Factors that influence catch production and fishing decisions of small-scale fishers during extreme weather

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Abstract. Under normal natural conditions, fish production increases during the fishing season. However, climate change manifestations, such as extreme weather events, has significantly affected the fishing decisions of small-scale fishers. This study used quantitative along with a survey approach to investigate the impact of extreme weather events potentially cause by the climate change. The Cobb-Douglas production function model analyzes the regression estimation of catch production with the Ordinary Least Square (OLS) and maximum likelihood estimation (MLE) methods, using the logit model regression equation, which is the probability of a fisher's decision to increase the fish catch. This study found that fishing season, time at sea, fishing technology, and social conditions affected catch production during normal, natural conditions. This differs from the productivity under extreme weather conditions, presumably due to the climate change, which have a negative impact. When extreme weather occurs, the catch, fishing time, and formal education of the fishermen influence their decision to catch fish. Adaptation strategies play an essential role when extreme weather occurs, being a significant issue in economic development policy. Fishers can conduct fishing closer to the coastal areas for safety reasons. In addition, aquaculture production is an alternative to marine fishing and acts like an insurance for overcoming the uncertainty of income and feasibility of the capture fisheries.
Key Words: extreme weather, catch production, fishing decisions catch.

Introduction. For the period of the fishing season, under normal and natural conditions, fishers should be able to obtain increased catch yields and thus to improve. The household economy (Yang et al 2022), measured through both financial indicators, the household income (Jones et al 2022) and the household consumption expenditure (Oladimeji et al 2015). Extreme weather events, potentially due to the global climate change, significantly threatens catch production, fishers' income, and ecological sustainability in the global fisheries subsector (Mcowen et al 2015; Rogers-Bennett et al 2022). Currently, it significantly interferes with the capture fisheries activities (Mabe & Asase 2020), due to the rising sea surface temperatures, to the increasing intensity and frequency of tidal waves/tsunamis, as well as to extreme rainfall and winds (Shaffril et al 2017). Climate change significantly impacts the marine ecosystems and coastal regions where small-scale fishers reside, particularly in developing countries (Selvaraj et al 2022). Global climate change is causing extreme weather (Ilarri et al 2022), disrupting the socio-economic balance (Savo et al 2017), including the future fishing opportunities (Erauskin-Extramiana et al 2023).

The current research area is focused on the global climate change, with extreme weather manifestations in the Sulawesi Strait marine waters directly adjacent to the coast of Makassar City, Indonesia. Globally it also occurs almost all over the world, such as in the coastal cities of Bangladesh (Rahman & Rahman 2015), the marine waters of the Pacific Islands (Hanich et al 2018), the East Coast of Peninsular Malaysia (Samah et al 2019), the marine waters of Ghana (Mabe & Asase 2020), the coastal zone and seas of China (Cai et al 2021), and the sea of Portugal (Ilarri et al 2022). Indonesia's location, between two continents and two oceans, makes it vulnerable to natural disasters like extreme weather. Extreme weather is a crucial topic in today's world (Gallicchio 2017) designating an unusual weather event or climate condition that can disrupt people's lives and natural ecosystems. Coastal ecosystems are expected to face substantial impacts due to extreme weather events (Servino et al 2018). The factor that causes extreme weather in Indonesia is the wind blowing from the Asian continent to the Australian continent, called the Asian Monsoon. Extreme weather signs include rapid cloud buildup with Cumulonimbus clouds in transitional seasons, heavy rain with lightning, tidal waves, high waves in coastal areas, and sudden, potentially tornado-causing winds.

The Agency for Meteorology, Climatology and Geophysics (AMCG) issues early warnings when high wind speeds and sea waves are expected, for the safety of shipping or fishing vessels, and cargo/cruise ships. High wind speeds and sea waves pose a high risk to shipping safety. The size of ocean waves has a significant impact on fishing activities, and on the risks and opportunities for fishermen who heavily rely on marine resources (Maltby et al 2021). The Ministry of Maritime Affairs and Fisheries (MAF) also urges fishermen and fishing boat owners to be aware of extreme weather. It has even ordered them not to go to sea until the weather returns to normal. Extreme weather causes a decrease in fishing trips due to uncertain catches and influences fishers' decision. On average, fishers in the study area do not go out to sea to catch fish due to safety considerations related to extreme weather conditions consisting of large sea waves accompanied by strong winds. As a result, many fishers are unemployed, and much time is spent repairing their fishing gear. Despite the risks, some fishermen still fish near coastal areas to meet their family's needs. Fishermen often complain about not getting results despite incurring high operational costs while fishing. Extreme weather caused by climate change can disrupt the socio-economic balance of fishing activities, affecting the price of fresh marine fish and the income of small-scale fishers, reducing the resilience of fishing communities, and limiting their diversification options (Savo et al 2017).

The urgency of this paper lies in understanding small-scale fishers' decision-making in the face of extreme weather caused by the global climate change which determine the fisheries management strategies and practices (Wise et al 2012; Sultan, 2020) but also influences the economic development policy (Mbaye et al 2023) and the fisheries climate adaptation policy (Szmkowiak & Steinkruger 2023). In addition, fishermen as producers or suppliers of fishery commodities support the global food production system (Limuwa et al 2018) and food security in the world (Torres et al 2022) and contribute to the poverty alleviation (Kalikoski et al 2018). Small-scale fishermen also need special attention, because they may need help to meet their own food needs. Coastal countries face the challenge of achieving sustainable marine development in the midst of the global climate change (Daly et al 2021). The Committee on Fisheries (COFI) and its subcommittees support the sustainable development and protection of small-scale fisheries. These fisheries provide two-thirds of the targeted catch for human consumption and 90% of employment, as stated in the international fisheries policy documents (FAO 2016).

Several studies have been conducted on the impact of climate change on fishing activities in Malaysia (Samah et al 2019), on the adaptation strategies to climate change and fishing practices of traditional fishermen in the Volta Basin, Ghana (Mabe & Asase, 2020), on the fishers' perceptions of the climate change risk in the UK (Maltby et al 2021), and on the economic vulnerability of the fishing households in Colombia's south Pacific region, due to the extreme weather events potentially due to the climate change (Selvaraj et al 2022). However, a research study on how small-scale fishers decide to catch fish during global climate change with extreme weather has never been done. This study aims to investigate the probability of the decision of small-scale fishers to catch fish during an extreme weather, using a logit estimation model. In addition, it also examines the factors determining the catch productivity under normal conditions, during the fishing season with the Cobb-Douglas production function approach.

Material and Method

Study area. Makassar City is a strategic local traffic lane in South Sulawesi. The Makassar City area has coordinates of 119° east longitude and 5.8° south latitude with an altitude varying between 1 and 25 m above sea level. The air temperature is between

20 and 32°C. The area is on a slope of 0 to 5° to the west, so the coastal area is flat. Makassar City covers an area of approximately 175.77 km^2 of land and includes 11 islands in the Makassar Strait. It also has a water area of around 100 km^2. The city is between two rivers - the Tallo River flows into the north of the city, and the Jeneberang River flows into the south. The boundaries of Makassar are the Maros Regency at the east, the Makassar Strait at the east, the Pangkajene Islands Regency at the north, and the Gowa Regency at the south. The total population is 1,168,258, with a population density of 6,646.5 km^{-2}. The research area, Makassar City, administratively consists of 14 sub-districts and 143 urban villages.

Makassar City is directly adjacent to the west coast by the sea waters of the Sulawesi Strait. The sea wind speed ranges from 5 to 25 knots when in blows from the North to the Northeast and from 8 to 20 when it blows from the Southwest to the Northwest, with sea waves reaching 4-6 m in the Sulawesi Sea. According to the Center for Maritime Meteorology, the wave height criteria used in forecasting sea waves and daily weather according to the Sea State Code are: water areas with calm sea waves ranging from 0.1 to 0.5 m, low sea waves (0.5 to 1.25 m), medium sea waves (1.25 to 2.50 m), high sea waves (2.50 to 4.0 m), very high sea waves (4.0 to 6.0 m), extreme sea waves (6.0 to 9.0 m), and very extreme sea waves (9.0 to 14.0 m). According to the Center for Maritime Meteorology, certain wind speeds and wave heights pose a high risk to the safety of shipping vessels. For fishing boats, the threshold is a wind speed greater than 15 knots and a wave height above 1.25 m. Barges are at risk when the wind speed exceeds 16 knots and wave height exceeds 1.5 m. Ferries are at risk when the wind speed exceeds 21 knots, and wave height exceeds 2.5 m. Large-size ships, such as cargo ships and cruise ships, are at risk when the wind speed exceeds 27 knots and wave height exceeds 4.0 m.

Analytical method. The research method used was a quantitative survey conducted from February to April 2023. It was based on the time dimension using cross-sectional data sourced from primary data obtained directly from fishermen respondents. The data collection method involved a questionnaire, observations, and interviews. Purposive sampling identified 79 small-scale fishing households as research respondents due to their significant representativity for the fishery sector in for the fishery sector in Makassar City. The analysis model of this research estimates the factors that influence catch production during the normal fishing seasons and the decision-making of fishers in catching fish during extreme weather events potentially caused by the global climate change. Estimations of the factors affecting the catch production utilizes the Cobb-Douglas production function (Debertin 2012; Yang et al 2022). Meanwhile, the estimation of how fishers decide to fish is based on the response to a qualitative dependent variable or logit model (Pampel 2000; Yang et al 2022).

The Cobb-Douglas production function (Debertin 2012) is expressed as follows:

$$Q = AK^{\alpha} L^{\beta}$$

The Cobb-Douglas production function assumes that the sum of the output elasticities of capital and labor, respectively, is equal to one, namely $\alpha + \beta = 1$ so this production function is a first-degree homogeneous or linear homogeneous production function. If $\alpha + \beta = 1$, then $\beta = 1 - \alpha$, so that:

$$Q = AK^{\alpha} L^{1-\alpha}$$

The Cobb-Douglas production's generalized form is:

$$Y = \alpha X_1^{\beta 1} X_2^{\beta 2} ,..., X_n^{\beta n}$$

Where:
α - an efficiency parameter;
n - the total number of input variables (goods);

$X_1, ..., X_n$ - the (non-negative) quantities of good consumed, produced, etc.;
$\beta_1, ..., \beta_n$ - an elasticity parameter for good i.

The estimation of catch production during the fishing season is expressed as a multiple regression using the Ordinary Least Square (OLS) method:

$$CtF = \beta_0\ CthSea^{Dm}\ TmSea^{\beta 1}\ OEPwr^{\beta 2}\ FAge^{\beta 3}\ FFEdu^{\beta 4}\ ExpSea^{\beta 5}\ \mu_1$$

The equation above is converted into natural logarithm (Ln) form as follows:

$$LnCtF = Ln\beta_0 + DmCthSea + \beta_1 LnTmSea + \beta_2 LnOEPwr + \beta_3 LnFAge + \beta_4 LnFFEdu + \beta_5 LnExpSea + Ln\mu_1$$

Where:
CtF - the catch production;
β_0 - the intercept;
Dm - the regression coefficient of the fishing season dummy variable, 1 for season, 0 for off-season;
$\beta_1, ..., \beta_5$ - the regression coefficient of the independent variable;
CthSea - the fishing season;
OEPwr - the outboard engine power;
TmSea - the time spent at sea;
FAge - the fishermen's age;
FFEdu - the number of years of formal education;
ExpSea - the number of years of experience at sea;
μ_1 - the error term.

The estimation of fishermen's decision to catch fish us the analysis of the logistic distribution function or the cumulative logistic probability function (Pampel 2000) as a decision-making method, as follows:

$$P_i = F(Z_i) = (\beta_0 + \beta_i X_i) = 1/\ (1 + e^{-Zi}) = 1/\ (1 + e^{-(\beta 0\ +\ \beta i Xi)})$$

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

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

$$(1 + e^{-Zi})\ P_i = 1$$

From the above equation will result in the following equation:

$$e^{-Zi}\ Pi/\ (1 - P_i)/\ P_i$$

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

$$Z_i = Ln\ (P_i/\ (1 - P_i) = \beta_0 + \beta_1 X_i$$

Referring to the above equation (Z_i), the estimation of fishermen's decisions to catch fish when extreme weather conditions occur uses maximum likelihood (MLE) with the logit model regression equation:

$$FDEW = Ln(P_i/\ (1 - P_i) = \beta_6 + \beta_7 LnCtchPr + \beta_8 LnOEPwr + \beta_9 LnTmSea + \beta_{10} LnFAge + \beta_{11} LnFFEdu + \beta_{12} LnExpSea + \mu_2$$

Where:
FDEW - the fishermen' decision to catch fish during extreme weather (1, choose not to catch; 0, for other);
P_i - probability with a value between 0 and 1. β_6 is the intercept;
CtchPr - catch production;
$\beta_7,\ldots,\beta_{12}$ - the regression coefficients of the independent variables;
OEPwr - the outboard engine power;
TmSea - the time spent at sea;
FAge - the fishermen's age;
FFEdu - the number of years of formal education;
ExpSea - the number of years of experience at sea;
μ_2 - the error term.

Results and Discussion

Social conditions, fishing technology, and fishing operations. The adverse impact of extreme weather, potentially caused by climate change, affects the social conditions of coastal fishermen. This study aims to identify the social variables that affect catch production during the fishing season and extreme weather. The social conditions of fishermen include age, formal education, and fishing experience (Table 1).

Table 1

Social conditions, fishing technology, and fishing operations

Variable	*Description*	*Frequency*	*Percentage*
Fishers' age (year)	20 to 29	17	21.51
	30 to 39	27	34.17
	40 to 49	26	32.91
	50 to 59	9	11.39
Fishers' formal education (year)	Did not finish elementary school	8	10.12
	Finished elementary school	23	29.11
	Did not finish junior high school	15	18.89
	Finished junior high school	21	26.58
	Did not finish high school	2	2.53
	Finished high school	10	12.65
Experience at sea (year)	5 to 14	10	12.65
	15 to 24	51	64.55
	23 to 34	18	22.78
Outboard engine power (power knot, PK)	3	5	6.32
	5	8	10.12
	6	14	17.72
	7	17	21.51
	10	16	20.25
	12	12	15.19
	15	7	8.86
Time at sea (hours)	5 to 6	4	5.06
	7 to 8	44	55.69
	9 to 10	31	39.24

As fishermen age, their physical strength decreases, negatively affecting their productivity. On average, fishermen are most productive between the age range of 20-50, accounting for 88.61% of the fishermen in this study. Formal education can increase knowledge and enable better decision-making. However, most of the fishers in this study only completed primary education; only 23 of them (29.11%) have graduated the primary school and 8 of them were unable to complete their primary education. Therefore, fishers' decisions are mostly based on fishing experience. Fishing experience and education indicate economic diversification strategies for fishers' livelihoods (Marín-

Monroy & Ojeda-Ruiz de la Peña 2016). Most fishermen had a fishing experience ranging between 15-24 years, accounting for 64.55% of the fishermen in the study. Fishing experience determines the fishing operations duration and is related mostly to technology such as motorboat power engines. However, extreme weather can have a significant impact on the fishing activities of the fishermen, despite their experience. Social factors influence fishers' attitude towards the risk-related decisions (de Oliveira Estevo et al 2021). In addition to socioeconomic factors, cultural norms play an essential role in fishers' decision-making process. (Bisack & Clay 2020). Thus, social factors contribute to the household economy, alleviate poverty in coastal communities (Islam et al 2011) and significantly affect fisher households' welfare level (Al-Jabri et al 2013).

Furthermore, technology and fishing operation factors are also used as variables that affect fishermen's catch production and fishing decisions. The reference fishing technology in this study is the outboard motor boat, expressed in power knots (PK). On average, 7 PK outboard engine boats, consisting of 64.55% of were used (Table 1) to reach the fishing ground. Fishermen use outboard engines to navigate their motorboats (locally known as "Katinting"). The size of the outboard engine power will affect the fishing operations or the time spent at sea. The average duration of a fishing session is 7 to 8 hours, for 55.69% of the respondents. The time spent at sea is closely related to the number of fishing trips (Muallil et al 2013). The longer the time spent at sea, in the fishing area, the greater the chance of getting a good catch. The capacity of the outboard engine used will affect the distance traveled. The greater the distance traveled across the fishing area, the greater the possibility of increasing the income (Al-Jabri et al 2013).

However, the extreme weather has prevented many fishermen from going to sea. Many fishermen spend their time repairing the fishing gear, such as longlines and gillnets. However, some respondents, as many as 3 - 5 fishermen, also try to fish around the coast to fulfill their family's needs even though the catch is not on target. The time spend at sea and the fishing technology used can significantly affect fishers' income also in combination with the global climate change (Shaffril et al 2017). Frequent extreme weather events can disrupt fishing operations or reduce the time spent at sea (Predragovic et al 2023). These conditions result in significant economic losses in the fishing industry worldwide.

Catch production and fishermen's decision to go to sea. The production function of the catch under normal conditions (catch season) uses an ordinary least squares (OLS) regression estimation model (Table 2). The decision function of fishermen operating during extreme weather events (potentially due to the global climate change) uses a maximum likelihood estimation of the logit regression model (Table 3). The goodness of fit of the catch production function, measured with the adjusted R^2 or Nagelkerke R^2 shows a contribution of all independent variables to the variation of the catch production reaching 87.3 and 84.9%, respectively, by to the fishers' decision function to catch fish. The F-test value was used to test the catch production function hypothesis simultaneously. In contrast, a -2 log likelihood estimation was used for the fishers' decision function to catch fish, and both values indicate that all independent variables have a simultaneous effect on the dependent variable.

On the other hand, the partial effect of independent variables was determined using the t-test and Wald-test on each function of catch production and fishermen's decisions to catch. The effect of changes in the independent variable the changes in the dependent variable (catch production and fishing decisions) by analyzing each of its regression coefficient values (β_i). The decision response of fishermen to catch fish uses the Exp (β_i) value or odds ratio to explain change of the probability (or potential opportunity) to catch fish on extreme weather.

During normal conditions or fishing season, small-scale fishers in the study area actively catch fish. As the catch production increases, it positively influences the enhancement of household economies. The estimated catch production results indicate that the fishing season significantly and positively affects catch production, with a regression coefficient value of 10.080, as shown in Table 2. During a fishing season in the Makassar Strait, fishermen keep track of the production increases. They assume that certain factors, such as the length of time spent at sea, the strength of the outboard engine, and social conditions (such as the fishers' age, formal education, and fishing experience), remain constant or are held constant, ceteris paribus. The positive value of the coefficient of fishing season has an impact on catch production. This finding supports the expected theory, that is, catch production is higher during the fishing season than during the off-season. Fishing season is crucial in increasing the effectiveness of fishermen's fishing and can significantly contribute to the household income (Rahim et al 2021) and consumption expenditure (Rahim et al 2018).The fishing season marks a higher abundance of fish biomass during a certain period, in response to environmental changes.

Table 2

Estimation of factors influencing catch production during the fishing season

Independent variable	*Expected sing*	*Coefficients (β_i)*	*Std. error*	*t-test*	*Sig.*
Catch season	Positive	10.080***	2.965	3.40	0.001
Time at sea	Positive	2.909***	0.455	2.80	0.007
Outboard engine power	Positive	2.578***	1.039	5.66	0.000
Fishers' age	Negative	0.620***	0.168	3.70	0.000
Fishers' education	Positive	0.991**	0.418	2.37	0.020
Experience at sea	Positive	0.439**	0.203	2.17	0.034
Intercept	-37.4366				
F-test	9.64				
Adjusted R^2	0.873				
n	79				

*** is a significance level (type 1 error) of 1% or a confidence level of 99%; ** is a significance level of 5% or a confidence level of 95%.

In contrast, when there is global climate change, such as extreme weather, small-scale fishers generally do not fish at sea. Fishers admit that bad weather conditions in the form of strong winds accompanied by waves of more than 2 m make it difficult for fishermen to catch fish by setting nets or fishing. Fishermen consider the safety risks to themselves and their boats, and often choose to rest while repairing damaged fishing gear and cleaning the boat engine. To fulfil the economic requirements of their households, including food and non-food expenses, some fishermen prefer to fish near the coast and not far from the coastal area. Despite their efforts in catching, they frequently experience situations when they fail to secure a catch. The estimation of the catch production's influence on the fishing decision shows a positive and significant effect, with a regression coefficient value of 0.269. Moreover, the Exp (βi) value of 1.309 is greater than 1, thus the opportunities for fishers to catch fish are getting bigger, even though the natural conditions are not expected (Table 3). These findings provide insights into how extreme weather events can affect fishing practices. Extreme weather events caused by global climate change (Ilarri et al 2022) can affect marine ecosystems (Servino et al 2018) and coastal areas (Selvaraj et al 2022). Despite the risk to the fishermen's safety. However, the economic needs of the household are most important for small-scale fishers in the study area. Fishing takes place close to land or in coastal areas. Short fishing times lead to drastically reduced catches and income. According to Rahim et al (2020), the area where fishermen live can influence fishermen's choice of fishing locations because it depends on the technology used, such as boats and fishing gear.

The small-scale fishers' catch is a primary source of income for coastal communities in developing countries. However, global climate change with extreme weather, such as tidal waves and sea breeze speeds, has disrupted shipping activities in the capture fisheries sector. This study result is in line with Thoya & Daw (2019): in Kenya, extreme weather has a long-term impact on the income of households that rely on fishing as main source of livelihood. The wind speed of the east and west monsoon negatively influences the time spent sea (Muskananfola et al 2021) and the catch yield, simultaneously increasing the risks, especially for the small-scale fishermen in coastal areas. Small-scale fishers heavily rely on stable weather for their economic activities (Shaffril et al 2017). The global climate change may cause temperature fluctuations in the Pacific Ocean (El Nino and La Nina). This phenomenon causes the sea surface temperature to change, thus affecting the pattern of fish life. The populations of many fish species will shift as temperature changes impact the upwelling zone, where foraging fish are typically found.

Table 3

Estimation of factors that influence fishers' decisions to catch during extreme weather events (possibly due to the global climate change)

Independent variable	*Coefficients (β_i)*	*Std. error*	*Wald-test*	*Sig.*	*Exp (β_i)*
Catch production	0.269	0.128	4.420	0.036	1.309
Outboard engine power	- 0.44	0.349	0.016	0.899	0.957
Time at sea	0.340	0.742	0.210	0.647	1.405
Fishers' age	- 0.149	0.162	0.793	0.373	0.861
Fishers' education	0.147	0.277	0.284	0.594	1.159
Experience at sea	0.031	0.132	0.054	0.817	0.970
Intercept		- 9.347			
Nagelkerke R^2		0.849			
-2 Log Likelihood		27.670			
n		79			

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

The time at sea covers the fishing operations during several trips (Muallil et al 2013). It has a coefficient value of 2.909 and has a positive and significant effect on the production of small-scale fishers on the coastal area of Makassar City (Table 2). The longest fishing time is 9 to 10 hours per trip for 31 of the fishermen (Table 1). On average, small-scale fishers leave or the fishing ground area at around 06.00 pm and return at dawn, around 05.00–07.00 am. The time spent at sea by small-scale fishers using motorized boats with outboard engines is significantly shorter than that of large-scale fishermen operating motorized vessels with higher gross tonnage power. The boat type commonly used in this area referred to as "Katinting". Fishing ground that is closer to the coast does not provide opportunities for small-scale fishers to get more catches. Thus, they can reduce their income. On the other hand, fishing ground areas that are far away provide higher opportunities to increase catch production.

Time at sea does not significantly affect fishing decisions for small-scale fishers when extreme weather conditions occur. Nevertheless, there is a tendency among fishermen to prefer prolonged fishing activities within the coastal proximity or in mainland areas (Table 3). These findings are evident from the Exp (βi) value of 1.405 as a high opportunity to catch. Extreme weather determines small-scale fishers to linger at sea to fish near the coast. Due to the high wind speed and rough sea waves, fishers refrain from venturing to sea, regardless of prevailing weather conditions. Small-scale fishers lack access to up-to-date weather information as a reference for fishing, relying solely on their fishing experience and senses to predict and locate fishing grounds (Muskananfola et al 2021). Furthermore, the variable power of the outboard engine used by small-scale fishing boats in coastal areas has the coefficient value of 2.578 with a positive effect on the catch production. The power of outboard engines, as a fishing technology for small-scale fishers, is the independent variable that has the greatest influence compared to other variables (catching season, length of time at sea, and social conditions of fishers). The power of the outboard engine or fishing technology used by fishers varies widely between 3 and 15 Power knots (PK). The use of 7 PK was the most widely used by as many as 17 fishers (21.51%), while five fishers (6.32%) used only 3 PK engines (Table 1). The decision of fishers in choosing far/near marine waters for fishing depends on the power of the boat engine (Rahim et al 2020), which enables them to reach the fishing ground and thus to increase their income (Al-Jabri et al 2013).

The age of fishers positively influences the catch production with a coefficient value of 0.620 (Table 2). Every time the fisher's age increases, the catch production increases, although, intuitively, increasing age will reduce the productivity. The physical demands of sea fishing necessitate fishers to possess robust physical strength, and the age of fishers significantly impacts their fishing choices (Liao et al 2019). At a relatively old age, they already have more work experience. However, their productivity will also decrease with physical conditions related to ageing. Young fishers are more likely to achieve significant catches due to their higher productivity than older fishers. Most of the respondents (27 individuals) were between 30 and 39 years. A small number of respondents (9) were between 50 and 59. All respondents (79 people) were at the productive age (Table 1). The small-scale fishers in the coastal area of Makassar City are responsible as family breadwinners so that older fishers maintain their productivity. In the Philippine West Philippine Sea region, the younger fishers catch fish more often than older fishers (Muallil et al 2013). It differs in Taiwan, where fishermen over 40 contribute to their household income by fishing in the sea (Lu et al 2020). In addition to the production factors, time at sea, and fishing technology, extreme weather conditions (season) influences the catch productivity and thus it indirectly affects the social and economic welfare of fishermen (Shaffril et al 2017).

Social conditions include age, education, family size, working families (Rahim et al 2022; Villasante et al 2022), while economic conditions include income (Di Cintio et al 2023; Alam & Yousuf 2024). In the current research, social conditions include age of fishers, formal education of fishers and fishing experience (Table 1). The age of fishers does not influence their decision to catch fish, regardless of the impacts of extreme weather conditions (Table 3). The extreme weather reduces their productivity, which records a relative increase with the age. This result is not in line with the findings of Samah et al (2019): in Malaysia, there is a non-productive age of fishers when extreme weather occurs, which affects the health of fishers, especially the elderly. The level of formal education is one of the indicators of productivity fluctuations. The higher the level of formal education, the higher the productivity. Managing a fishing business is a decision to take business risks. Coastal communities, in general, have acquired fishing knowledge through intergenerational transfer, as parents who work as fishers have passed down their expertise to younger generations. The formal education level of fishers has a coefficient value of 0.991. It has a positive and significant effect on increasing the catch production (Table 2). As formal education increases, small-scale fishers will be able to innovate to increase catch production.

In contrast, in the findings of Adili & Antonia (2017), related to the coastal region of Tanzania, in the Indian Ocean, the education level of fishermen does not affect the catch production. In the study area, the formal education level of fishers is primarily at the elementary school (ES) level, rather than in the junior high school (JHS) or high school (HS) level. (Table 1). Out of the total number of fishermen surveyed, 31 fishermen, or 39.23%, have elementary school education. Furthermore, 26.58% of the fishermen are junior high school graduates, while 12.65% are high school graduates. Therefore, fishermen’s formal education level is still low.

In connection with the extreme weather events, potentially due to the global climate change, income will decrease even more because low levels of education make it difficult to find work other than fishing or to innovate in fishing activities. Despite lacking formal education, small-scale fishers in coastal areas can innovate independently by drawing on the hereditary knowledge passed down to them by their parents, who also never attended school. According to the regression coefficient value estimation, education does not significantly affect the decision to catch. However, the Exp value (βi) of 1.159 is greater than 1 (Table 3), providing an opportunity to catch in extreme weather. Armed with experience at sea, fishers can catch around the coast, but not far from coastal areas, to meet the needs of their families. Small-scale fishers in developing countries still face negative stereotypes due to their lack of education, and this perception has not entirely disappeared. Coastal communities often suffer from economic deprivation due to limited access to formal education for fishers, resulting in structural poverty. Small-scale fishers are often marginalized as they belong to one of the most economically disadvantaged groups in many countries, often characterized as "the poorest of the poor."

Experience at sea as a factor of social conditions positively affects the production of fisher catches with a coefficient value of 0.439 (Table 2). The chance of getting more catches increases with a fisherman's experience in catching fish. The majority (51 individuals) of the fishermen with the most sea experience, were between 15 and 24 years old (Table 2). Small-scale fishing activities rely solely on work experience at sea and do not utilize guidelines or technology to determine the fishing grounds. The fishing knowledge and experience in determining gathering points, characteristics of fish and the type of bait used, acquired since the fisher’s childhood, have helped him determine the yield potential, but is the estimated yield might be different during extreme weather. Generally, fishers do not catch fish in the sea, but some catch it for household needs, although only on the outskirts near the coastal plains, producing small quantities of fish types which might not match the desired target.

Conclusions. Under normal conditions, small-scale fishers can improve their household economy by increasing the effectiveness of their fishing to obtain greater catches. Catch production is affected by various factors, including the fishing season, time spent at sea, fishing technology (such as outboard engine power), and social conditions (such as age, formal education, and experience of fishers). Climate change might introduce a bias, due to the influence of extreme weather events. Fishermen cannot fish under bad weather conditions in the form of strong winds accompanied by high waves. However, some fishermen fish near the coast and close to the coastal area to fulfil the economic needs of their households. The decision of fishers to go to sea is influenced by their catch potential, the time spent at sea, and their level of education. Education is the most significant factor in a fisher's decision to go to sea. Extreme weather events, occurring more frequently under the global climate change conditions, will impact fishermen's decision to catch fish. Fisher's decisions refer to the economic behaviour of small-scale fishers who produce in order to meet the economic needs of their households. In the face of climate change and extreme weather, small-scale fishermen can adopt an adaptation strategy. One of the main concerns in economic development policy is the development of adaptation strategies to climate change. To increase community resilience, adaptation strategies include reducing fishing trips to nearby coastal areas for safety, and utilizing aquaculture as an alternative to offshore fishing.

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