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Climate Change Represented by Seasonal Rainfall, Temperature, and Wind Speed Trends in North Coastal of Java, Indonesia: Implications on Marine Capture Fisheries

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***Abstract*— Climate change poses a significant threats to the livelihoods of people living in coastal areas, especially in the developing world. Consequently, locally relevant data are necessary to inform for livelihood adaptation planning. This study provides empirical information on historical and future seasonal climate trends based on observation and modeling. Modeling is a necessary tool for assessing future impacts of climate change. This study focuses in the North Coastal of Java, which is one of the most vulnerable regions of Indonesia, and where communities are highly dependent on capture fisheries. This paper presents information for historical and future seasonal climate trends in Northern Coast Regional of Java (NCRJ), Indonesia, where livelihoods are highly vulnerable to current climate change. Historical climate trend is investigated using observational data from two climate stations in NCJ, which are Tegal Station of Meteorological, Climatological and Geophysical Agency (Tegal SMCGA) and Semarang Station of Climatological and Geophysical Agency (Semarang SMCGA) from 1978 – 2017. Future climate is examined using a climate time trends model and predicted to 2100. Changes in temperature and wind speed of the NCJ are influenced by time and are expected to continue to increase every year. Temperature is suggested to increase by around 0.024 and 0.035, while wind speed also increased by 0.052. Temperature and wind speed changes that continue to increase each year indicate that the NCRJ is one of the coastal areas in Indonesia vulnerable to the climate change effects.**

***Keywords*—climate change; seasonal rainfall; marine capture fisheries; wind speed.**

I. INTRODUCTION

The coastal communities of developing countries in the Asia-Pacific region are heavy dependence on fisheries resources [1] and climate change impacts are most likely to be felt at the local scale by resource-dependent communities [2]. In general, resources- dependent communities are more susceptible to climate change impact, but they have more power to face the impact due to their experience facing climate variability as well [3]. Climate change is the most widespread anthropogenic threat for ocean ecosystems [4], affecting sea temperature, sea-level, ocean pH, rainfall and ocean circulation [5]. These effects of climate change on ocean conditions will have an impact on ocean organisms, the composition of marine communities and ecosystem function [6], increasing the complexity of the challenges facing fisheries [7]. Hence generating and effectively communicating locally-relevant climate change information is an important prerequisite for informed decision-making and livelihood adaptation planning [8]–[10]. At the minimum, the information should include climate variability and change which has been experienced historically and may be expected in the future, as well as the uncertainties around these estimates.

Some experts believe that changes in climate for the next decades will be faster than anything that the world has experienced since the beginning of the human civilization and will lead us to unprecedented conditions for the human society. As Diamond says, relatively small changes in climate have had, at times, tremendous consequences on societies locally, illustrating the potential for serious consequences of climate change [11], [12]. Murniati reported in her study that climate change will have multiple effects on food security in Indonesia, due to rainfall variability [13]. One of the primary challenges is that information about projected climate is usually only available at global and national scales, and is rarely available at the sub-national and local scale, especially in less developed countries [14]. This is also true in Indonesia, where little scientific data on current climate change available [15]. Hence there is a gap in research and capacity to monitor and climate change projects, particularly at sub-national and local scales [16], [17] where adaptation planning and the action should be done [18]. Herlina suggested that designing any program related to any community should include the community from the planning, implementing, and evaluating the program [19].

This study provides empirical information on historical and future seasonal climate trends based on observation and modeling. Modeling is a necessary tool for assessing future impacts of climate change. It focuses on the North Coastal of Java, which is one of the most vulnerable regions of Indonesia, and where communities are highly dependent on capture fisheries. The specific purposes of this study are: (1) to document the historical seasonal climate trends from climate station data; (2) to describe the likely future climate trends using the climate regression simulation model; and (3) to explain the potential implications for the capture fisheries sector.

II. Material and Method

A. *Observed data and study area*

Annual climate data of rainfall, air temperature, and wind speed from Semarang Station of Meteorological, Climatological, and Geophysical Agency (Semarang SMCGA) and Tegal Station of Meteorological, Climatological, and Geophysical Agency (Tegal SMCGA) were used. Semarang SMCGA representing areas of Batang and Kendal Regencies, while Tegal SMCGA represents Pekalongan, Pemalang, and Tegal Regencies. The focus of this study is the Northern Coast Region of Java (NCRJ), which is the most vulnerable to climate change compared to other regions in Indonesia (Fig. 1).

Fig. 1 Study area of the Northern Coast Region of Java

This is because the NCRJ is a relatively flat area. Besides, land in the NCRJ is a young sediment that has not experienced lithification processes; hence it was susceptible to land subsidence resulting in a higher risk of flooding. Within the next 100 years the coastline of Pekalongan Regency, Central Java, would shift 2 km inward due to sea-level rise of 80 cm [20].

B. *Climate trends*

Data on annual rainfall, air temperature, and wind speed from 1985 – 2017 from the Meteorological, Climatological, and Geophysical Agency of Central Java Province were used to evaluate the climate change trends in the north coast of Java. The climate change trends were also analyzed using the time trend model to understand whether there was any effect of time on each climate parameter. The model is as follows:

$$Y = \beta_0 + \beta_1 t \quad (1)$$

where:
Y = Rainfall; temperature; wind speed
β_0 = Constant
β_1 = Regression coefficient
t = Time

III. Result and Discussion

Climate change takes place for a long time (slow face) and changes slowly [21]. Changes in various climate parameters that take place slowly are due to various extreme events that occur in climate variability that takes place continuously. Table 1 shows the effect of time on climate parameters, including changes in rainfall, temperature and wind speed in the NCRJ.

A. *Historical observed climate trends*

1) Rainfall changes: Changes in rainfall on the NCRJ are not affected by time. The pattern of rainfall in Indonesia is generally influenced by several factors, including monsoon, Inter-Tropical Convergence Zone (ITCZ), Indian Ocean Dipole Mode (IODM), El-Nino Southern Oscillation (ENSO), and other regional circulation in the Pacific Ocean and the Indian Ocean, as well as local factors. Indonesia is in the equatorial region that geographically causes a large amount of evaporation and precipitation. Annual rainfall in Indonesia range from < 1000 mm in the eastern part to > 4000 mm in the western part of Indonesia, and it is classified as high with an average of >2000 mm [22]. Regression analysis of annual rainfall for 38 years on the NCRJ shows that no significant change in annual rainfall during this period. However, annual rainfall varies significantly among the years, ranging from about 1600 mm in the driest year to more than 3000 mm in the wettest year (Fig. 2).

TABLE I
CLIMATE TRENDS REGRESSION IN SEMARANG SMCGA AND TEGAL SMCGA

Dependent Variable	**Semarang SMCGA**						**Tegal SMCGA**					
	Variables	**B**	**R^2**	**t**	**Sig**	**CV**	**Variables**	**B**	**R^2**	**t**	**Sig**	**CV**
Rainfall §	Constant β_0 Time β_1	2343.142 -1.544	0.002	18.088 -.280	0.000 0.781	0.158	Constant β_0 Time β_1	1873.654 -3.011	0.014	20.695 -0.686	0.000 0.497	0.143
Rainfall ¶	Constant β_0 Time β_1	2203.284 9.344	0.023	12.721 0.646	0.000 0.526	0.154	Constant β_0 Time β_1	1869.232 -4.803	0.010	14.122 -0.435	0.000 0.669	0.157
Rainfall $	Constant β_0 Time β_1	2496.933 -18.970	0.019	8.251 -0.389	0.000 0.707	0.183	Constant β_0 Time β_1	1674.333 20.921	0.033	6.777 0.525	0.000 0.614	0.188
Temperature	Constant β_0 Time β_1	27.107 0.024	0.678	435.557 8.954	0.000 0.000	0.012	Constant β_0 Time β_1	26.641 0.035	0.577	247.364 6.716	0.000 0.000	0.017
Wind speed	Constant β_0 Time β_1	4.410 0.052	0.353	16.532 4.552	0.000 0.000	0.293	Constant β_0 Time β_1	3.689 0.020	0.031	8.981 1.029	0.000 0.311	0.186

§: Rainfall of the last 39 years (1978 – 2017); ¶: Rainfall of the last 20 year (1997 – 2017); $: Rainfall of the last 10 year (2007 – 2017); CV = coefficient of variant

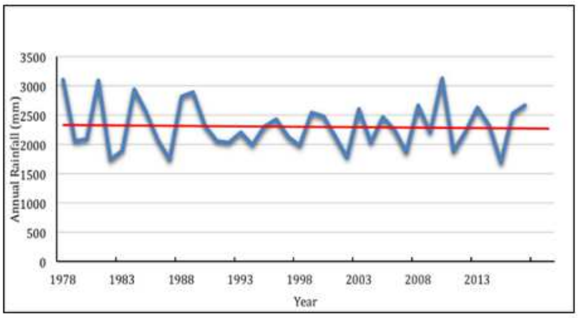

Fig. 2a Annual rainfall change in Semarang SMCGA

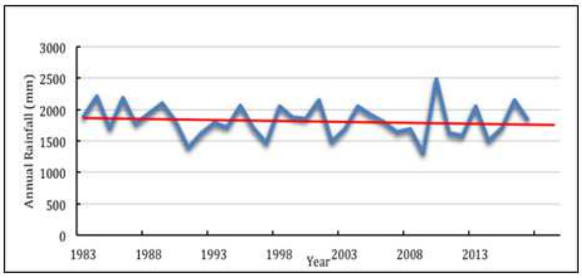

Fig. 2b Annual rainfall change in Tegal SMCGA

For example, annual rainfall in 2010 was much higher compared to the annual rainfall in 2009 and 2011. This variability was recorded by some communities such as farmers, and fishermen and mistakenly interpreted as climate change. The previous study conducted in Eastern Indonesia (Lombok) indicated different trends during the last 37 years [23]. Rainfall was reported to be drier indicated by increasing Q value for the Schmidt and Ferguson Climate Classification System from 105.45 (E type, slightly dry) in 1960 to 166.67 (F type, dry) in the year of 2000, Other studies in the Eastern Indonesia (Eastern Nusa Tenggara) indicated that annual rainfall was increased up to 20 – 30 % in the western part of Lombok, but it was decreased to about 30 - 40 % in Sumbawa [24]. The trend of decreasing annual rainfall was showed in a climate change study in Bengkulu Sumatera [25]. It was reported that during the last 40 years some areas of West Coast of Sumatra, annual rainfall was significantly decreased, resulting in shifting of the climate class from A (very wet, Q = 0 - 143) to B (wet, Q = 143 - 333) in the Schmidt and Ferguson Climate Classification System. Those vary responses to climate change among different areas indicating that local factor significantly affects annual rainfall in respective regions.

2) Temperature: Temperature changes on the NCRJ are influenced by time and have a regression coefficient of 0.024 in Semarang SMCGA and 0.035 in Tegal SMCGA, which means that every year there will be an increase in temperatures of 0.024°C and 0.035°C, respectively (Table 1). The rise in Earth's temperature is marked by sea surface temperature because it provides a more regional and global picture than the land temperature, which is affected by local factors. There is an increase in temperature on the NCRJ every year (Fig. 3). The year 2016 is the hottest year of all 37 years of recorded data. The average temperature of the earth's surface is around 0.45°C - 0.56°C. It is above the average temperature of the planet in the period 1981 – 201. This increase in temperature will continue to occur. The average temperature in Indonesia in 2000-2100 was estimated to increase by 1°C; it is higher than the rise in the previous century, of 0.65°C [26]. A similar trend of increasing temperature was reported by [19] in Eastern Nusa Tenggara.

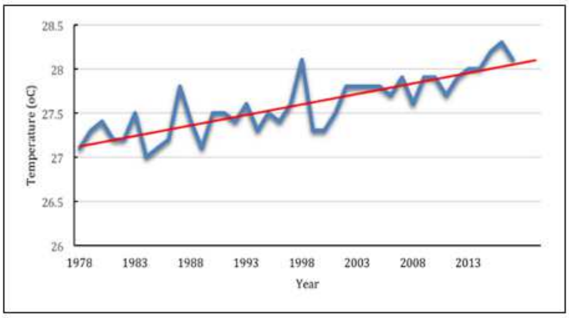

Fig. 3a Annual temperature change in Semarang SMCGA

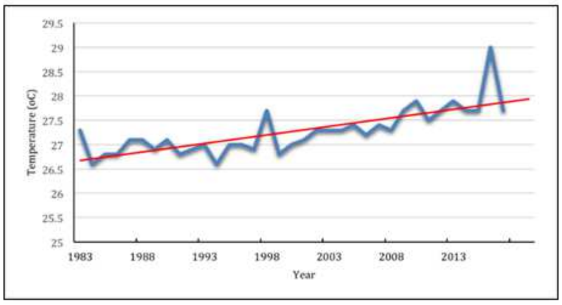

Fig. 3b Annual temperature change in Tegal SMCGA

3) Wind speed: Changes in wind speed on the NCRJ are influenced by time and have a regression coefficient of 0,052 in Semarang Station and 0.020, in Tegal Station which means that each year there will be an increase in wind speed of 0,052 km /hour and 0.020 km/hour, respectively (Table 1). Wind speeds on the NCRJ increase every year. Significant wind speed increase accrued in 2000 and 2015 indicating awful weather this year. In addition, since 1999 - 2002, there has been an increase in storms and high waves in Indonesia suggested as a result of climate change. Increasing wind speed resulting in increasing energy to blow water vapor to the more top place that promotes increasing cloud and rainfall.

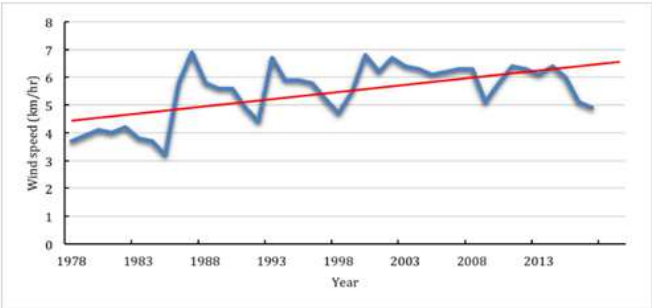

Fig. 4a Wind speed change in Semarang SMCGA

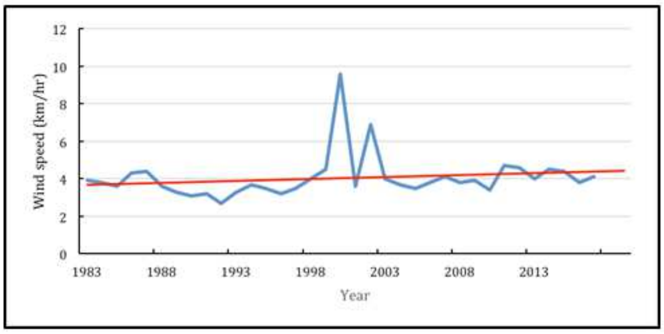

Fig. 4b Wind speed change in Tegal SMCGA

The wave highly correlated with wind speed and usually coincides with monsoonal winds known as West Monsoon (WM) and East Monsoon (EM) in Indonesia [27]. During December - February, the continent of Australia and the Coral Sea gets more solar energy and heat than the Asian continent and the South China Sea. As a result, low pressure occurs in the Australia continent while high pressure occurs in Asia. This situation causes wind currents from the Asian continent to the Australian continent. In Indonesia North Monsoon in the Northern Hemisphere while in the Southern Hemisphere known as Western to Northwest Monsoon knows this wind as the Northeast. In general, they have known as WM that coincide with the wet season in Indonesia. Because this wind passes through the Pacific Ocean and the Indian Ocean, that carries a lot of water vapor, resulting in the rainy season in Indonesia. The rainy season covers the entire territory of Indonesia, with uneven distribution, not only between the western and eastern parts of Indonesia but also between the coastal areas and the inland areas. The western and inland parts are wetter than the eastern and coastal parts [28]. An opposite condition occurs during June-August, which was known as EM that coincides with the dry season in Indonesia, with some exception of the west coast of Sumatra, Southeast Sulawesi, and the southern coast of Irian Jaya. Between the dry and the wet seasons, there is a season called a transition season, it occurs during March – May and September – November. The characteristics of the transition season are: high air temperature, irregular wind direction and sudden rainfall with high intensity occur in a short and dense time.

B. Future Climate Trends

1) Rainfall: Annual rainfall on the northern coast of Java do not affect due to time, which means that no significant annual rainfall changes during the last 37 years. It most likely due to the high variability of yearly rainfall among the recorded years, with the coefficient of variation (CV) is around 0,15 – 0,18 (Table 1). This high variation is mainly due to local factors that significantly affect the rainfall in certain areas. As mentioned before, that beside the monsoon, ITCZ, IODM, ENSO, and other regional circulation in the Pacific Ocean and the Indian Ocean, rainfall is significantly affected by local factors, such as topography, coastal or inland position, elevation, and leeward or backward positions.

It is predicted that in 2010-2039, there would be an increase in the chance of higher amounts of rainfall in Indonesia where the rainy season will be slightly longer than usual [19]. In addition, the Indonesian region is flanked by positive anomalies of 0.2-0.9 mm of rain zoning that occur around the Pacific Ocean and the Indonesian Ocean. Likewise, the case is found along the Karimata strait, the Banda Sea to the Arafura Sea [29]. The monthly rainfall in the Cisangkui watershed West Java would increase 15.5 – 24.5 mm in 2041 – 2060, and 1.5 – 5.5 mm in the period of 2061 – 2085 [30]. This forecast is in line with the results of simulations conducted by CNRM, which stated that until the end of the 21st century, there would be an increase in the amount of rainfall in Southeast Asia [31].

2) Temperature: One element of climate that functions as a weather controller are the air temperature. The fact is that the average air temperature in 1850 has changed considerably compared to the current situation. Based on the climate trend regression model, temperatures on the NCRJ will continue to increase until the year 2100 (Fig. 5). This is in line with the research of Ref. [32], which states that the average air temperature will continue to increase because higher levels of greenhouse gases trigger it in the atmosphere, including CO_2. There is a positive correlation between CO_2 concentration and air temperature, which means that the higher the concentration of CO_2 in the atmosphere, the higher the average air temperature.

An increase in average air temperature results in rising sea levels, which cause inundation on lowland and swampy areas in coastal areas and small islands. The sea-level rise causing several losses such as the erosion of coastline or abrasion and rob. Rob floods are expected to continue to increase both in frequency and affected areas in the future [33]. Rob flooding will also be a disaster that has a more severe effect due to improper land use and management in coastal areas. It will threaten the coastal line of more than 80,000 km in Indonesia [34, 35]. Increased development in coastal areas for economic purposes, tourism, residential areas, and industry and trade are forms of improper use and management of land in coastal areas [36]. The northern coastal region of Java, especially in cities located in the Northern Coast of Central Java, such as Brebes, Pemalang, Batang, Kendal, Semarang, Demak, Jepara and Rembang are cities that are often affected by tidal floods [37].

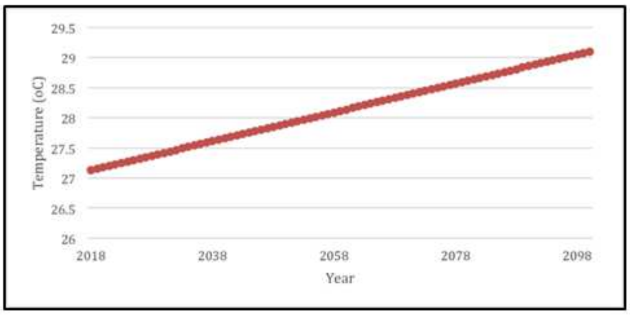

Fig. 5a Future temperature trend in Semarang SCMGA

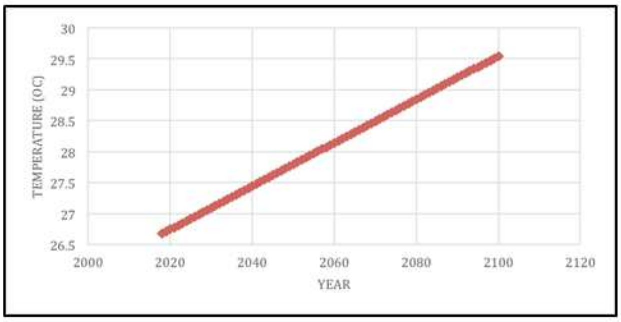

Fig. 5b Future temperature trend in Tegal SCMGA

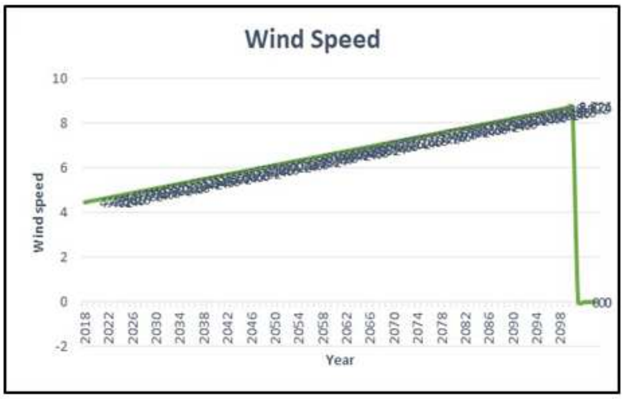

Fig. 5c Future wind speed trend in Semarang SCMG

3) Wind speed: The climate trends model predicts the speed of the wind on the NCRJ will continue to increase (Fig. 5). Strong winds have a large role in the occurrence of rob. As a strong wind occur, it will push the water vapor to the higher altitude that it promotes thunderstorm and higher wave, the sea level rise on the beach, which is commonly called wind set-up. Rob is a significant problem in the NCRJ and tidal floods have had several adverse impacts on residents around the coastal area. One of the negative impacts happened in the economic sector due to tidal flooding is a disturbance that directly impacts paddy fields. Consequently, it results in reducing land productivity. Mileti and Gottschlich *cited in* [38] state that there are at least three main systems are threatened with losses during a disaster, namely:

- Physical environment;
- Social environment, affect the quantity and quality of the population; and
- The built environment, such as buildings and infrastructure.

C. Potential implications of climate change on marine capture fisheries

Changes in rainfall significantly affect the number of trips and catch in the event of rain during the capture operation; it affects the number of settings and hauling resulting in reducing captured fish. As a consequent, fish production has decreased resulting in decreasing fishermen's income. Increased rainfall also causes disruption of water salinity that impacts the orientation of migration and distribution of fish. The high intensity of solar radiation on stiller sea-level conditions usually occurs during EM (March – November) causes higher absorption of heat into seawater to make a warmer water temperature. Conversely, in the WM (December-February), the temperature is cooler. This is because in WM the wind speed and the rainfall are high. The high rain means that the intensity of solar radiation is relatively low and the more undulating sea surface reduces the penetration of heat into seawater.

High wind results in increasing rainfall and faster movement of seawater, giving rise to tidal waves. The tidal waves of the sea as well as higher rain, result in rising local and temporary sea levels. Thus, large ocean currents will have an impact on the inundation of infrastructure in the coastal areas, damage the coastal ecosystem, and reduced the coastal land area. Fishing activities will undoubtedly be disrupted because of threatening weather, resulting in fishers losing their potential revenue. Fishers will feel expenditures due to abrasion because they must spend money to make dikes [39].

Fishers on the NCRJ also feel the impact of climate change on capture fisheries. Changing season patterns as a result of climate change makes it difficult for fishers to precisely predict the change between WM and EM occur. Many fishers mistakenly consider the seasonal wind patterns when going to sea and affect the safety of fishers and fish catches. It is related to their knowledge of climate change. Most fishermen are not well educated with respect to climate change. As mentioned by Murniati that education level will affect the capabilities of any community facing climate change [13]. Climate change also caused severe coastal erosion on the NCRJ. [40] Reported that the area lost from Brebes to Rembang reaches more than 4,000 ha. With an average loss due to abrasion is 5-30 meters per year. The abrasion also caused damage and loss of mangrove ecosystem, smallholder plantations, aquaculture areas, and residential settlements on the shoreline. It is about 96% of the mangrove ecosystem along the NCRJ was damaged generally due to abrasion. Overall, the impact of climate change felt by fishers in capture fisheries in the NCRJ is as follows:

- Decreased the quality of the coastal environment and small islands due to coastal erosion,

- Reduced fisheries productivity due to damage to mangrove ecosystems and coral reefs due to rising seawater temperature and changes in groundwater regimes.
- Fishers need more time and money to find fishing spots due to fish migration or damage to fish habitat and fishing ground.
- Damage to aquaculture land due to flooding caused by rising sea levels.
- Damage to houses and potential loss of life due to extreme events in the form of tropical storms and high waves [40].

IV. CONCLUSIONS

Changing in climate parameters, including rainfall, temperature, and wind speed, affect fishermen fishing activities of the NCRJ. There is an influence of time on changes in temperature and wind speed and is predicted to continue to increase every year. An increase in the average air temperature results in rising sea levels which causes several impacts such as increasing abrasion, areas and depth of tidal floods or rob, damaging infrastructure, and fishermen houses of the NCRJ. Rob floods are predicted to continue to increase both in frequency and depth in the future. Strong winds have a large role in the occurrence of rob. As a strong wind occur, it raises wave high and its power of destruction. The impact of climate change on capture fisheries on the NCRJ are: 1) decreasing the quality of the coastal environment and small islands due to coastal erosion; 2) reducing fisheries productivity due to damaging mangrove ecosystems and coral reefs; 3) requiring more time and money to find fishing spots due to fish migration or damaging fisheries habitat and fishing ground; 4) damaging aquaculture land due to flooding caused by rising sea levels, and 5) damaging houses and potential loss of life due to extreme events in the form of tropical storms and high waves.

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