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IMPACT OF GLOBAL WARMING ON AQUACULTURE IN NORWAY

M. Cüneyt Bağdatli [1], İlknur Uçak [2], Wadah Elsheikh [2]

[1] Nigde Omer Halisdemir University, Faculty of Architecture, Department of City and Regional Planning, Nigde, Turkey
[2] Nigde Omer Halisdemir University, Faculty of Agricultural Sciences and Technologies, Nigde, Turkey

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Corresponding Author
M. Cüneyt Bağdatli,
cuneytbagdatli@gmail.com

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ABSTRACT

While aquaculture is predicted to play a significant role in addressing future global food demands, climate change is having a complex impact on aquaculture output. Climate change will have an effect on output levels, growth, feeding efficiency, and consequently farm productivity and profitability. The most significant challenges facing aquaculture are current and future climate change, which affects the viability of fish farming in Norway and around the world. Global warming and climate change have resulted in a decline in lake waters, an increase in sea level, changes in streams, and changes in precipitation models, all of which have begun to have a negative influence on all aquatic animals. According to the findings of this study, the yearly maximum temperature was 21.1 °C in July and the lowest was -2.8 °C in January, with the minimum temperature ranging from 13.5 °C in July to -7.5 °C in January. The highest average temperature was 17.4 °C in July, and the lowest was -5.1 °C in January. In terms of precipitation, the greatest was 118 mm in August, while the lowest was 56 mm in March. In terms of rainy days, the highest total was 11 mm in August, while the lowest total was 6 mm in March. In November, the humidity reached 90%, whereas in June, it was 66%. On bright days, the highest daylight hours were recorded in June at 12.1 hours, and the lowest hours were recorded in December at 2.5 hours. In this research, we explicitly investigated how these climate components may affect aquaculture in Norway. As a result, because it affects the stability of fish farming, this significant environmental issue must be addressed. It is critical to shed light on and thoroughly analyse the elements related to climate change in order to avoid the damages that result from them, as well as to identify strategies to adapt to these conditions and limit their effects on production and productivity. Corrective efforts should be implemented to reduce climate change and its consequences on fish output.

Keywords: Global Warming, Climate Change, Aquaculture, Norway

1. INTRODUCTION

Climate change is affecting marine environments all around the world IPCC. (2014). with a rise in global mean surface air temperature ranging from 1°C to 4°C by 2100, depending on the greenhouse gas emission scenario adopted. Finfish aquaculture is becoming an increasingly important source of protein production for human consumption, adds to food security, and accounts for more than half of worldwide seafood output as the world's population increases food demand. Aquaculture is projected to become even more important in the future due to overexploitation of wild fish supplies Food and Agriculture Organization. (2018). Food production is a critical component of the climate challenge, and aquaculture is critical for global food security. According to the OECD/FAO, aquaculture production will surpass wild catch fisheries in volume for the first time in 2022 (Organization for Economic Co-Operation and Development, and F. A. O. (2019)). Norway is the world's leading producer of Atlantic salmon, and aquaculture is Norway's second most important export industry. The majority of the world's aquaculture production is carried out by small-scale growers in the global south Galappaththi et al. (2020).

Climate change has put the world in jeopardy as a result of increased carbon emissions and greenhouse gas emissions. Carbon is one of the most basic elements of life and exhibits search without being fixed. The level of CO_2 diminishes the protective effect of the bard layer. This has the effect of causing irregular precipitation and severe temperature increases Bağdatlı and Arıkan (2020). Population expansion, combined with the climate change phenomenon, will generate multiple problems for the global food supply, and we will confront numerous nutritional issues in the near future. By gradually attaining the world's 8 billion population, humanity faces a serious difficulty in meeting the expanding population's food needs Bağdatlı et al. (2015). Depending on population growth, it is very important to determine different food sources beforehand and to know the total production Oztekin (2021), Oztekin and Dingil (2022).

Today, there are many studies conducted to improve traditional agriculture Oztekin (2012), Oztekin (2021). However, climate change and increasing needs create the need for production in different areas. Aquaculture production has increased dramatically in recent decades, with global output increasing from 2.6 million metric tons (mt) in 1970 to 87.5 million mt in 2020 FAO (2022). This has been accomplished through widespread margin growth, as production has risen in new nations and for new species, as well as intense margin growth, as new knowledge and technology have led to more intensive production practices, typically on a bigger scale Asche et al. (2022). In fact, compared to wild fisheries landings, aquaculture output is concentrated on a few species, with carp, oysters, salmon, shrimp, and tilapia becoming genuinely global species farmed across many continents Garlock et al. (2020). The key drivers of this process are innovations, including information transfer and agricultural adoptions that contribute to increased productivity and cheaper production costs Kumar and Engle (2016).

Salmon is one of the most successful aquaculture species in terms of production growth, with a growth rate that is faster than overall aquaculture production growth, and it is the world's second largest species by value after shrimp Asche et al. (2022). Furthermore, it is technologically advanced in a variety of aspects, from inputs to the manufacturing process and the supply chain Kumar and Engle (2016). Norway is the largest producer, accounting for more than half of all production in most years Iversen et al. (2020).

Norwegian salmon has a similar role not only in salmon aquaculture, but also in aquaculture internationally, as knowledge and technology from salmon are transferred to other species Kumar and Engle (2016).

Norwegian salmon aquaculture consists of two species, Atlantic salmon (Salmo salar) and rainbow trout (Onchorynchus mykiss), and began in the 1950s as a "backyard business" by fisherman with a variety of alternative production concepts mostly inspired by the European trout industry Asche and Bjorndal (2011). Because Norway is a tiny country with a population of roughly 5 million people, the domestic market quickly became saturated, and the sector shifted to worldwide markets, exporting more than 95% of its production to over 100 countries Straume et al. (2020). Many obstacles confronting aquaculture both raise production costs, providing private incentives to fix the issue, and have environmental externalities that have necessitated actions or resulted in the use of alternative structures or sites to avoid the issues Asche et al. (2022). This incentivizes innovation. For illustrate, early tiny farms frequently operated in areas with poor water quality and oxygenation, which were aggravated by the farms and offered incentives to relocate farms to more exposed regions. Moving farms to progressively more exposed offshore locations has recently been encouraged in part by decreased salmon lice numbers Afewerki et al. (2023).

Climate change can stymie long-term progress in the aquaculture business by magnifying and compounding other environmental issues. Climate change may cause significant structural changes in aquaculture, including changes in fish species, optimal production range, and siting patterns. Temperature is critical in the aquaculture sector because it affects growth rate, algal blooms, and disease and parasite infestation rates. A warmer thermal regime may cause changes in species abundance, distribution, and composition. This includes jellyfish, poisonous algae, parasites, viruses, and illnesses, all of which have the potential to affect aquaculture, and the link between climate change and disease risks is becoming increasingly clear Callaway et al. (2012). Furthermore, atmospheric elements that include the climate variables such as air temperature, precipitation, relative humidity, atmospheric pressure, wind speed, etc., and the air pollutants affect each other in the atmospheric periphery Zateroglu (2021a), Zateroglu (2021d). Additionally, an increment in the emissions of air pollutants originated from anthropogenic and natural sources i.e., power plants, motor vehicles, fossil fuel combustion for domestic heating and industrial usage, population growth, has an impact on the urban climate system, degrade the urban air quality, and contribute the climate change Zateroglu (2021a), Zateroglu (2021d), Zateroglu (2021e), Zateroglu (2022).

Weather and climate have a significant impact on all sorts of agriculture, including aquaculture. The main issues influencing aquaculture include high temperatures, varying evaporation degrees, decreased rainfall, and high water consumption needs. Water temperature has a significant impact on aquaculture production Elsheikh et al. (2022a). Therefore, the purpose of this study is to investigate the effects of climate change on aquaculture productivity in Norway.

2. MATERIAL AND METHOD

The Norwegian coast is 21,000 kilometers long, with enormous potential for developing the country's fisheries and marine aquaculture. Norway has 90,000 km2 of sea under its authority, which is almost one-third of the entire land area.

The fishing industry has been a key industry in Norway throughout its history. Because of the country's geographical characteristics, vast coastline, and climatic variables, it is well suited for this business. According to the most recent FAO statistics, Norway was the ninth largest capture fishery and the seventh largest aquaculture producer in 2018 Organization for Economic Co-Operation and Development, and F. A. O. (2019). This study was conducted in Norway to study the effects of climate change on aquaculture Figure 1.

Figure 1

Figure 1 The Location of Research Area

In this study, the linear regression approach was used to analyze climate data, and the standard deviation was also obtained. The Linear Regression Model is the most often used type of regression in applications, and it is one of statistics' oldest and most investigated areas. Regression analysis is a statistical technique for explaining quantitative relationships between one or more explanatory variables and a response variable Salihi and Üçler (2021), Zateroglu (2021b), Zateroglu (2021c), Zateroglu (2021f), Zateroglu (2022).

3. RESEARCH FINDINGS

The long-term minimum, maximum, and average temperatures (°C), precipitation (mm), humidity (%), rainy days, and sunny hours data from the study region were studied in this study. Figure 2 depicts a fluctuation graph of the minimum temperature data.

Figure 2

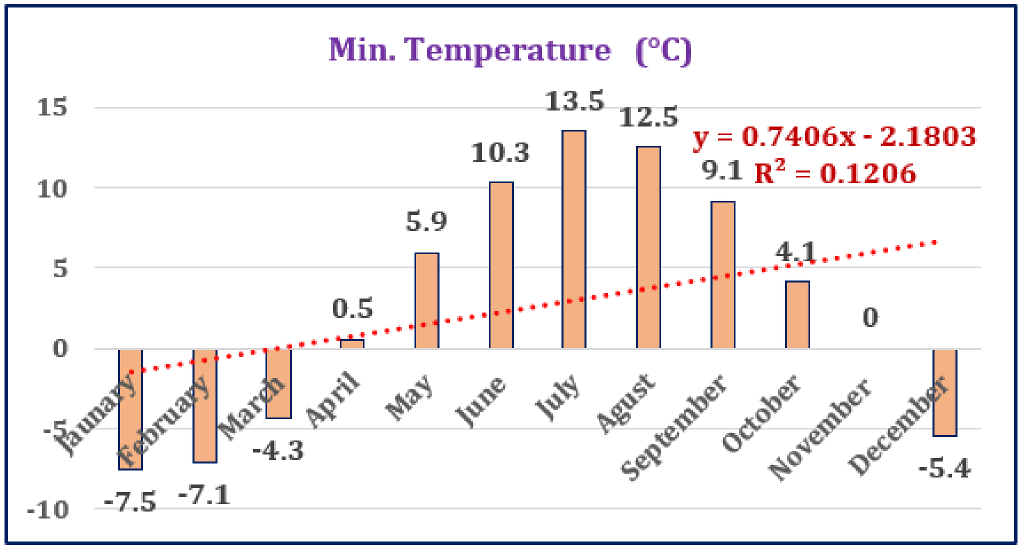

Figure 2 The Distributions of Min. Temperature

The minimum temperature ranged from 15.4 °C in January to -7.5 °C in June. R^2 for Minimum temperature is 0.1206 which mean actual values are not closer to predicted values. The variation graph of the max temperature data is shown in Figure 3.

Figure 3

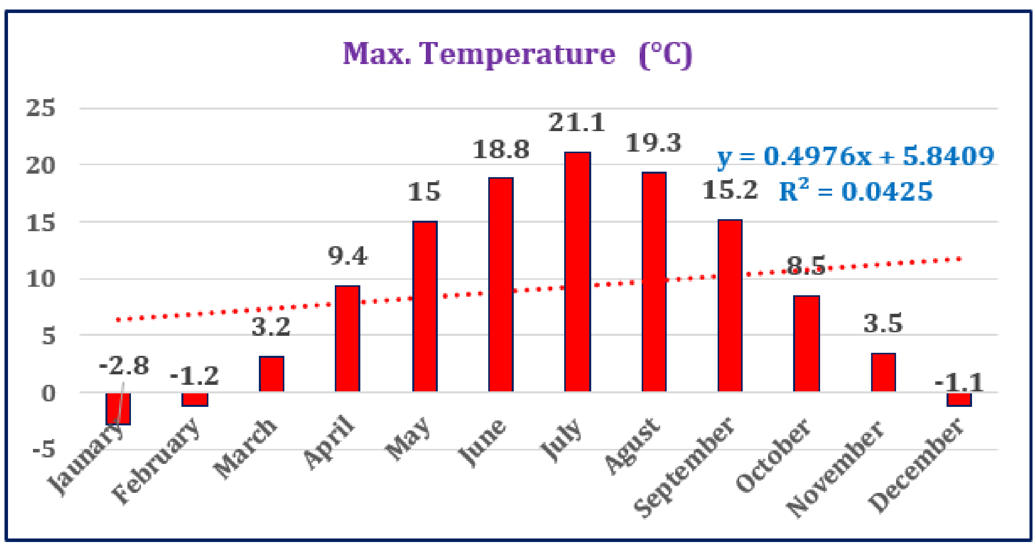

Figure 3 The Distributions of Max. Temperature

The annual maximum temperature was 21.1 °C in June, while the lowest maximum temperature was -2.8 °C in January. The R^2 for the highest temperature is 0.0425, indicating that actual measurements and projections are not very closely related. Figure 4 depicts a fluctuation graph of average temperature data.

Figure 4

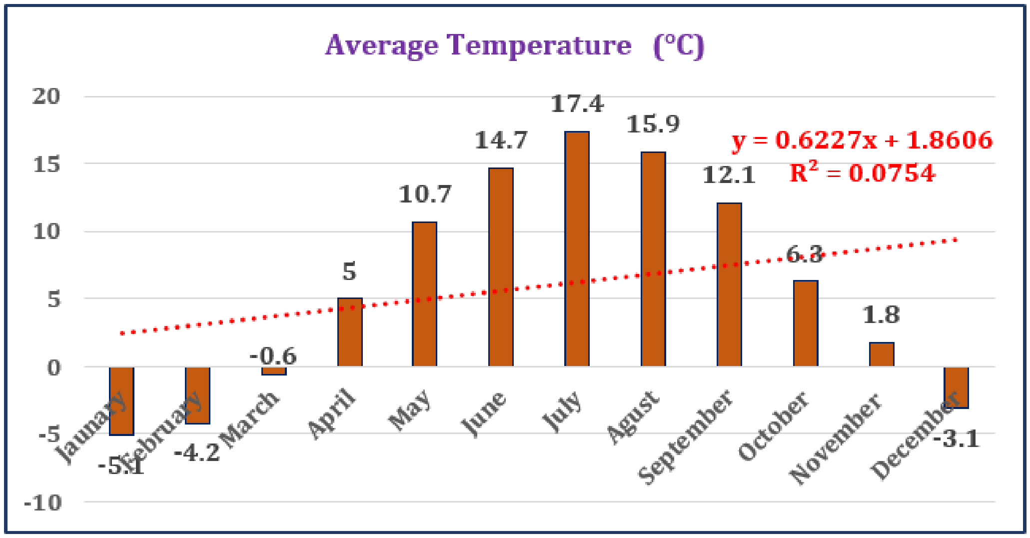

Figure 4 The Distributions of Average Temperature

The highest average temperature was 17.4 °C in July and the lowest was -5.1 °C in January. R^2 is 0.0754, indicating that real values are not much closer to projected values. Figure 5 depicts the Change graph of Precipitation data.

Figure 5

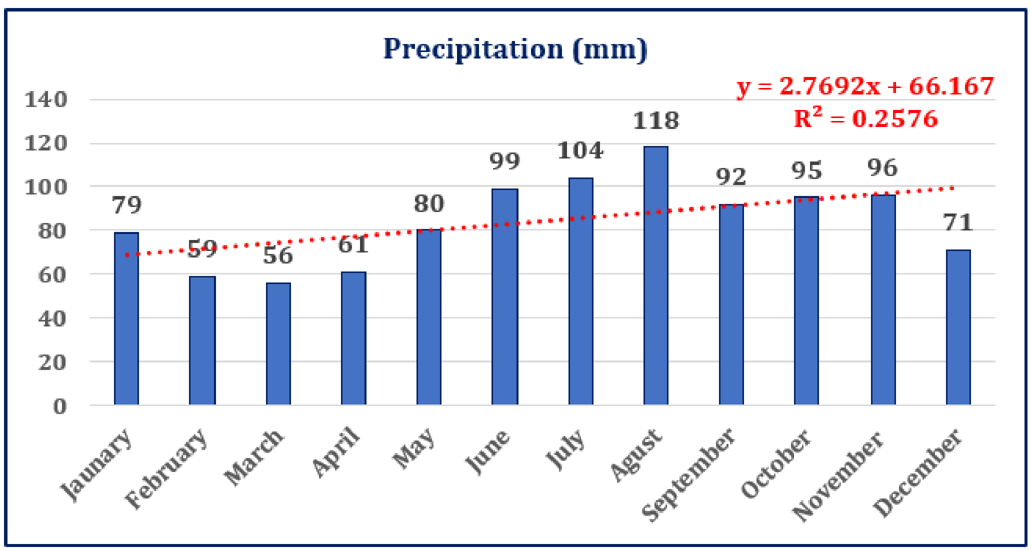

Figure 5 The distributions of Precipitation

In terms of precipitation, the highest total was 118 mm in August, while the lowest total was 56 mm in March. R^2 is 0.2576, indicating that actual values are not considerably closer to expected values. Figure 6 depicts the Rainy Days Change Graph.

Figure 6

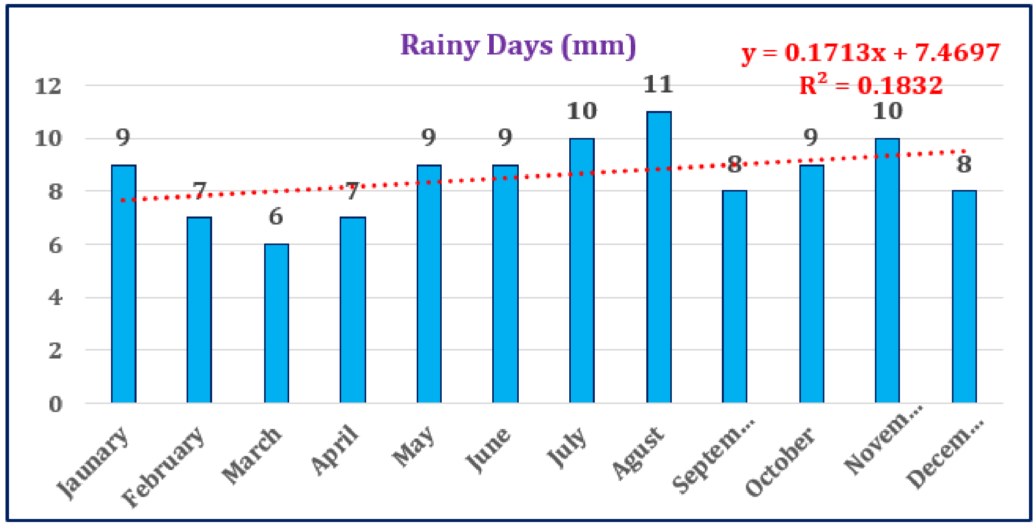

Figure 6 The distributions of Rainy Days

The rainy days in the study area had the highest value of 11 mm in August and the lowest value of 6 mm in March, with an R^2 of 0.1832, indicating that actual values are not substantially closer to expectations. The change graph of humudity is shown in Figure 7.

Figure 7

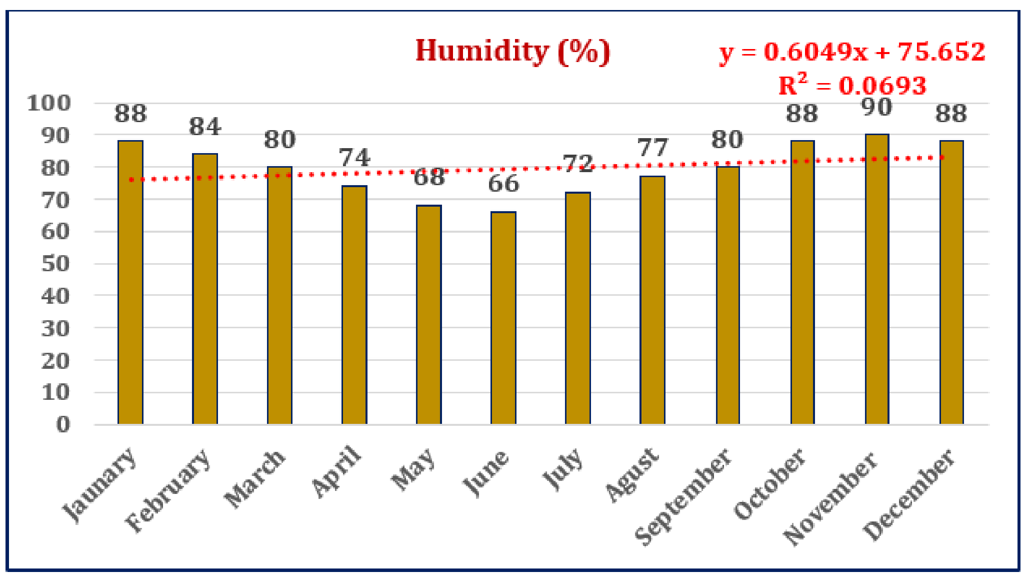

Figure 7 The distributions of Humidity

The maximum humidity was 90% in November and the lowest was 66% in June. R^2 was 0.0693, indicating that actual values are not significantly closer to expectations. The variation graph of the sunny days are shown in Figure 8.

Figure 8

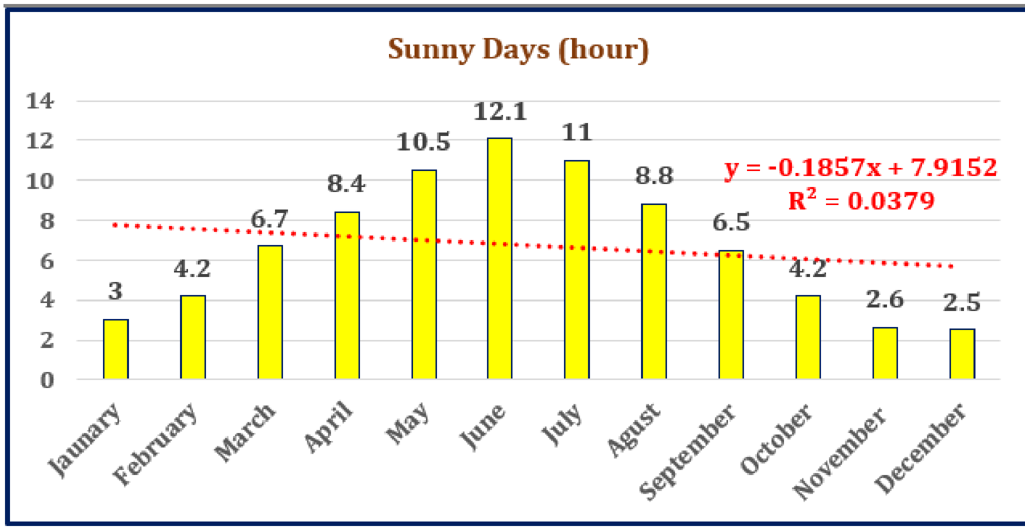

Figure 8 The distributions of Sunny Days

The maximum daylight hours were observed in June, when it was 12.1 hours, while the lowest hours were reported in February, when it was 3 hours. or sunny days, R^2 is 0.0379, indicating that actual values are not much closer to predictions. Table 1 summarizes the annual average and total values of some climate data, as well as the corresponding R^2 and standard deviations.

Table 1

Table 1 The average or total values and standard deviation of some climate data for Norway

Climate Parameters	Average	Standard deviation
Min. Temperature (°C)	2.63	7.6892
Max. Temperature (°C)	9.08	8.6995
Average Temperature (°C)	5.91	8.1754
Precipitation (mm) (Total)	1010.00	19.6739
Humidity (%)	79.58	8.2842
Rainy Days (Total)	103	1.4434
Sunny Hours (hour)	6.71	3.4387

Table 1 shows the climatic change data, including average temperatures (°C), minimum temperatures (°C), maximum temperatures (°C), precipitation (mm), humidity (%), rainy days, and sunny hours for the whole year. When we look at the standard deviation, average temperature, lowest temperature, maximum temperature, and humidity all have almost the same value but a lower value than precipitation. Rainy days and sunny hours have lower values than all other variables, indicating that these variables have relatively little variability across all months of the year; however, precipitation fluctuates so much since it has the largest standard deviation value.

Norwegian aquaculture has grown rapidly, particularly in the new millennium. The industry has improved in terms of biological elements and engineering, and new potential aquaculture species other than salmonids are emerging. This advancement, however, has brought forth some severe issues that must be recognized Bergheim (2012). Norway produced 4 million tonnes of fish (including mollusks and crustaceans) in 2018, worth USD 10814.6 million. Aquaculture contributed 77% of this value, while fisheries contributed 23%. The quantity generated climbed by 17% between 2008 and 2018, but the value increased by 104% Organization for Economic Co-Operation and Development. (2021).

Due to the thermal dependence of metabolic activity, predicted temperature changes are expected to have a major influence on ectothermic creatures such as fish. The last three decades have been noticeably warmer, with a rise in global surface temperature of +0.2 °C every decade. Climate forecasts for the next century show an increase in sea surface temperature of 1 to 3 degrees Celsius (DeLong et al., 2017; Morley et al., 2018). Furthermore, global circulation models forecast a rise in ocean heat content due to ice sheet and glacier mass loss, as well as an increase in the frequency, severity, and duration of extreme events. Warming trends have been more pronounced in the Northern Hemisphere than in the Southern Hemisphere, and warming rates are generally larger at higher latitudes than in tropical regions IPCC. (2019), Tokarska and Gillett (2018).

Climate change is predicted to endanger marine ecosystems and, as a result, aquaculture. Increasing sea temperatures may eventually cause significant changes in aquaculture species, optimal production ranges, and localization patterns. Increasing sea temperatures will cause a shift in the distribution of creatures in the water, including seaweeds, as well as a general northward shift of farmed organisms. Rising summer sea surface temperatures could be a concern for farmed animals acclimated to survive in cold water. As a result, aquaculture species productivity may suffer, and Southern Norway may become less appropriate for species such as salmon, with socioeconomic consequences Hermansen and Heen (2012), Stévant et al. (2017). Such climate changes may eventually result in northern areas being more suitable for mariculture than southern parts Bergh et al. (2007). A study conducted by Callaway et al. (2012) on the effects of climate change on aquaculture species in the United Kingdom and Ireland concluded that increased sea temperatures and changes in hydrodynamic regimes will have an impact on macroalgal cultivation; however, the effects will likely vary depending on species and geographic location Stévant et al. (2017). The aquaculture value chain is a growing sector of the Norwegian fish industry, with an estimated 33,700 employees in 2017 Johansen et al. (2019).

The aquaculture industry is reliant on the water quality and meteorological conditions along the Norwegian coast. The largest influence of climate change is thought to be on ocean temperatures and the frequency of extreme weather. Ocean acidification and salinity changes caused by increased freshwater intrusion into the straits may have an influence on this area in the long run. Which affects the contribution of fish farming to the annual fish production in Norway, as shown in Figure 9 World, B. (2020).

Figure 9

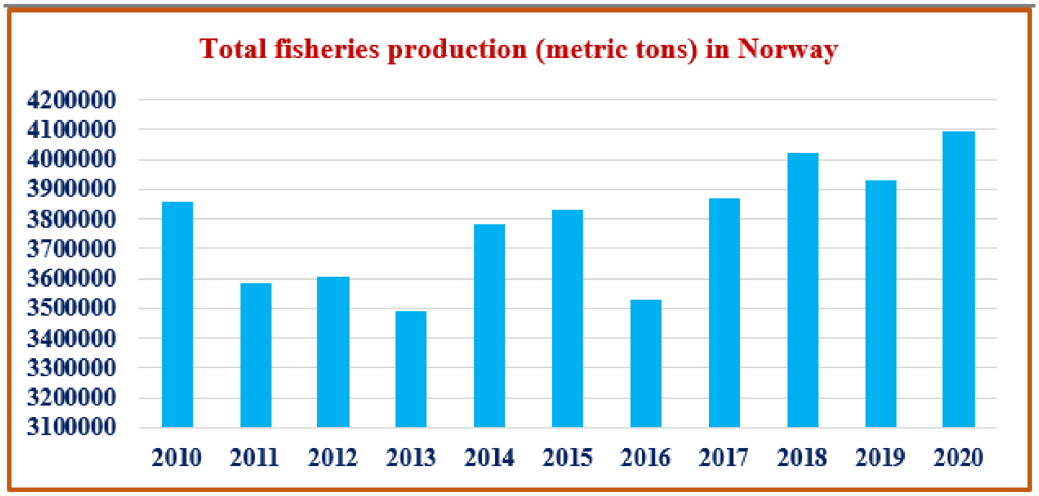

Figure 9 Total Fisheries Production In Norway (World Bank, 2020)

4. CONCLUSION AND RECOMMENDATIONS

Climate change has put the world at risk as a result of increased carbon emissions and greenhouse gas emissions. The level of CO2 reduces the protective use of the bard layer. As a result of this action, it produces unpredictable precipitation and severe temperature increases Bağdatlı and Arıkan (2020). Temperature extremes have a harmful impact on the lives of living creatures Bağdatlı and Can (2020), Afreen et al. (2022). Climate change and global warming are diminishing accessible water resources practically everywhere on the planet Uçak and Bağdatlı (2017), Elsheikh et al. (2022b).

Aquaculture and fisheries provide a safe refuge for millions of people who rely on them to sustain a decent standard of living. On the other hand, climate change is a huge threat to global fisheries and fish farming. As a result, this significant environmental issue must be addressed as it affects the stability of fish farming, which provides a source of income for millions of families in addition to being an essential food supply.

As a result, it is critical to shine a light on and thoroughly analyze the elements related to climate change in order to avoid the damages that come from them, as well as to identify strategies to adapt to these conditions and limit their effects on production and productivity. Future studies should be directly tied to adaptation to climate change. Rising sea temperatures are projected to threaten marine ecosystems by causing dramatic changes in aquaculture species, optimal production ranges, and settlement patterns, and southern Norway may become less suited for species such as salmon. All of these may have an impact on the production of aquaculture species.

CONFLICT OF INTERESTS

None.

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