermen in Palanro Village at IDR 8.2 million and Mallawa Village at IDR 7.3 million (Table 2). Kupa Village endures the most severe effects during inclement weather relative to the neighboring village. The mean monthly income of fishermen's households in Kupa Village is IDR 7.9 million, which is inferior to that of fishermen in Mallawa Village at IDR 9 million and Palanro Village at IDR 10.3 million (Table 2). Both communities possess a margin of error of 1% or a confidence interval of 99% (Table 3).

Table 3. Analysis of Household Income Determinants of Fishermen in Fishing Season and Extreme Weather

Independent Variables	ES	Fishing Season				Extreme Weather			
		Coeff.	Std. Error	Sig.	VIF	Coeff.	Std. Error	Sig.	VIF
Age of household head	+	-0.018^{ns}	0.071	0.802	1.194	0.046^{ns}	0.089	0.603	1.194
Working family members	+	0.008^{ns}	0.022	0.716	1.205	-0.004^{ns}	0.027	0.896	1.205
Dummy of Kupa Village	+	0.340***	0.044	0.000	1.568	-1.413***	0.054	0.000	1.568
Dummy of Mallawa Village	+	–	–	–	–	-0.154**	0.067	0.024	–
Dummy of Cilellang Village	+	0.332***	0.054	0.000	1.408	–	–	–	1.408
Dummy of Palanro Village	+	0.142**	0.059	0.016	1.346	-0.131**	0.073	0.017	1.346
Intercept		15.816***		0.000		15.793***		0.000	
R^2					0.702				0.611
n					288				288

*** is a level error significance of 1% (0.01) or a confidence level of 99%. ** is a level error significance of 5% (0.05) or a confidence level of 95%. ^{ns} is not significant. ES is an expectation sign. If VIF < 10, there was no multicollinearity, but if VIF > 10, there was a multicollinearity. Fishing Season (Mallawa Village dummy as a control variable). Extreme Weather (Cilellang Village dummy as a control variable).

In comparison, the Palanro Village dummy demonstrates an error rate of 5%, equivalent to a confidence level of 95% (Table 3). The results indicate that the income of fishermen's households in Kupa Village surpasses that of the control village, Mallawa Village. Similarly, Cillellang and Palanro communities surpass their comparative communities. This situation aligns with field data, indicating that the income from fishing efforts in Kupa Village is IDR 432 thousand per trip, exceeding that of fishermen in Mallawa Village, which is IDR 309 thousand each trip. Similarly, the earnings from fishing endeavors in Cilellang and Palanro Villages are IDR 411 thousand and IDR 313 thousand for each trip, respectively (Table 2)

Nonetheless, substantial variances arise during extreme weather. The dummy variables in the Kupa, Mallawa, and Palanro Village zones adversely affect the income of fishermen's households (Table 3). Kupa Village achieved a 1% error rate (99% confidence), while Mallawa and Palanro Villages earned a 5% error rate (95% confidence), respectively. Every region inhabited by fishermen possesses distinct characteristics. A 1% rise in regional disparities will influence the drop in family income among fishermen in the various areas: Kupa Village by 1.413, Mallawa Village by 0.154, Palanro Village by 0.340, Cilellang Village by 0.332, and Palanro Village again by 0.131. Cilellang Village is this study's control variable (Table 3). The results demonstrate that the household income of fishermen in Cilellang Village, as a control variable, is inferior to that of fishermen in Mallawa and Palanro Villages (Table 2). Likewise, the cash generated from fishing operations can alter household earnings. This condition corresponds with the findings of Thoya & Daw (2019) in Kenya, demonstrating that severe weather conditions impact the income of fishermen's households obtained from marine fish captures.

Coastal regions have access to natural resources, including plentiful marine fish. Coastal areas also offer diverse natural resources on land, which differ according to the specific characteristics of each place. The area along the coast next to Mallawa Village has good land for farming. This lets the locals grow food, like rice, and plants, like vegetables, which increases the income of the fishermen's homes used as research samples. In contrast to the coastal region of Cilellang Village, the terrain is barren, limiting options for fishermen to diversify their non-fishing revenue sources. The revenue of fishermen's households in Mallawa Village surpasses that of Cilellang Village (Table 2). The coastal region of Kupa Village benefits from proximity to market access points, including the Fish Auction Place (FAP) and the fish landing facility (FLF). Traders from Pare-pare City visit fishermen in Kupa Village to purchase their catch. The distance from Pare-Pare City to Kupa Village, Barru Regency, is about 20 kilometers, attainable in 30 minutes. Furthermore, intermediary traders furnish market data and price lists for fish fishermen's favor. Compared to Palanro Village, the distance from Pare-Pare City is considerable, resulting in fishermen selling their catches locally at reduced prices. The income of fishermen in Kupa Village is lower than that of fishermen in Palanro Village (Table 2). This circumstance impacts the economic stability of fishermen's households.

On the other hand, the age of the head of the household, in this case, the fisherman, and the number of working family members do not affect household income. Age does not affect household income because there is an average unproductive age of >69 years, as many as 19 people or 6.60% (Table 1), but still fishing. Age is significant in identifying a person's status and role in society and understanding specific issues (Ali et al., 2023) —however, their productivity declines as fishermen age, as fishing requires physical strength and stamina. Changes in age have a notable effect on fishing choices (Liao et al., 2019). Although they are relatively old, they have more experience at sea. Young fishers have a greater chance of making significant catches than older fishers due to their higher productivity. Most fishermen are still young, aged 25-46, with 102 or 35.42% (Table 1). In Taiwan, fishermen over 40 contribute significantly to household income through fishing (Lu et al., 2020).

Moreover, the quantity of employed family members does not influence household income, as evidenced by the 112 (38.89%) fishing homes with non-working family members (Table 1). Family members who are unemployed or have minimal involvement in fishing or other income-generating activities adversely affect the home economy. Relative to the quantity of employed family members, it has ramifications for supplementary revenue sources. Coastal fishing households depend solely on their husbands, who are fishermen, as the primary providers based on the fishing yields from the sea. Fishermen acknowledge the critical responsibility of caring for their partners and many children. This result corresponds with the study by Tikadar et al. (2022) in the Northeastern region of Bangladesh, indicating that family size does not influence the income of fishing households.

Determinants of Household Consumption Expenditure of Fishermen

We utilize the VIF method for multicollinearity assessment to evaluate the determinants of household consumption spending among small-scale fishers. The VIF technique test indicated the absence of multicollinearity, as the VIF value was below 10 (Table 4). The R^2 statistic suggests that household income, the educational attainment of the fisherman's spouse, family size, and the geographical difference dummy account for 65.6% of household expenditures during the fishing season and 64.7% during extreme weather conditions. The residual contributions from other unmodeled components are 34.4% and 35.3%, respectively (Table 4).

During the fishing season, the household expenditure on food and non-food goods for small-scale fishermen is influenced by their household income, with a 10% margin of error, signifying that each IDR 1 gain in family income leads to a rise of IDR 0.146 in consumption expenditure. Nonetheless, under extreme weather conditions, their expenditures stay constant (Table 4). This finding corresponds with research by Ayisi et al. (2023) in Ghana, demonstrating that income affects household consumption expenditure. During the fishing season and adverse weather conditions, small-scale fishermen's average household consumption expenditure throughout the four research sites remains consistently IDR 2.5 million monthly (Table 2). However, the variation is contingent upon the particular type of objects desired. The categories of primary products encompass food items like rice, accompaniments, cooking oil, and cigarettes. Secondary products include non-food things such as education, electricity, PDAM water, healthcare, and fishing essentials (fuel and bait). Economic variables, including income, influence household behavior in determining consumption expenditures for both food and non-food goods.

This finding contrasts with those from other countries. In Bangladesh, household income positively affects household consumption expenditure among fishers in coastal areas (Khan et al., 2012). Similarly, in West Africa, fishers' household consumption expenditure increases as their income rises due to productive fishing (Weigel et al., 2018). The results of this study align with those of (Marimuthu et al., 2015) in India, who found that income can increase the percentage reduction in consumption.

The wife's education does not influence household consumption expenditure throughout the fishing season or adverse weather circumstances. The wife's formal education is predominantly at the junior high school level, including 120 individuals or 41.67%, with an additional 23 fishermen's spouses, representing 7.99%, having not completed any schooling (Table 1). The wife's formal education influences her perspective. Nonetheless, this scenario continues empowering the wife to oversee and regulate her family economy, including consumption expenditures (food and non-food items). The inadequate formal education of women in the fisheries industry would influence decision-making about the family's economic sustenance, as observed in Sierra Leone, West Africa (Olapade & Sesay, 2019). The influence of formal education on women's decision-making power to enhance work quality is significant (Dhanaraj & Mahambare, 2019).

The number of family members supported does not affect household consumption expenditure. The family head sustains 5-6 persons or 49 fishing households (Table 1). This syndrome originates from substantial social factors inside lasting familial relationships. When a fisherman is unsuccessful in catching fish, other proficient fishermen aid their families in securing sustenance during the fishing season and adverse weather conditions. The consumption patterns of small-scale coastal fishing households vary. They devote most of their income to food consumption instead of non-food expenditures. Rice, vegetables, and cigarettes constitute most of their dietary intake, whereas fuel oil, children's education, and spouse jewelry predominantly define their non-dietary expenditures.

The regional inequality dummy is the principal factor influencing household consumption expenditure, as seen by Cilellang Village in Table 4. Cilellang Village negatively affects household consumption spending during the fishing season. Statistics indicate that a 1% increase in regional inequalities in Cilellang Village correlates with a 0.281 decrease in household expenditures for fishermen throughout the fishing season. The error margin is 1%, indicating that the results are 99% accurate. Palanro Village and Kupa Village achieved 5% and 10% error rates, respectively (Table 4). Household consumption expenditures stem from spending on both food and non-food goods. Household consumption expenditure exhibits

Table 4. Analysis of Household Consumption Expenditure Determinants of Fishermen in Fishing Season and Extreme Weather

Independent Variables	ES	Fishing Season				Extreme Weather			
		Coeff.	Std. Error	Sig.	VIF	Coeff.	Std. Error	Sig.	VIF
Household income	+	0.146*	0.075	0.051	1.264	0.065 ^{ns}	0.066	0.323	1.113
Wife's education	+	0.036^{ns}	0.072	0.621	1.005	0.026 ^{ns}	0.072	0.716	1.001
Covered family members	+	0.046 ^{ns}	0.048	0.347	1.005	0.034 ^{ns}	0.049	0.485	1.012
Dummy of Kupa Village	+	0,105*	0.059	0.078	1.884	-0.137*	0.055	0.064	1.585
Dummy of Mallawa Village	+	–	–	–		-0.221***	0.068	0.001	1.434
Dummy of Cilellang Village	+	-0.281***	0.072	0.000	1.591	–	–	–	
Dummy of Palanro Village	+	-0.148**	0.073	0.045	1.362	0.164***	0.074	0.003	1.358
Konstanta		12.262***		0.000		13.551***		0.000	
R^2					0.656				0.647
n					288				288

*** 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% (0,010) or confidence level 90%; ^{ns} is not significant; and ES is an expectation sign. If VIF < 10, there was no multicollinearity, but if VIF > 10, there was a multicollinearity. Fishing Season (Mallawa Village dummy as a control variable). Extreme Weather (Cilellang Village dummy as a control variable) considerable variation among distinct research regions. During the fishing season, fishermen's maximum household consumption expenditure in Kupa Village is IDR 3.2 million per month, whereas in Mallawa Village, it is IDR 2.4 million per month (Table 2). As the catch escalates, household income surges, resulting in an increase in consumption expenditure for both food and non-food goods. The food items include rice, fish, vegetables, and cooking oil. Non-consumables include gasoline, apparel, power expenses, water charges, and mobile phone credit. Outboard motors for fishing vessels, land transportation, and motorcycles use petalite gasoline.

On the other hand, when bad weather hits, regional differences (Kupa, Mallawa, and Palanro) are the only things that affect how much fishermen spend on goods and services, with a 1% error margin or 99% confidence level. The Mallawa Village dummy exerts the most substantial impact on household consumption expenditure. Also, when the weather is the same bad, the dummy factors for Mallawa Village and Kupa Village hurt the household spending of fishermen at the 1% and 10% significance levels, equal to 99% and 90% confidence levels, respectively (Table 4). This signifies that the household consumption expenditure of fishermen in Cilellang Village, as a control variable, is inferior to that of Kupa, Mallawa, and Palanro Villages.

The seaside region of Palanro Village serves as the capital of Mallusetasi District, Barru Regency, and possesses the most proximate market access relative to other coastal locations. Elevated consumption expenditure facilitates the procurement of food and non-food necessities, particularly near market access. Nonetheless, according to observations in the field, the household consumption expenditure of fishermen in Kupa Village exceeds that of other villages (Mallawa, Cilelangan) and Palanro Village (Table 2). Cultural and prestige reasons frequently dictate traditional events aimed at enhancing the status of fishermen's households in coastal regions, including weddings and folk festivals, particularly during fishing seasons and adverse weather conditions. These findings differ from small-scale fishing communities in the coastal area of North Wales, England, regarding the culture of "good fishermen" by respecting fishing equipment and maintaining safety at sea, which will form social capital that has an impact on the household economy (Gustavsson et al., 2017). For instance, the study focuses on the consumer expenditures of fishermen.

Furthermore, the disparities in coastal regions concerning the robust patron-client connection in Palanro Village are more pronounced than in other coastal places. Patron-client connections mitigate the quotidian economic challenges faced by fishermen's homes. This link can be an adaptive mechanism, particularly in adverse weather situations. The patrons' involvement in the research's coastal regions significantly benefits small-scale fishermen. In addition to facilitating funding for maritime ventures, they also get fish catches from fishermen at a fair price. Miñarro et al. (2016) assert that the patron-client system is prevalent in numerous nations within small-scale fisheries, which significantly manage exploited marine resources.

Fishermen's Adaptation Decision Responses during Extreme Weather

Small-scale fishers in coastal areas make adaptation decisions in response to extreme weather events caused by climate change to meet their household economic needs. Adaptation strategies in the fisheries sector can help alleviate poverty in coastal areas. Several factors strongly influence the ability to make effective adaptation decisions. Fishing income, fishing experience, and formal education offer greater opportunities for small-scale fishers to make adaptation decisions during extreme weather events in the study area. The probability level of each variable is ≥1 (Table 5). This enables fishermen to adapt more effectively during extreme weather, improving their household economy, income, and consumption expenditure.

Table 5. Analysis of Adaptation Decision Responses of Small-scale Fishermen during extreme weather

Independent Variable	Coefficient	Standard Error	Wald-test	Sig.	Exp.(β_i)
Fishing business income	0.000	0.000	0.236	0.627	1.000
Experience at sea	0.009	0.010	0.041	0.840	1.002
Formal education of fishers	0.032	0.052	0.389	0.533	1.033
Family dependents	-0.131	0.143	0.840	0.359	0.877
Dummy of Kupa Village	-0.674	0.363	3.458	0.063	0.509
Dummy of Mallawa Village	-0.783	0.431	3.301	0.069	0.457
Dummy of Cilellang Village	-0.338	0.474	0.509	0.476	0.713
Intercept					1.674
Nagelkerke R^2					0.032
-2 Log Likelihood					335.379
n					288

The probability is greater if the Exp(βi) ≥ 1 value. Conversely, if the value of Exp(β_i) ≤ 1, then the probability is smaller. Palanro Village dummy as a control variable.

The decision-making regarding adaptation among small-scale fishermen in coastal regions is significantly affected by the income generated from fishing per trip under severe weather conditions. Severe weather conditions exert a negligible influence on the domestic economy. The mean revenue from the fishing enterprise per excursion in the four sampled villages during the fishing season and adverse weather conditions was nearly the same, amounting to IDR 366 thousand per trip and IDR 360 thousand per trip (Table 2). During extreme weather, fishermen in Mallawa Village earned IDR 381 thousand per trip, while those in Palanro Sub-district earned IDR 387 thousand per trip when analyzed by region (village/sub-district). The revenue generated from the fishing enterprises in the two areas exceeded that of the comparative villages, specifically Kupa Village at IDR 335 thousand per trip and Cilellang Village at IDR 325 thousand per trip (Table 2). An adaptation decision is a process of modifying or reacting to environmental changes. Fishermen must use adaptation strategies to address the challenges and capitalize on opportunities climate change presents in coastal regions. Le Bras et al. (2024) say that adaptation is a way to stay alive based on changing behavior and includes a series of responses to changes in the environment and within an organism.

These findings differ from those of Mozumder et al. (2023), who reported that fishermen's adaptation strategies in the coastal areas of Bangladesh during extreme weather involve seeking alternative livelihoods, such as aquaculture, supported by access to credit. Adaptation strategies can reduce risks associated with fishing routines, strengthen social relationships in coastal communities, and increase knowledge about climate change adaptation planning (Shaffril et al., 2017).

In addition to fishing income, fishing experience and the formal education of fishermen as heads of households also contribute significantly to their ability to make adaptation decisions during extreme weather events in the study area (Table 5). The average fishing experience of small-scale fishermen ranges from 30 to 40 years, enabling them to adapt more effectively to extreme weather conditions. Fishing experience is crucial for improving fish production (Macusi et al., 2021). It also provides fishermen with valuable knowledge of the biodiversity of aquatic environments and fishing areas (Rosa et al., 2014).

Similarly, the formal education level of fishermen provides opportunities for them to make adaptation decisions. Basic education (primary, junior high, and senior high school) is prevalent in the study area, with 29 fishermen not completing primary school. However, a unique case is that of a fisherman with a bachelor's degree who also serves as the head of Kupa village. His higher education has enabled him to make more informed decisions and act as a key source of information for several groups of fishermen. He frequently provides crucial data on weather conditions relevant to fishing activities, such as sea wind speed and wave height. This finding contrasts sharply with the situation in the coastal areas of Western Kenya, where fishermen with higher levels of formal education tend to take more risks in their fishing decisions (Olale & Henson, 2012).

The study of differences between Kupa, Mallawa, and Cilellang Villages in how fishermen make adaptive decisions shows that Exp(βi) ≤1, which means the chance is decreasing (Table 5). This outcome indicates a deficiency in fishermen's tolerance to harsh weather conditions. There is a range of income from fishing businesses during extreme weather. For example, fishermen in Kupa Village make IDR 335 thousand per trip, Mallawa Village makes IDR 381 thousand per trip, and Cilellang Village makes IDR 325 thousand per trip. These amounts are less than the IDR 397 thousand per trip that fishermen in Palanro Village make, which is used as the control variable (Table 2).

The adaptation decisions of fishermen during harsh weather conditions differ across each coastal region in the research. Elevated sea levels immediately impact the coastal areas of Kupa and Mallawa Villages, leading to tidal inundations. The tidal flood phenomenon transpires when alterations in the sea surface position result from high tides that submerge the land. The high tide inundates inhabitants' settlements along the roadway from Barru Regency to Pare-Pare City, resulting from elevated sea waves. This syndrome instills fear among fishermen, deterring them from venturing into the sea to harvest fish. Nevertheless, the pressing economic demands of households have compelled fishermen to modify their fishing patterns or relocate their fishing sites. Fishing occurs in shallow seas next to coastal regions due to elevated wave activity and vigorous winds. This circumstance renders the fishermen's family economics unstable or in decline.

This varies for fishermen in Palanro and Mallawa Villages. Extreme weather directly impacts these fishermen, yet they continue to adapt by fishing in the open sea. The waves and wind are mitigated due to obstruction by a small island named "Dutungan." This circumstance causes the family economics to resemble that of the fishing season. This study contrasts with the findings of Shaffril et al. (2017) in Malaysia's coastal regions, where fishermen adjust to extreme weather by diminishing fishing activities, enhancing social connections, securing credit, and disseminating knowledge regarding climate change. Similarly, fishermen in Africa's coastal regions employ sociological and cultural adaptations, including magical-religious traditions, to embrace policy (Mbaye et al., 2023).

Research Implications for Policy

The findings of this study are expected to provide a basis for the government and stakeholders to formulate community-based adaptation policies to strengthen the resilience of small-scale fishing communities worldwide against climate change. Adapting to rapidly changing conditions is a considerable challenge in enhancing the sustainability of global small-scale fisheries systems. Climate change constitutes a major global challenge marked by uncertainty. Adaptation decisions are based on the selections made by small-scale fishermen in the research area to meet their households' economic requirements. Their survival is heavily dependent on the catch and the ensuing profits. The revenue from fishing, experience, and governmental support programs affects fishermen's resilience in adverse weather circumstances.

Adaptation is the principal approach for alleviating the detrimental impacts of climate change on the fisheries sector (N'Souvi et al., 2024), and this plan will clarify how small-scale fishermen can modify their practices in response to harsh weather conditions caused by climate change. Moreover, authorities can bolster the resilience of fishing communities against the forthcoming challenges presented by climate change. Addressing the risks linked to fishing techniques is essential, as these practices pose safety concerns that fishers need to acknowledge. Climate change has detrimental impacts on the well-being of fishermen. Therefore, observing extreme and erratic weather conditions while fishing is essential. Mobile applications, available at no cost on Android devices, provide varied information, especially regarding weather conditions, to reduce disaster risk. This encompasses information on meteorological conditions, fishing sites, fish poaching, fish conservation, fish commerce, and the documentation of fish catch records. Adapting to rapidly changing conditions is a considerable challenge in enhancing the sustainability of global small-scale fisheries systems. Adaptation decisions pertain to the selections made by small-scale fishermen in the study area to meet their households' economic requirements. Government support programs, fishing revenue, and experience affect fishermen's resilience in adverse weather circumstances.

Adapting to climate change is essential for improving global food security, especially for small-scale fishing households (Rahman et al., 2022). We expect that small-scale fishermen would adeptly adapt to year-round fishing activity, especially during inclement weather circumstances. Fishermen households must design adaptive solutions to meet their economic needs. Le Bras et al. (2024) propose adopting survival adaptation tactics to address environmental alterations during extreme weather events.

Adaptation techniques can be changed and adapted to fit the needs, skills, and interests of small-scale fishermen in each coastal area. These techniques include economic, social, and ecological adaptation strategies. (1) Economic adaptation strategies encompass income diversification via the establishment of alternative livelihoods in aquaculture as a substitute for marine fishing. (2) Social adaptation strategies include reducing risks, improving social connections, and participating in planning for adaptation. (3) Approaches to adapting to environmental changes emphasize the conservation of mangrove forests, where blue carbon is captured in coastal ecosystems and brackish water species such as fish and shrimp thrive, crucial for people's livelihoods.

Furthermore, fishermen can maintain their economic viability during this period. Policymakers can distribute social security funds through government assistance programs, employing insurance, credit, and patron-client relationship models. Fisheries insurance is crucial for safeguarding against risks associated with fishing vessels, catches, and fishermen (Yu et al., 2024). Insurance alleviates income fluctuations to bolster the sustainability goals of capture fisheries during extreme weather events. The Fisherman's Insurance Premium Assistance (FIPA) may be distributed to small-scale fishermen to provide insurance coverage for accidents, permanent disabilities, medical expenses, and death benefits.

Moreover, low-interest credit loans can aid fishermen in maintaining their purchasing power and avoiding indebtedness to capital owners. The capacity to obtain credit and the additional funds acquired should help fishermen catch fish, optimize the productive aspects of their catch, and subsequently influence consumer spending patterns. An adaptive strategy for mitigating the economic constraints fishermen face is fostering social interactions. If policymakers cannot develop assistance programs, they may leverage this bond to create a patron-client relationship.

Conclusions

In the examined areas (Kupa, Mallawa, Cilellang, and Palanro Villages), fishermen's average household income and expenditure disparity are more significant during the fishing season than during adverse weather conditions. However, disparities are present among the sampled regions; during the fishing season, fishermen's income and consumer expenditures in Kupa Village and Cilellang Village exceed those of the two fishing villages (Mallawa and Palanro Villages). Conversely, under severe weather circumstances, fishermen in Mallawa and Palanro Villages attain more household income and consumption expenditure than their Kupa and Cilellang villages counterparts.

Disparities in household income among fishermen are influenced by regional differences between villages, which serve as houses for small-scale fishermen during the fishing season, and by poor weather conditions. The age of the household head, in this case, the fisherman, and the number of employed family members do not affect household income. In contrast, household income and regional disparities influence household consumption expenditure throughout the fishing season. Conversely, regional variances affect extreme weather phenomena. Small-scale fishermen are more inclined to make adaptive decisions during extreme weather events owing to their income from fishing, experience, and formal education. Fishermen will demonstrate increased adaptation in fishing operations during inclement weather, improving family economies. Some coastal fishermen modify their fishing methods or move to shallow waters near the coast. Nonetheless, many fishermen do not change their fishing methods or move elsewhere because the small islands provide protection, reducing the strength of sea winds and wave heights.

These results highlight the importance of adaptation strategies for small coastal fishing communities to improve family incomes in reaction to the impacts of extreme weather due to climate change. Adaptation strategies can be tailored to small-scale fishermen's needs, skills, and interests in different coastal areas. These approaches include financial, social, and environmental adaptation actions. Furthermore, fishermen can sustain the household economy throughout this time. Policymakers can allocate social security money via government aid programs, employing insurance, credit, and patron-client relationship frameworks.

Future research should focus on adaptation strategies and the resilience of fishing communities in extreme weather conditions. The applied strategies will influence fishermen's future choices. These techniques seek to alleviate the impacts of climate change, encompassing severe weather occurrences. Coastal communities depend significantly on the fishing sector, with fishermen constituting their principal source of sustenance. Climate change profoundly affects fishermen's activities and marine fishing locations, manifesting as extreme high tides, intense winds, and heightened precipitation. Resilience will be linked to the sustainable livelihood strategy framework. The livelihood strategy approach evaluates financial, human, and physical social capital as determinants affecting the food security of fishing households.

Ethical Statement

All research processes have been approved by the Institute for Research and Community Service, Makassar State University (Decree, Number: 1040459/E5/PG.02.00/2024) under the Ministry of Education and Culture Research and Technology, Directorate of Higher Education, Indonesia.

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Author Contribution

Abd. Rahim: collecting research data, writing manuscripts in the form of introduction, Method (data analysis techniques), Result, Discussion, and Conclusion. Abdul Malik: collecting research data, translating articles and Grammarly articles. Diah Retno Dwi Hastuti: collecting research data, processing research data and data analysis.

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

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