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Sustaining Business Amid Climate Change: Profit Drift and Investment Risks in Pelagic Fisheries

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Abstract

This study examines the impact of climate change on the financial vulnerability and pelagic fisheries in Fisheries Management Area 711 investment risks, covering the ground fishing area of the Natuna Sea, the North Natuna Sea, and the Karimata Strait through direct survey. Data was collected from 100 fishermen using a quantitative approach and structural equation modeling (SEM) through a Likert-scale questionnaire to examine the interrelations among climatic factors, adaptive strategy, investment risk, and income. Findings demonstrate that storm frequency affects resource availability and investment risk, underscoring susceptibility to extreme weather phenomena. Investment risk functioned as a mediator, substantially influencing adaptive strategies and income. Adaptive solutions were identified to mitigate the adverse effects of investment risk on income by around 50 percent. Nonetheless, factors like sea level rise and sea temperature have shown no direct significant impact, indicating potential delayed or perceived consequences. The study underscores the importance of community-based adaptation measures to mitigate climate-induced economic vulnerabilities in fisheries, emphasizing the need for policymakers to enhance risk literacy among fishermen for improved socio-economic resilience.

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Introduction

Climate change is a global issue that significantly impacts various sectors, including the fisheries sector. Zone 1 of PIT (Measured Fisheries Potential–*Potensi Ikan Terukur*) or WPP (Fisheries Management Area–*Wilayah Pengelolaan Perikanan*) 711, which includes the waters of the Natuna Sea, the North Natuna Sea, and the Karimata Strait, is one of the areas that is highly vulnerable to climate change, which poses multifaceted threats to both ecological systems and socio-economic livelihoods. The chosen areas play a crucial role in Indonesia's marine fishery production. The region supports diverse pelagic species such as tuna, mackerel, and small pelagic fish like scad and anchovies, which are economically significant for local fishing communities.

WPP 711's fishing communities are primarily small-scale operators with limited financial resources and adaptive capacity. For instance, the westerly wind season in the Natuna Sea from December to February leads to increased wind speeds, high sea waves, heavy rain, and storms, making shipping activities dangerous. Small seafarers and traditional fishermen avoid going to sea due to the safety risks of 2-2.5 metres waves. Large ships in the fishing industry or commercial shipping may still go to sea, but with high vigilance. These communities rely on predictable seasonal cycles and localized knowledge of fish behavior, but with increasing unpredictability in migration and weather patterns, they face increased income instability and investment risks. According to data from the Ministry of Maritime Affairs and Fisheries, fishery production in WPP 711 in 2023 will reach 1.5 million tons. However, it is expected to decline due to climate change affecting fish habitat and migration patterns (Kementerian Kelautan dan Perikanan, 2024).

The study gap is reflected in the lack of understanding of how climate change specifically affects business and financial risks in the fisheries sector in WPP 711. Some previous studies (Brander, 2010; Tidd et al., 2023) have discussed the impacts of climate change in general. Still, no one has thoroughly analyzed the financial implications and business risks faced by fisheries business actors in the region, considering ecological and economic impacts, and a unique approach to climate change effects.

The formulation of the problems that will be answered in this study is: (i) What are the impacts of climate change on fisheries ecosystems in WPP 711? (ii) How is climate change affecting the catch and income of large pelagic fishers in WPP 711? (iii) What are the investment risks faced by fisheries sector players due to climate change? (iv) How does climate change affect investment risks for fishery business actors, especially large pelagic catch fish? (v) What adaptive strategies can be implemented to reduce and mitigate these negative impacts?

Figure 1. Pelagic Fish Fishing Ground Area of WPP 1
Source: Processed Cartographic Picture by Author (2025)

This study examines the challenges faced by the fisheries sector in the fisheries management area WPP 711 due to climate change, affecting income and investment risks for large pelagic fishers. The findings are crucial for academics, practitioners, and policymakers, providing a reference for further research on climate change and the fisheries sector. Practitioners, particularly fishermen and entrepreneurs, will gain insight into potential risks and manage them effectively. Policymakers and stakeholders can use the findings to develop effective management policies and support economic sustainability in coastal communities.

Literature Review

Theoretical Framework

Developed from the concept by Lane and Stephenson (1998), which emphasizes the importance of evidence-based risk management in fisheries decision-making, this study uses the theoretical framework of the Risk Assessment and Adaptive Management Framework, which combines environmental, economic,

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and behavioral dimensions to evaluate and respond to the impact of climate change on the fisheries sector. This approach is in line with the concept developed in the context of this study, climate change, such as fish migration and the availability of marine resources, affects investment risk, which in turn impacts fishermen's income and adaptive strategies (Sethi, 2010). By mapping the direct and indirect paths of the influence of these variables, this framework provides a robust analytical structure to formulate adaptive policies that support the socio-economic resilience of the fisheries sector.

Climate Change in the Fisheries Sector

Climate change is expected to have a significant impact on capturing fisheries globally. Rising sea temperatures cause a shift in fish distribution and productivity (Brander, 2007; Cheung et al., 2012). Ocean acidification can also affect particular fish species (Cheung et al., 2012; Vivekanandan & Jeyabaskaran, 2010). In addition, changes in rainfall and extreme weather events will have an impact on marine fisheries (Brander, 2007; Daw et al., 2009).

Climate change is reshaping major pelagic fish distribution and migration patterns, thus leading to changes for coastal and fisheries communities (Crear et al., 2023; Dell'Apa et al., 2023). Many fishermen move toward different domestic and international fishing grounds to establish essential adaptive strategies (Asiedu et al., 2022). Nevertheless, the pelagic fish resources in certain regions are within acceptable limitations (Riadi et al., 2024; Sasarari et al., 2019).

Management strategies need to take into account climate-induced changes in species abundance and distribution to ensure sustainable fisheries (Dell'Apa et al., 2023). While local fishing pressures may affect fish availability, factors across the Pacific may have a more significant influence on pelagic fish populations (Boggs & Kikkawa, 1993). These changes threaten food security, livelihoods, and the economy that depends on fisheries (Ndlovu & Charlebois, 2020; Vivekanandan & Jeyabaskaran, 2010). However, the impact will vary regionally, with potential benefits in some high-latitude regions (Brander, 2007). Adaptive strategies include flexible governance, ecosystem-based management, and reduction of fishing pressures (Brander, 2007; Daw et al., 2009).

H1. Climate change will increase investment risks in the capture fisheries sector, which will impact declining incomes.

Climate Change on Fishermen's Income

Climate change has a significant impact on fisheries productivity in Indonesia (Cintra et al., 2017). This phenomenon causes changes in fishing regions and seasons, increased risks at sea, barriers to fishermen's access, and reduced fishermen's income (Patriana & Satria, 2015). This impact has resulted in a decrease in fishermen's catches (Ulfa, 2018) and milkfish production in ponds (Sirajuddin et al., 2023). Environmental factors such as climate change and natural disasters can disrupt fishing conditions due to changes in fish migration and the availability of marine resources (Kanchan & Hebbar, 2024). These shifts in fish migration and the availability of marine resources affect the composition of catches, timing, and locations of recreational and commercial fisheries (Crear et al., 2023). Environmental changes, coupled with overfishing, have led to a decline in pelagic fish populations, impacting fishermen's livelihoods (Boggs & Kikkawa, 1993; Kimirei et al., 2008). The fisheries sector contains various risks, which encompass natural risks together with ecological risks and market risks, followed by technical and managerial risks (Mohsin et al., 2020).

H2a. Areas experiencing climate change vulnerability will cause fishers to face significant income decline because of shifting fish migration patterns.

H2b. Areas of high climate change vulnerability will cause fishers to face significant income decline due to changes in the availability of marine resources.

Climate Change and Investment Risks

The effects of climate change inflict substantial threats to worldwide fishing operations while harming fish populations, along with local communities and financial investments. The projected rise in sea temperatures, together with ocean acidification, shows that it will affect species distribution while also impacting their productivity through its greatest impact on tropical and subtropical regions (Cheung et al., 2012; Kanchan & Hebbar, 2024; Sethi et al., 2012). Other studies expound that climate risks vary geographically in challenging areas such as North America and South Australia because of maritime fleets (Dunlop & Brown; Peter, 2008). Meanwhile, a greater risk of the capture of equatorial regions due to cyclones (Vivekanandan & Jeyabaskaran, 2010). Capture fisheries investment generally includes investment in fishing vessels, equipment, and human resources (Dunlop & Brown, Peter, 2008; Mohsin et al., 2020; Kanchan & Hebbar, 2024). A risk assessment framework provides a measurement tool to analyze climate effects on harvesting strategies, which supports operational decision-making. Smallholder fishermen demonstrate limited awareness of investment dangers because they have restricted business analytical abilities and basic financial skills (Yulianti et al., 2020).

H3a. Climate change will increase investment risks in the capture fisheries sector due to changes in fish migration patterns.

H3b. Climate change will increase investment risks in the capture fisheries sector due to the availability of marine resources.

Investment Risk Mitigation Strategy for Climate Change and Fishermen's Income

Fishermen adopt various adaptive strategies, such as catching up with the fishing season, diversifying livelihoods, and modifying cultivation techniques (Patriana & Satria, 2015; Sirajuddin et al., 2023). Studies in various regions confirm the influence of climate variables such as temperature, rainfall, and wind speed on capture fisheries production (Illahi et al., 2023; Jabnabillah & Reza, 2024). Short-term, medium-term, and long-term policies are needed to reduce the vulnerability of the fisheries sector (Cintra et al., 2017). Risk management techniques, such as decision analysis tools and portfolio management, can help address these challenges (Sethi, 2010). Quantitative risk measures reveal that Alaskan fisheries have substantial catch and revenue risks, with higher productivity species tending to be more at risk (Sethi et al., 2012). Small-scale fisheries face special hazards related to working conditions and boat design (Ben-Yami, 2000).

Strategies for managing risk include optimizing the use of weather information, expanding fishing areas, and diversifying catches (Yulianti et al., 2020). Risk assessment in fisheries management aims to evaluate the potential consequences of uncertainty, while risk management involves decision-making under uncertainty (Francis & Shotton, 1997). Integrated decision-making frameworks and risk analysis methodologies can improve fisheries management (Lane & Stephenson, 1998a). In aquaculture fisheries, hazard identification, control, and monitoring are essential for risk management (Ezekiel et al., 2011). Local studies, such as those in Sambas, Indonesia, highlight specific risk factors that affect small-scale fisheries (Lindawati & Rahadian, 2016).

H4. Implementing adaptive strategies will significantly reduce the negative impact of climate change on fishers' incomes.

Research Method

Population and Sample

This research employs a descriptive methodology utilizing a quantitative approach. The population comprised traditional fishermen in Fisheries Management Area (WPP) 711, encompassing the waters of the Karimata Strait, the Natuna Sea, and the North Natuna Sea. Samples were obtained through purposive sampling, targeting respondents who are active large pelagic fishers directly experiencing the effects of climate change in the WPP 711 region. The sample size of N equals 100 is determined due to geographical and logistical constraints, as well as the notion of data saturation in PLS-SEM research (Hair et al., 2019).

Research Design and Instruments

A survey-based quantitative method was applied to identify several factors in this study. The questionnaire was distributed online and offline. The online questionnaire is created through a Google form and distributed through social media. Enumerators are prepared to distribute the questionnaire directly to select locations in Indonesia. Respondents were asked to answer questions on a five-point Likert scale, ranging from “strongly agree” to “strongly disagree”.

The research design was correlational, and data were collected through documentation techniques, focusing on indicators of bound variables such as fishers' annual income, number of fish catches, and investment risks, linked to mediated variables through indicators such as the availability of marine resources and fish migration patterns. It is further associated with the impacts of climate change, such as changes in sea temperature, frequency and intensity of storms, sea level rise, changes in ocean currents, and El Niño and La Niña events. The analysis includes parameter estimation, logistic regression testing, model suitability testing, robustness testing, and model fit using the Sobel test.

Data Analysis

The data analysis in this study employed Structural Equation Modeling (SEM) to examine the complex relationships among climatic variables, resource availability, investment risk, adaptive strategies, and income. SEM was chosen for its ability to assess both measurement models (construct validity and reliability of latent variables) and structural models (direct and indirect relationships among variables) (Hair et al., 2019). Model estimation and testing were carried out using parameter estimation techniques, including Maximum Likelihood Estimation (MLE), and were evaluated based on several goodness-of-fit indices. To test the mediating effects of investment risk between climate factors and income/adaptive strategies, the Sobel test was used as a complementary analysis to examine the significance of indirect effects within the SEM framework (Sobel, 1982). The illustration of the research framework is presented in Figure 2.

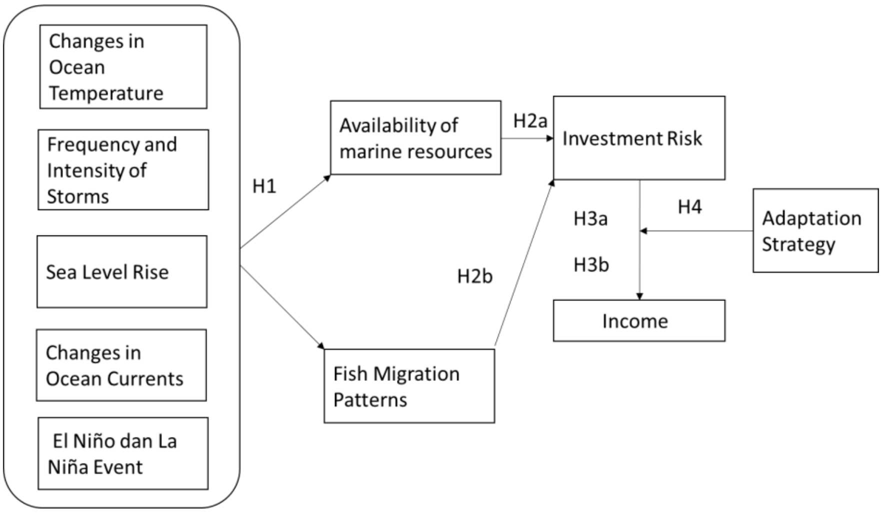

Figure 2. Research Framework

Results and Discussion

Result

From the Outer Model Test results in Figure 3, there is still an outer loading value (β) below 0.70, where the latent variable must be excluded from the smart PLS analysis indicator (Hair, 2019). The latent variables are AS1, AS2, AS5, IN1, IR1, SC1 and SF2.

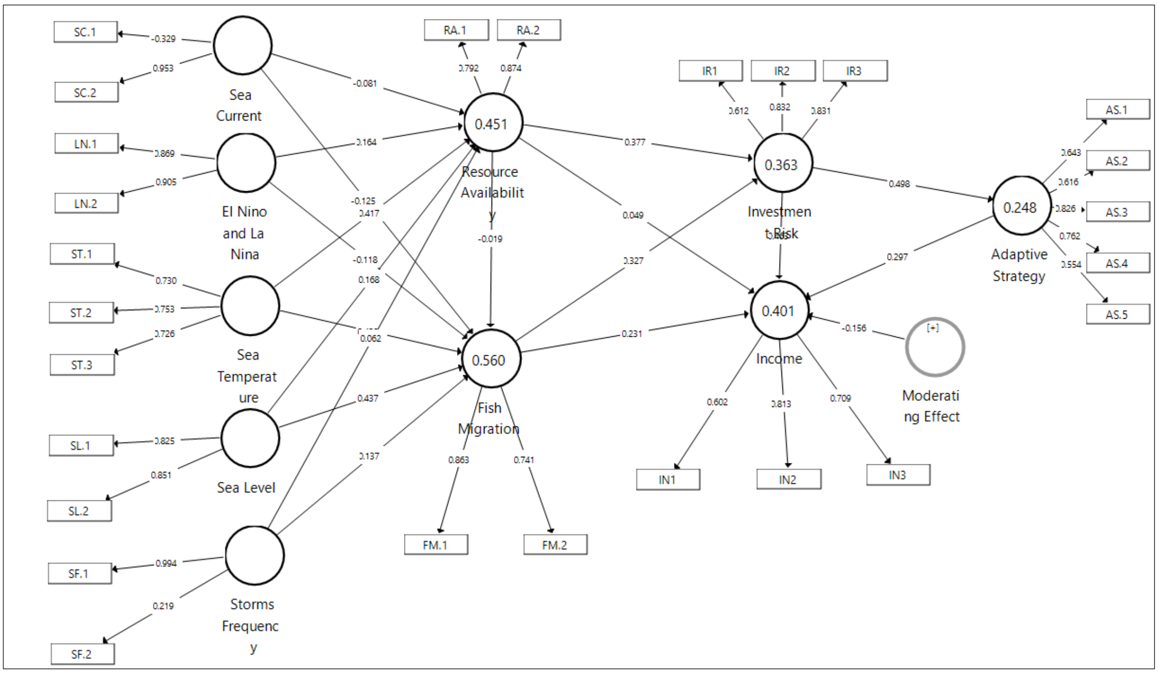

Figure 2. First Stage Path Analysis
Source: Primary data processed (2025)

Furthermore, after the outer loading test is carried out, the second stage of testing is carried out, which comprises the construct validity and reliability test, as shown in Table 1.

Table 1. Validity and Reliability Test

Construct	Items	O	Cronbach's Alpha	rho_A	CR	(AVE)
Investment Risk	IR2	0.874	0.700	0.701	0.870	0.769
	IR3	0.881				
Income	IN2	0.846	0.584	0.585	0.828	0.706
	IN3	0.834				
Adaptive Strategy	AS2	0.739	0.696	0.721	0.831	0.622
	AS3	0.871				
	AS4	0.750				
Resource Availability	RA1	0.803	0.576	0.589	0.824	0.701
	RA2	0.870				
Fish Migration	FM1	1.108	0,980	0.986	0.988	0.998
Sea Temperature	ST1	0.793	0.463	0.466	0.788	0.650
	ST2	0.816				
Storms Frequency	SF1	0.829	0.463	0.466	0.788	0.650
	SF2	0.783				
El Nino and La Nina	LN1	0.916	0.732	0.764	0.880	0.786
	LN2	0.856				
Sea Current	SC2	1.010	0.988	0.999	0.978	0.988
Sea Level	SL1	0.797	0.567	0.582	0.821	0.696
	SL2	0.870				

Source: Primary data processed (2025)

A composite reliability (CR) score higher than 0.70 reflects a satisfactory level of internal consistency within the construct. The measurement results show that most constructs meet this criterion. Although some indicators have an outer loading <0.70, the decision to remove or maintain them is based on their contribution to the overall reliability of the construct. Indicators with an outer loading between 0.4–0.7 are acceptable in exploratory studies, as long as the construct still has a CR value of >0.70 and AVE >0.5 (Hair et al., 2019). Therefore, indicators that do not meet these criteria and do not strengthen the reliability of the construct have been eliminated. The Investment Risk construct shows a CR value of 0.870 with Cronbach's Alpha of 0.700, which means this construct is reliable. Adaptive Strategy is also classified as reliable with a value of CR=0.831 and Cronbach's Alpha=0.696, α<0.70, but it is still acceptable for exploratory research and a new conceptual model (Hair et al., 2019).

Construct Income, Resource Availability, and Sea Level have CR values of 0.828, 0.824, and 0.821, respectively. The El Niño and La Niña constructs show high reliability with a CR value of 0.880. Meanwhile, constructs such as Fish Migration and Sea Current show CR and AVE (Average Variance Extracted) values 1.000.

In addition, the convergent validity is evaluated using AVE values, which indicate how much variance of the indicator is successfully explained by its construct. AVE values exceeding 0.50 indicate good convergent validity. All model constructs demonstrate adequate to excellent convergent validity due to their minimum AVE value of 0.622. The performance indicators of Fish Migration, Sea Current, El Niño, and La Niña demonstrate superior representation of their measured constructs because their AVE values exceed 0.786.

The R-squared value (R^2) demonstrates the exact amount of endogenous construct variation that results from exogenous construct inputs in the model. According to Hair et al. (2019), the interpretative scale for R^2 values becomes substantial at ≥0.75, moderate at ≥0.50, weak at ≥0.25, and very weak at <0.25. The Resource Availability construct demonstrated the highest R^2=0.440, followed by R^2 of the Income construct 0.361, and the Adaptive Strategy exhibited 0.237. The R^2 value for Investment Risk is 0.220, while Fish Migration holds an R^2=0.184. The variables in the model show the strongest influence on Resource Availability and Income constructs. However, Fish Migration receives the least predictive value because fishermen gave homogeneous (single) responses to this indicator. SmartPLS software allowed researchers to perform the direct variable relationship analysis through Structural Equation Modeling (SEM) procedures. This test aims to determine the significant influence of constructs in the built model. The significance criteria used were a p-value of <0.05 and a t-statistical value of >1.96, which indicates that the relationship between these variables is statistically significant at a 95% confidence level.

The analysis results show that several relationships between variables in the model have a significant influence. Fish Migration was shown to significantly affect Adaptive Strategy (β=0.160, p =0.002), Income (β=0.326, p=0.001), and Investment Risk (β=0.328, p=0.000). This shows that changes in fish migration patterns felt by fishermen have a direct impact on their adaptive strategies, income earned, and risk perceptions of investment in the fisheries sector. Furthermore, Investment Risk significantly affected the Adaptive Strategy (β=0.487, p=0.000) and Income (β=0.444, p=0.000), indicating that the perception of investment risk triggered the adjustment strategy and impacted fishermen's income.

Moreover, Figure 4 depicts the support of adaptive strategy moderating the investment risk, significantly affecting the income (T-Stat=3.289> T-Table=1.97, α=0.05). The adaptive strategy reduced the rise of investment risk from 44.4%(β=0.444, T-Value=3.507, α=0.05) to 21.6% (β=0.216, T-Value=3.289, α=0.05).

Another interesting finding was the significant moderation effect of the Adaptive Strategy on Income (β=-0.216, p=0.001). This effect is negative, indicating that as adaptive strategies increase, the influence of other factors on income tends to decrease. In addition, Resource Availability also significantly influences Adaptive Strategy (β=0.129, p=0.015) and Investment Risk (β=0.265, p=0.003), showing that perception of the availability of marine resources also determines fishermen's adaptation and investment decisions.

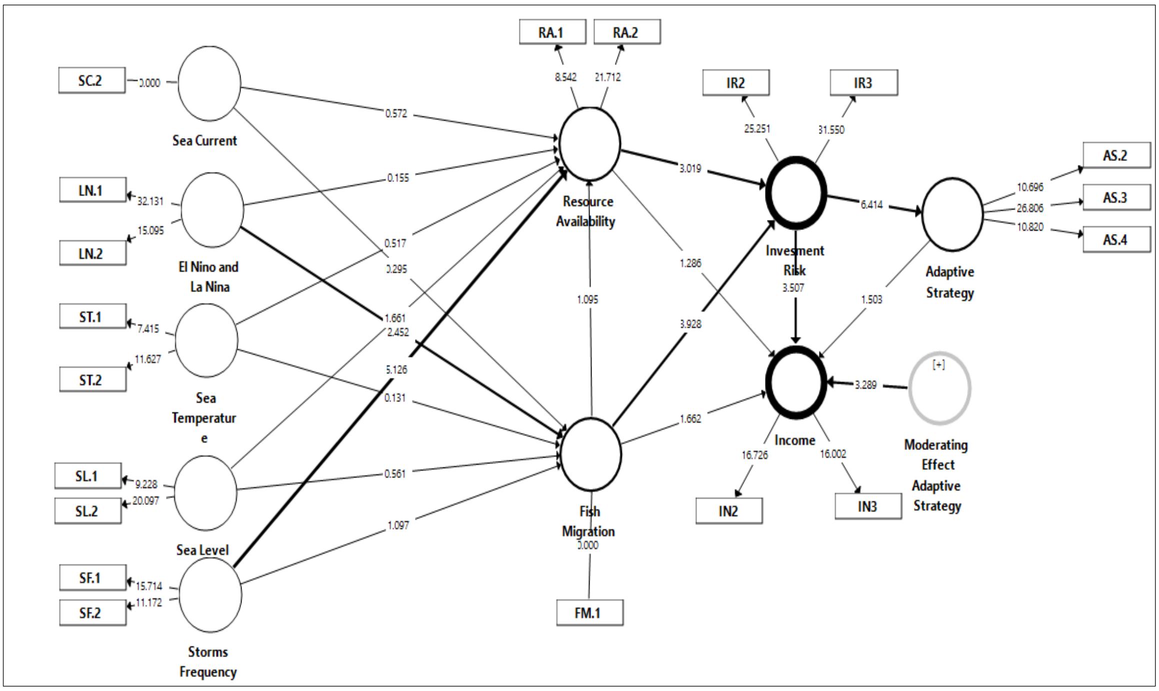

Figure 3. Second Stage Path Analysis
Source: Primary data processed (2025)

Storm Frequency or storm frequency was also found to be significant for several constructs, namely Adaptive Strategy (β=0.094, p=0.029), Investment Risk (β=0.194, p=0.007), and Resource Availability (β=0.532, p=0.000). These findings reinforce the assumption that extreme climate change directly influences the dynamics and decisions of fishermen in managing their businesses.

Meanwhile, in Table 2, the relationship between El Niño and La Niña and Fish Migration showed significant results (β = 0.285, p = 0.015), which supports the literature that global climate phenomena impact fish migration patterns. However, the relationship between El Niño and La Niña and other constructs such as Adaptive Strategy, Income, Investment Risk, and Resource Availability is insignificant.

Table 2. Direct and Indirect Interrelationships amongst Construct Variables

Effect	O	M	STDEV	O/STDEV	*p*
Indirect Correlation					
El Nino and La Nina → Fish Migration → Investment Risk → Adaptive Strategy	0.049	0.049	0.026	1.926**	0.055
Fish Migration → Investment Risk → Adaptive Strategy	0.173	0.172	0.052	3.324*	0.001
Storms Frequency → Resource Availability → Investment Risk → Adaptive Strategy	0.07	0.076	0.036	1.965**	0.05
El Nino and La Nina → Fish Migration → Resource Availability → Investment Risk → Adaptive Strategy → Income	-0.001	-0.001	0.001	0.613*	0.004
Storms Frequency → Resource Availability → Investment Risk → Adaptive Strategy → Income	0.011	0.012	0.01	1.065**	0.028
El Nino and La Nina → Fish Migration → Investment Risk → Income	0.037	0.037	0.022	1.709***	0.088
Fish Migration → Investment Risk → Income	0.131	0.131	0.054	2.408**	0.016
El Nino and La Nina → Fish Migration → Investment Risk	0.101	0.1	0.049	2.055**	0.04
Storms Frequency → Resource Availability → Investment Risk	0.145	0.151	0.062	2.336**	0.02

 Jurnal REKSA: Rekayasa Keuangan, Syariah dan Audit
Vol. 12, No. 1, March 2025, pp. 80-93

Effect	O	M	STDEV	O/STDEV	*p*
Direct Correlation					
El Nino and La Nina → Fish Migration	0.285	0.287	0.116	2.452**	0.015
El Nino and La Nina → Income	0.093	0.091	0.049	1.893***	0.059
Fish Migration → Adaptive Strategy	0.16	0.159	0.05	3.165*	0.002
Fish Migration → Income	0.326	0.322	0.093	3.496*	0.001
Fish Migration → Investment Risk_	0.328	0.324	0.089	3.697*	0.000
Investment Risk → Adaptive Strategy	0.487	0.492	0.076	6.414*	0.000
Investment Risk → Income	0.444	0.448	0.09	4.904*	0.000
Moderating Effect of Adaptive Strategy → Income	0.216	0.218	0.066	3.289*	0.001
Resource Availability → Adaptive Strategy	0.129	0.135	0.053	2.446**	0.015
Resource Availability → Investment Risk_	0.265	0.27	0.088	3.019*	0.003
Storms Frequency → Adaptive Strategy	0.094	0.101	0.043	2.19**	0.029
Storms Frequency → Investment Risk_	0.194	0.202	0.072	2.699*	0.007
Storms Frequency → Resource Availability	0.532	0.535	0.112	4.728*	0.000

*** p<0.01, ** p<0.05, * p<0.10

Source: Primary data processed (2025)

An insignificant relationship was found in most of the pathways of Sea Current, Sea Level, and Sea Temperature to other constructs, with a p-value>0.05 and a t-statistic <1.96. This indicates that in respondents' perceptions, these variables do not have a strong direct influence on adaptive strategies, income, investment risks, or perceptions of the availability of marine resources.

Based on the results in Table 3 of the robustness test, the Standardized Root Mean Square Residual (SRMR) value for the saturated model is 0.089 and for the estimated model is 0.131. An SRMR value below 0.10 for a saturated model indicates a good match between the model and the data. For the estimated model, the d_ULS and d_G values were 3.285 and 0.822. Although there is no standard threshold value for these two sizes, the smaller the value, the better. The Chi-Square in the model is estimated at 479,976, and the NFI value is 0.830, which is still close to the acceptable value threshold (>0.80 for an excellent model). A Root Mean Square Theta (rms ψ) value of 0.233 indicates that the model is still within the tolerance limit for residual errors in reflective constructs.

Table 3. Robustness Test and Model Fit Test

Robustness Test	Saturated Model	Estimated Model	rms Theta (ψ)
SRMR	0.089	0.131	0.233
d_ULS	1.519	3.285	
d_G	0.702	0.822	
Chi-Square	441.317	479.976	
NFI	0.884	0.83	
Model of Fit	**SSO**	**SSE**	**Q^2 (=1-SSE/SSO)**
Adaptive Strategy	300	261.295	0.129
Fish Migration	100	93.08	0.069
Income	200	159.305	0.203
Investment Risk	200	168.692	0.157
Resource Availability	200	149.375	0.253
El Nino and La Nina	200	200	
Sea Current	100	100	
Sea Level	200	200	
Sea Temperature	200	200	
Storms Frequency	200	200	
Moderating Effect of Adaptive Strategy	100	100	

Source: Primary data processed (2025)

In addition, predictive relevance testing using Q^2 values (Stone-Geisser's Q^2) shows the model's predictive ability for endogenous constructs. The Q^2 value is calculated from the predicted residual squares (SSE) ratio to the total SSO (Sum of Squares Observed) in the Sobel test. The results showed that the Resource Availability construct had the highest Q^2 value of 0.253, followed by Income (0.203), Investment Risk (0.157), Adaptive Strategy (0.129), and Fish Migration (0.069). A value of $Q^2 > 0$ indicates that the model has relevant predictive capabilities. In contrast, constructs such as El Niño and La Niña, Sea Current, Sea Level, Sea Temperature, and Storm Frequency have a value of $Q^2 = 0$ because other constructs in the model do not predict them and function as exogenous constructs. Furthermore, the study's robustness test and fit model indicate the structural model meets the fit for further analysis, with adequate structural validity and good predictive ability of endogenous constructs. However, some values need improvement, such as SRMR and NFI.

Discussion

The model test results show that fish migration, investment risk, and storm frequency are the main constructs that strongly influence the adaptation and economic behaviour of fishermen. These findings can serve as a basis for formulating climate change adaptive policies in the fisheries sector, especially in the context of increasing the socio-economic resilience of fishers to climate risks. Most impacts in the model are transmitted through intermediate steps, which chiefly involve the Investment Risk construct and Adaptive Strategy. The identified pathways present essential targets that policy builders should focus on when creating measures for improving fishers' adaptation capacity by managing risks and enhancing resources.

The study found that fishermen's perceptions of Sea Current, Sea Level, and Sea Water Temperature are insignificant due to the long-term and indirect impacts on fisheries productivity. Small-scale fishers are more sensitive to visible changes like storms and fish migration than invisible or not immediately felt variables. Rising sea temperatures may affect fish ecosystems in the long term, but fishermen only care about daily catch and access to the sea. Traditional fishers in WPP 711 have limited knowledge or access to oceanographic information, making their perception of these variables low or irrelevant in daily decision making. They focus on more directly impacting variables, such as storm frequency or fish migration patterns, that directly impact operational decisions and catches. Water temperature, sea level, and ocean currents are considered less relevant or not directly related to investment decisions like replacing fishing gear or expanding fishing areas. Respondent perceptions for these variables are homogeneous or uniform, with most fishermen answering with the same pattern, resulting in insufficient variation for significant statistical relationships in the SEM-PLS model.

The findings support Hypothesis 1, which suggests that temperature-caused pelagic species redistributions affect commercial fishery activities. Dell'Apa et al. (2023) confirmed that temperature-caused pelagic species redistributions affect commercial fishery activities. Meanwhile, fish migration patterns lead to fishermen modifying catch methods and business locations, increasing the chances of income generation for productive species (Sethi et al., 2012). Investment risk plays a central role in this situation, with fish migration causing significant changes in investment risk, influencing adaptive strategies, and income.

Answering Hypothesis 2, the results showed that Fish Migration works through Investment Risk to impact Adaptive Strategy, and Storm Frequency connects with Resource Availability to influence Investment Risk. The research outcome demonstrates that environmental impacts are transmitted through mediation chains, according to Lane and Stephenson (1998), within integrated risk analysis approaches for fisheries sector decision-making.

The frequency of storms directly impacts both how resources are available to users and the level of investment risk. The distribution system of marine resources becomes disrupted by extreme weather conditions, thus affecting potential investment risks. Research conducted by (Dunlop et al., 2012) has

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proven that severe weather events generate business unpredictability that diminishes marine industrial investment stability. This also confirms that Hypothesis 3 is supported.

Research revealed that the moderation of adaptive strategies has substantial impacts on the study, as exhibited in Hypothesis 4. The negative relationship between Adaptive Strategy and Income at $p = 0.001$ indicates that adaptive strategies create effective protection against the adverse impacts of other variables on income. The research demonstrates how Yulianti et al. (2020) proposed that community-based risk management enhances fishermen's economic resilience. These investigation results verify all four research hypotheses about how climate change influences fisherman's financial well-being and their investment dangers and adaptation approaches. The significance values from direct and indirect paths within an acceptable model validity confirm these four hypotheses.

The tested structural models confirm reliable and valid measurements of the study components. The predictive model indicates predictive relevance since most endogenous constructs show positive Q^2 values while the entire construct maintains SRMR, CR, and AVE values within acceptable ranges. Research findings demonstrate that sea level and sea temperature variables do not significantly impact the results. Study participants could reach this conclusion either because they do not believe the variable is developed strongly or because its effects remain extended to the future (Brander, 2007).

Small-scale fishers face significant challenges due to limited awareness of investment risks and climate variability. Localized climate information services, training programs, community-based early warning systems, and promoting adaptive fishing practices and livelihood diversification are recommended to address this. Governments can offer subsidies or low-interest loans for transitioning to alternative gear types, diversification grants for aquaculture or non-fishing livelihoods, and seasonal fishing calendars co-developed with local communities.

Moreover, improving financial resilience and investment security is crucial, with micro-insurance schemes, risk-sharing financing mechanisms, and climate-resilient infrastructure development. Community-based co-management systems must evolve to reflect local realities, and governance structures should be institutionalized to ensure long-term sustainability and equitable resource distribution (Susanto & Rahardjo, 2022). Furthermore, strengthening market access and value chain integration is essential for stabilizing incomes amid climatic uncertainty. Digital marketplaces, cold chain and processing hubs, and certification and branding of sustainable catches can help fishermen access better prices and reduce spoilage. Regional collaboration with countries bordering the Natuna Sea and Karimata Strait, particularly Indonesia, Malaysia, and the Philippines, should collaborate on joint stock assessments and coordinated fishing quotas to prevent overexploitation.

Conclusion

This research shows that the WPP 711 fisheries region demonstrates how climate change influences the ecological equilibrium and monetary stability of its fishing sector. The successful implementation of adaptive approaches with economic benefits depends on three essential features: fish movements, investment challenges, and storm occurrence frequencies. Changing ocean temperatures and shifting ocean currents modify fish migration behaviours, which produce consequent effects on investment risks while impacting financial performance. The strategic distribution of diverse assets across different industrial sectors by fishery operators, combined with risk management approaches, delivers the highest possible revenue success during climate adversity. The research develops a complete structure that combines environmental impacts with economic risk measurements to solve existing problems in fisheries and climate evaluation. Budgetary decisions for sustainable fisheries need to combine ecological research with monetary sustainability requirements.

This study also has several limitations, such as its focus on Fisheries Management Area 711, a sub-region not representative of Indonesia's broader marine ecosystems. The cross-sectional design also limits the ability to track changes over time, particularly long-term shifts in fish migration patterns or the evolution of investment behaviors in response to environmental stressors. The reliance on self-reported data introduced potential biases, as respondents were asked to recall past experiences related to climate events, income fluctuations, and adaptive strategies. Likert-scale questionnaires provided qualitative depth but were inherently subjective and may not fully reflect objective economic or ecological realities.

Future research will profit from expanding the study scope and collecting detailed economic data within the investigation framework. It could benefit from integrating quantitative economic indicators and incorporating other influential socioeconomic factors. The investigation needs prolonged observation to detect how ecological climate changes affect financial conditions and fish resource sustainability. It should consider a broader geographic reach, adopting mixed-method approaches that combine survey-based data with remote sensing technologies and GIS-based tracking systems. Longitudinal studies are also recommended to understand better how investment risks, adaptive behaviors, and income levels evolve.

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