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The Assessment Of Whale Shark Distribution In Correlation With Climatic Changes Along The Coastal Regions Of Thailand

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This study evaluates the distribution of whale sharks (Rhincodon typus) in relation to climatic changes along Thailand's coastal regions. Global climate change, including rising sea temperatures, shifts in ocean currents, and increased ocean acidification, has significantly impacted marine ecosystems and the behavior of large marine species such as whale sharks. The research examines whale shark sightings in key coastal areas, including Surin Island, Koh Ha, and Mu Koh Chumphon National Park, over a 20-year period using quantitative methods. Questionnaires were distributed to divers, fishermen, and local communities. The results reveal that 56.1% of the 305 respondents reported encountering whale sharks, with the highest frequency observed at Koh Ha and Hat Noppharat Thara-Mu Ko Phi Phi National Park (30.4%), followed by Shark Point in Phuket (21.6%) and Koh Tao (13.5%). A statistically significant correlation was found between changes in sea surface temperatures and whale shark sightings, with the correlation between respondents' experience and perceived climate change effects ($r = .389$, $p < .01$) and the correlation between specific climate change impacts and mitigation and adaptation measures ($r = .732$, $p < .01$).
These findings indicate that climate change significantly influences whale shark distribution and foraging behavior, prompting shifts in their migration routes and habitats. The study highlights the need for proactive management and conservation strategies to protect whale sharks and marine biodiversity in Thailand. It provides crucial insights for the sustainable conservation planning of marine species across Southeast Asia.

Keywords: Whale Shark, Climate Changes, Coastal Regions, Marine Species.

Introduction

The Impact of Extreme Weather Events on Global Climate

The global climate is undergoing a profound transformation, with the intensity and frequency of extreme weather events escalating at an alarming rate. These extreme events, such as heatwaves,

intense rainfall and flooding, prolonged droughts, and wildfires, are the manifestations of the broader climate change phenomenon driven by human activities. According to the United Nations Framework Convention on Climate Change (UNFCCC, 2021), the world has entered a new era of "extreme weather" conditions, which have far-reaching consequences on various aspects of human and environmental well-being. The Intergovernmental Panel on Climate Change (IPCC) has linked the observed increase in global average temperatures to the surge in greenhouse gas emissions from human-induced activities, primarily the burning of fossil fuels, deforestation, and industrial processes.

The World Meteorological Organization has reported that these extreme weather patterns are adversely impacting agriculture, food and water security, public health, and triggering mass displacement of vulnerable populations. The economic toll of the damage to infrastructure and ecosystem degradation is estimated to reach hundreds of billions of dollars annually.

For Thailand, the Global Climate Risk Index 2021 by Germanwatch ranks the country as the 9th most vulnerable to the impacts of climate change, based on the extreme weather events experienced between 2000 and 2019 (Yang et al., 2021).

The Impact of Climate Change on the Behavior and Habitat of Whale Sharks

The impacts of climate change on marine ecosystems are becoming increasingly apparent, with significant consequences for large marine species like whale sharks. (Alter et al., 2010) Climate-driven changes in ocean temperatures, currents, and chemistry are altering the distribution and abundance of whale sharks' prey, forcing these animals to adapt to new environmental conditions. (Simmonds & Isaac, 2007), (Alter et al., 2010), (Simmonds & Isaac, 2007).

One of the primary ways of climate changes affecting the whale sharks is through changes in water temperature (Wang, 2022). The whale sharks are sensitive to water temperature, and as ocean temperatures rise, they may be compelled to shift their ranges to cooler waters (MacLeod, 2009). This can disrupt their traditional migratory patterns and foraging grounds, potentially leading to declines in their populations (Alter et al., 2010).

Moreover, the warming of the oceans is altering the distribution and abundance of the plankton and small fish that constitute the whale shark's diet. (Grose et al., 2020), (Wang, 2022) As the base of the marine food web is disrupted, whale sharks must search for new feeding grounds, which can be energetically costly and expose them to increased risks. (Wang, 2022)

In addition to temperature, changes in ocean chemistry due to increased CO2 absorption are impacting the health and reproduction of whale sharks and their prey. Ocean acidification can disrupt the formation of shells and skeletons in many marine organisms, reducing the availability of food for whale sharks (Wang, 2022). Furthermore, the effects of ocean acidification on the reproductive success of whale sharks and other large marine species remain poorly understood, but could lead to population declines.

Climate change is an increasingly pressing concern that has far-reaching implications for the survival and distribution of various marine species, including the iconic whale shark. One of the key factors contributing to the decline in whale shark populations is the indirect impact of human activities, particularly through the effects of climate change on fishing practices and marine pollution. (Alter et al., 2010) (Wang, 2022)

Conservation Status of Whale Shark in Thailand

The global conservation efforts for the whale shark (Rhincodon Typus) have been driven by the impacts of climate change on their survival. Worldwide, the whale shark (Rhincodon typus) is listed as "Endangered" on the International Union for Conservation of Nature (IUCN) Red List, due to various threats such as habitat destruction, illegal fishing, and bycatch in fisheries (Perrin, 2002).(Morales-Ramírez & Wang, 2020) In Thailand, the whale shark is also considered a protected species under the Wildlife Preservation and Protection Act of 2019, reflecting the country's commitment to safeguarding this iconic marine creature.

Thailand's coastal regions, particularly the Andaman Sea and the Gulf of Thailand, serve as important habitats for whale sharks (Morales-Ramírez & Wang, 2020). These gentle giants are frequently sighted in popular diving destinations like Koh Tao, Koh Phi Phi, and the Similan Islands, which attract numerous tourists and divers. The presence of whale sharks in these areas has fostered the development of ecotourism, provided economic opportunities while also highlighted the need for sustainable management practices. (Adisubroto & Pardede, 2021). To effectively protect the whale shark population in Thailand, a comprehensive conservation strategy is crucial. This would involve continued research to understand the species' population dynamics, threats, and habitat requirements, as well as strengthening enforcement to combat illegal fishing and trade. Collaboration between local communities, government agencies, and international organizations will be essential in developing and implementing effective conservation measures that ensure the long-term survival of the whale shark in Thailand and the broader Southeast Asian region. The aim of assessing the distribution of whale sharks in relation to climate change along the coast of Thailand is to investigate sightings of whale shark populations over the past 20 years in the coastal areas where encounters with whale sharks occur frequently. These areas include Surin Island, Koh Ha, Shark Point Phuket, Lipe, Mu Koh Chumphon National Park, and Koh Bida - Hin Bida. The data collected will help to project the likelihood of whale shark encounters in the next 20 years and can provide important information for the sustainable conservation of whale sharks in the marine environment.

Research Objective

The research objective is to analyze historical patterns and frequencies of whale shark encounters in specific coastal regions of Thailand—known for repeated sightings—over a twenty-year period. With the following secondary objectives:

1. To study the potential influence of climate change on the dispersal and presence of whale sharks in these areas. The sites of focus are Surin Island, Koh Ha, Shark Point Phuket, Lipe, Mu Koh Chumphon National Park, and Koh Bida - Hin Bida
2. To analyze the future trends in whale shark population encounters for the coming two decades
3. To gather vital information that could contribute to the sustainable preservation of whale sharks in their natural marine habitats

Research Conceptual Framework

The conceptual framework for the assessment of whale shark distribution in relation to climate change along the coastal regions of Thailand involves the following Figure 1.

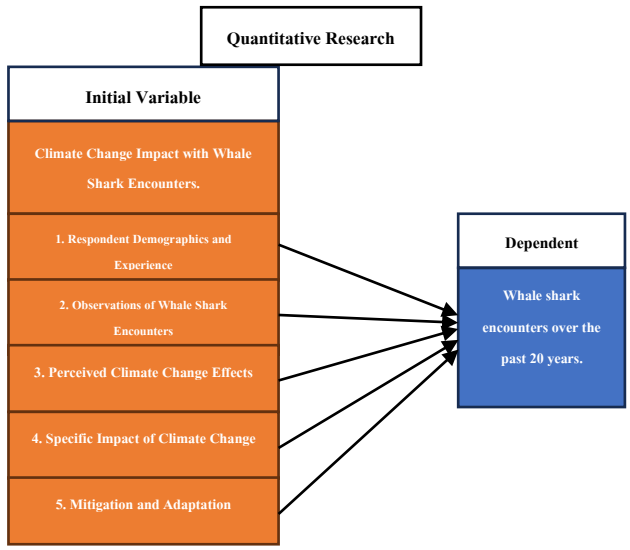

Figure 1 Conceptual Framework of Research

The Assessment of Whale Shark Distribution in Correlation with Climatic Changes Along the Coastal Regions of Thailand

This framework operates on the assumption that climate change is a key driver in altering marine habitats and whale shark distribution, potentially affecting the availability of food sources and the migration patterns of whale sharks.

Research Contributions

Build up a model that we can share publicly to locals and build up a model that explores climate change to use it as reference for researchers in the future.

Literature Reviews

Overview of Whale Shark Biology and Ecology

- Whale shake Taxonomy (Rhincodon typus).
  Kingdom: Animalia
  Phylum: Chordata
  Class: Chondrichthyes
  Subclass: Elasmobranchii

Order: Orectolobiformes
Family: Rhincodontidae
Genus: Rhincodon
Species: Rhincodon typus
Scientific Name: Rhincodon typus

The study of whale shake taxonomy is a fascinating field that delves into the intricate classification and relationships among these marine mammals. Cetaceans, which include whales, dolphins, and porpoises, are the most diverse group of aquatic mammals, with a fossil record dating back to the Middle Eocene period. The evolutionary history of these creatures is closely tied to their terrestrial ancestors, the nemonychids, which were primitive hoofed mammals with omnivorous diets (Fordyce et al., 1994).

- General characteristics and behavior of whale sharks.

Whale sharks, the largest known species of extant fish, are truly remarkable creatures that have captivated the attention of marine biologists and nature enthusiasts alike. These gentle giants, which can reach lengths of up to 18 meters (59 feet) and weigh as much as 34 metric tons (37. 5 short tons), are known for their distinctive spotted patterns and unique feeding behaviors. (Chang et al., 1997), (Stevens, 2007).

One of the most fascinating aspects of whale shark biology is their reproduction. Despite their massive size, very little is known about their reproductive habits, with fewer than 250 sightings recorded in the scientific literature (Chang et al., 1997). What is known, however, is that whale shark courtship involves intricate behaviors, such as males ceasing feeding, becoming aggressive, and displaying dominance behaviors to others. (Perry et al., 2020) During courtship, a female may be approached by either a solitary male or a group of males, who will then focus on or "nose" her cloaca, using their mouths to make and maintain contact with the female (Perry et al., 2020).

- Habitat preferences and migratory patterns.

Animals exhibit a remarkable diversity of movement patterns, driven by their innate preferences for specific habitats and the need to navigate dynamic environments (Joo et al., 2022). Migratory behavior, in particular, plays a crucial role in the survival and reproduction of many species, as individuals seek out optimal conditions for feeding, breeding, and avoiding threats (Hobson & Norris, 2008). Understanding the habitat preferences and migratory patterns of various animals is a central focus of ecological research, as it sheds light on the complex interplay between an organism's physiological adaptations, environmental factors, and evolutionary pressures.

Developing a comprehensive theory that explores the broader range of variation in movement patterns is essential for scaling up our understanding from the individual to the population and ecosystem levels (Shaw, 2020). Integrative frameworks, such as the movement ecology paradigm, provide a valuable lens for examining the multifaceted nature of animal movement, encompassing the internal state, motion, and navigation capacities of the individual, as well as the external factors that shape and constrain these behaviors.

Global Distribution of Whale Sharks

- Geographic regions where whale sharks are commonly found.

One such region is the Azores archipelago, located in the North Atlantic Ocean. The Azores are considered a "mid-Atlantic hotspot for marine megafauna research and conservation" (Afonso et al., 2020), hosting a diverse array of vulnerable and endangered vertebrate species, including whale sharks. The Azorean waters provide favorable conditions for whale sharks, with the presence of nutrient-rich currents and high biomass of potential prey items attracting these filter-feeding giants. (Romagosa et al., 2019) (Afonso et al., 2014) (Silva et al., 2013)

The mid-equatorial Atlantic, especially around the remote archipelago of St. Peter and St. Paul, Brazil, is a significant region for whale shark aggregations. These isolated volcanic islands are believed to be an important reproductive habitat for whale sharks in the central South Atlantic due to high abundances of whale sharks throughout the year. Additionally, the central South Atlantic is home to another significant whale shark aggregation site - the island of St. Helena. This remote island, located in the mid-South Atlantic, has been identified as an important reproductive habitat for the species, with consistent sightings of pregnant female whale sharks and newborn pups. The presence of these vulnerable life stages underscores the ecological significance of St. Helena as a critical refuge for whale shark populations in the Atlantic Ocean. (Hazin et al., 2008) (Macena & Hazin, 2016) (Stevens, 2007)

Whale sharks are commonly found in the Azores, St. Peter and St. Paul, and St. Helena but their distribution extends to tropical and subtropical waters across the globe, including the Indo-Pacific, Atlantic, and Caribbean Sea (Stevens, 2007) (Macena & Hazin, 2016) (Afonso et al., 2014) (Martin, 2007). Their remarkable migratory abilities have enabled them to thrive in numerous geographic regions worldwide.

- Seasonal and migratory movements on a global scale.

The study of seasonal and migratory movements on a global scale encompasses various disciplines such as ecology, climatology, and zoology (Bauer & Hoye, 2014). Tracking the movements of these organisms has become increasingly important in understanding the intricate web of interactions that shape our planet's ecosystems. Recent technological advancements have provided researchers with unprecedented insights into the spatio-temporal patterns of animal migrations, allowing for deeper appreciation of their evolutionary significance (Gnanadesikan et al., 2017).

Climate Change and Its Impact on Marine Ecosystems

- Overview of climate change effects on marine biodiversity.

Climate change poses a significant threat to the health and viability of the world's marine ecosystems, with far-reaching consequences for the biodiversity and ecological balance of our oceans. One of the primary drivers of these changes is the rapid warming of ocean temperatures, which has been well-documented in numerous scientific studies. As global temperatures continue to rise, marine heatwaves are becoming more frequent and intense, disrupting the delicate balance of these ecosystems. (Brown et al., 2024) (Williamson & Guinder, 2021)

- Impact of sea surface temperature changes on marine ecosystems.

The impact of rising sea surface temperatures on marine life is significant, with effects including more frequent and intense marine heatwaves, shifts in species distribution and behavior, disruptions to established fisheries, and potential consequences for ocean chemistry and circulation patterns. These changes are projected to have far-reaching and unprecedented ecological implications (Frölicher et al., 2018). As the global community works to address the root causes of climate change, targeted efforts to understand and mitigate the impacts of ocean warming on marine ecosystems will be crucial for ensuring the long-term resilience and sustainability of these vital natural resources. (Hennige & Roberts, 2019) (Doney et al., 2012) (Hoegh-Guldberg & Bruno, 2010) (Williamson & Guinder, 2021).

- Effects of ocean currents and their changes due to climate variations.

Ocean currents are driven by differences in water density influenced by factors like temperature, salinity, and the Earth's rotation. Warmer surface waters flow from the equator, while cooler waters sink and flow towards it, creating a global system of interconnected currents that transport heat and nutrients around the world. Climate change can affect these currents through altering wind patterns, changing ice melt rates in polar regions, and modifying ocean temperature and salinity balance.

One of the most significant impacts of climate change on ocean currents is the potential slowdown or even collapse of the Atlantic Meridional Overturning Circulation (AMOC), a crucial component of the global ocean circulation system. This circulation pattern is driven by the sinking of cold, dense water in the North Atlantic, which in turn drives the flow of warmer surface waters northward. However, as the climate warms, the melting of Arctic sea ice and the influx of freshwater from the Greenland ice sheet can disrupt this delicate balance, potentially leading to a slowdown or even a complete shutdown of the AMOC (Liu et al., 2017)(Delworth et al., 2008).(Frajka-Williams et al., 2019)Such a scenario could have far-reaching consequences, including changes in regional weather patterns, a decrease in the transport of heat to the North Atlantic region, and disruptions to marine ecosystems and fisheries.

The effects of climate change on ocean currents are not limited to the Atlantic, however. In the Pacific Ocean, the weakening of the Walker circulation, a large-scale atmospheric circulation pattern, has been linked to the intensification of El Niño events, which can have significant impacts on global weather patterns, marine ecosystems, an d human communities (Jiao, 2023).(Coats & Karnauskas, 2018). Similarly, in the Southern Ocean, the strengthening of the Antarctic Circumpolar Current due to changes in wind patterns and the melting of sea ice can have cascading effects on other ocean currents and the distribution of nutrients and other essential elements.

Overall, the effects of climate change on ocean currents are complex and far-reaching, with the potential to disrupt the delicate balance of global climate and marine ecosystems. Understanding these impacts and developing strategies to mitigate and adapt to them is crucial for the long-term sustainability of our planet.

- El Nino and La Nina acidification on marine species and habitats.

The El Niño-Southern Oscillation (ENSO) is a major driver of global climate patterns, with significant impacts on marine ecosystems around the world (Chapter 16: El Niño–Southern Oscillation, 2013). While the effects of El Niño and La Niña events on marine species and habitats have been extensively studied, the role of ocean acidification in modulating these impacts is less well understood. Ocean acidification, driven by the uptake of atmospheric carbon dioxide, is a critical threat to marine life, altering the chemistry of seawater and affecting the ability of organisms to build and maintain calcium carbonate shells and skeletons (Godbold & Calosi, 2013).

Ocean acidification can have widespread effects on marine organisms, with the severity of impacts depending on factors such as an organism's ability to regulate internal pH, the energetic costs of calcification, and interactions with other stressors. (Andersson et al., 2015) For example, many calcifying organisms like corals, mollusks, and echinoderms are highly vulnerable to the dissolution of their shells and skeletons under acidified conditions. (Cooley et al., 2009) Furthermore, reduced pH can impair other physiological processes such as growth, reproduction, and immune function in a wide range of marine taxa (Andersson et al., 2015).

Coral reefs are among the marine ecosystems most at risk from the combined effects of ocean acidification and climate variability associated with El Niño and La Niña events (Veron, 2011). Corals, the foundation species of reef ecosystems, are highly sensitive to changes in seawater chemistry and temperature. However, the long-term prognosis for coral reefs remains dire, as the frequency and intensity of these climate events are predicted to increase under climate change. (Andersson & Gledhill, 2013) (Veron, 2011) (Hoegh-Guldberg et al., 2017) (Hoegh-Guldberg et al., 2007). Widespread coral bleaching and mortality events have already been documented, leading to a dramatic loss of reef biodiversity and ecosystem services.

Methodology

Research Design

This study used survey research with a quantitative method to explore a relationship between the distribution of whale sharks and the impact of climate change along Thailand's coastal regions.

Population and Sample

- Population: The target population includes scuba divers, dive shop operators, local communities, and fishermen in key whale shark habitats such as Surin Island, Koh Ha, Shark Point Phuket, Lipe, Mu Koh Chumphon National Park, and Koh Bida-Hin Bida.
- Sample Size: A purposive sampling method will be used to select participants with extensive knowledge and experience in these areas. Approximately 400 respondents will be targeted, ensuring a balanced representation from different stakeholder groups.

Data Collection Methods

Quantitative Data Collection:

Questionnaires: Structured questionnaires will be distributed to scuba divers, dive shop operators, local peoples, and fishermen to gather data on whale shark sightings, perceived impacts of climate change, and local environmental changes over the past 20 years.

Historical Data Analysis: Analysis of existing records and databases on whale shark encounters, sea surface temperatures, and other climatic factors over the specified period.

Research Instruments

- Questionnaires: Developed to capture data on demographics, whale shark encounter frequency, and perceptions of climate change impacts.

Data Analysis

Quantitative Analysis

- Descriptive Statistics: To summarize demographic data and frequency of whale shark sightings.
- Trend Analysis: To examine changes in whale shark distribution and climatic variables over the past 20 years.
- Correlation Analysis: To explore relationships between climatic factors (e.g., sea surface temperature) and whale shark sightings.

Results

In this section, the researchers presented that this research employed a quantitative approach, utilizing questionnaires as the primary research instrument. The sample population included scuba divers, dive shop operators, local communities, and fishermen in key whale shark habitats, such as Surin Island, Koh Ha, Shark Point Phuket, Lipe, Mu Koh Chumphon National Park, and Koh Bida-Hin Bida. The research findings were divided into the following four parts.

Part 1: The Results of General Data

In this part, we analyzed the survey respondents reveals that the majority are female, totaling 181 individuals, which constitutes 59.3% of the respondents. This is followed by male respondents, totaling 109 individuals, accounting for 35.7%. The LGBTQ+ group represents the smallest category, with 15 respondents, making up 4.9% of the total. The age group with the highest representation is between 31 and 50 years old, with 201 individuals, accounting for 65.9% of the total respondents. In terms of experience, the majority of respondents have less than one year of experience in diving or working at a dive shop, totaling 131 individuals, which is 43.0%. This is followed by the group with more than 10 years of experience, comprising 75 individuals or 24.6%. Those with 1 to 5 years of experience account for 19.0% with 58 individuals, and the group with 6 to 10 years of experience represents the smallest category, with 41 individuals, accounting for 13.4%. The total number of respondents, after consolidating all age groups, is 305.

Past 2: The Results of Encountering whale sharks

In this part, the researchers analyzed encountering whale sharks reveals that most respondents, 171 individuals or 56.1%, have encountered whale sharks, while 134 respondents, or 43.9%,

have never encountered them. The primary role of the respondents is that of divers, comprising 175 individuals or 57.4%. This is followed by those involved in fishing, with 82 individuals or 26.9%. Observational tourists from boats make up 34 individuals or 11.1%, and the smallest group is tour guides, with 14 individuals or 4.6%. Among those who have encountered whale sharks, the most commonly reported location in Thailand is other sites such as Koh Haa and Hat Noppharat Thara-Mu Ko Phi Phi National Park in Krabi Province, reported by 52 individuals or 30.4%. The second most reported location is Shark Point in Phuket, with 37 individuals or 21.6%, followed by Koh Tao with 23 individuals or 13.5%. Mu Koh Chumphon National Park was reported by 19 individuals or 11.1%, Koh Bida - Hin Bida by 15 individuals or 8.8%, and Surin Island by 14 individuals or 8.2%. The location with the fewest reports is Lipe, with 11 individuals or 6.4%.

Past 3: The Results of Whale Shark Encounters and Climatic Changes Along the Coastal Regions of Thailand

In the past, researchers analyzed factors related to whale shark encounters and climate change in Thailand. The research results indicated that Respondent Demographics and Experience (OE) had a mean of 3.1698, which is closer to the highest possible value (4.00) than the lowest (2.00), with a low standard deviation (0.46270), indicating low variability in the data. Perceived Climate Change Effects (PE) had a mean of 2.5508, with a range from 1.00 to 3.80 and a standard deviation of 0.58989, indicating moderate variability. Specific Impact of Climate Change (CE) had a mean of 2.0203, with a range from 1.00 to 3.00 and a standard deviation of 0.54986, also indicating moderate variability. Mitigation and Adaptation (MA) had a mean of 2.8131, with a range from 1.20 to 3.80 and a standard deviation of 0.64530, indicating higher variability compared to OE, PE, and CE (Table 1)

Table 1 Mean and Standard Deviation of Whale Shark Encounters and Climatic Changes Along the Coastal Regions of Thailand

Variables	M	SD	Variance Level
Respondent Demographics and Experience (OE)	3.1698	0.4627	Low
Perceived climate change effects (PE)	2.5508	0.5899	Moderate
Specific impacts of climate change (CE)	2.0203	0.5499	Moderate
Mitigation and adaptation (MA)	2.8131	0.64530	High

Past 4: The Results of Analysis the Correlation between Whale Shark Encounters and Climatic Changes

In this past, researches analyzed correlation related between Whale Shark Encounters and Climatic Changes that respondent demographics and experience (OE), perceived climate change effects (PE), specific impacts of climate change (CE), and mitigation and adaptation (MA), were all significantly correlated. The OE variable had a positive correlation with both PE and CE, with OE3 showing a high correlation with OE1, OE2, and OE5, and a positive correlation with PE (r = .147*) and CE (r = .261**). The PE variable had a significant positive correlation with MA, especially PE1, which had a negative correlation with OE (r = -.347**) but a strong positive correlation with PE (r = .852**). The CE variable had a positive

correlation with MA, with CE4 showing a high positive correlation with CE (r = .293**) and MA (r = .578**). The MA variable had a positive correlation with CE and PE, with MA5 showing a high correlation with MA (r = .732**) and a strong positive correlation with PE (r = .344**). These findings indicated that climate change had impacted whale shark encounters in various areas of Thailand, and the relationships between the variables helped to explain the effects of climate change on whale shark distribution (Table 2).

Table 2

The Correlation between Whale Shark Encounters and Climatic Changes

	OE1	OE2	OE3	OE4	OE5	PE1	PE2	PE3	PE4	PE5	CE1	CE2	CE3	CE4	CE5	MA1	MA2	MA3	MA4	MA5	OE	PE	CE	MA
OE1	1																							
OE2	.398**	1																						
OE3	.426**	.508**	1																					
MA4	0.027	0.02	0.108	-.140*	.184**	.223**	0.091	0.082	0.073	-.323**	-0.095	.164**	0.001	-0.023	0.032	0.082	.280**	0.06	1					
MA5	-0.107	.211**	-0.025	-.129*	.238**	.344**	-0.081	0.031	.306**	.434**	.113*	.279**	0.029	.258**	.238**	.220**	.376**	.618**	-0.087	1				
OE	.540**	.511**	.767**	.385**	.239**	.268**	.198**	.236**	.193**	.227**	-0.089	-0.061	.215**	.414**	-.161**	.137*	.307**	-0.036	0.086	0.088	1			
PE	-.122*	0.061	.147*	.140*	.535**	.636**	.371**	.675**	.587**	.640**	.418**	.229**	.176**	.314**	.295**	.293**	.134*	.273**	0.059	.363**	.389**	1		
CE	0.03	-0.107	0.056	.261**	0.005	0.048	0.096	.351**	.344**	.686**	.593**	.669**	.445**	.503**	.707**	.279**	0.07	.217**	0.013	.315**	.128*	.508**	1	
MA	-0.088	0.102	0.063	-0.068	.293**	.461**	-0.065	0.077	.301**	.303**	0.031	.356**	0.043	.283**	.212**	.578**	.558**	.801**	.362**	.732**	.152**	.383**	.312**	1

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

Conclusion and Discussion

The descriptive analysis was conducted in alignment with the first research objective. The impact of climate change on the behavior and habitat of whale sharks (Rhincodon typus) was highlighted in this study, focusing on the changes in sea temperature and ocean chemistry caused by climate change. These changes have affected the distribution and migration of whale sharks, potentially forcing them to alter their habitats and foraging routes, which could lead to population declines in areas severely impacted by climate change. (Mullins et al., 2024)

The broader impact of climate change on marine biodiversity and the provision of ecosystem services was also examined. The projected changes in the distribution of whale sharks and other marine megafauna species due to climate change will have cascading effects on the communities and economies that depend on them (Grose et al., 2020)(Sequeira et al., 2014).

The data revealed that the majority of respondents who had encountered whale sharks had a high level of interaction with the species. The largest group, consisting of 171 individuals (56.1%), reported encountering whale sharks, primarily in areas with favorable marine environments, such as Koh Ha and Hat Noppharat Thara National Park in Krabi Province.(Adisubroto & Pardede, 2021)(Piboon et al., 2022)

Climate change may have affected the distribution of whale sharks in various regions of Thailand, as shifts in sea temperature and chemistry could result in reduced food sources, compelling the sharks to relocate or alter their migration routes in search of more suitable environments. As climate change continues to impact marine ecosystems, it will be crucial to

monitor and understand the implications for key marine species like the whale shark, in order to develop effective conservation strategies and ensure the sustainability of coastal livelihoods (Hossain et al., 2018). (Hossain et al., 2018) (Legaspi et al., 2020) (Sequeira et al., 2014) (Mullins et al., 2024)

When analyzing the survey responses and statistical data, it was found that whale shark distribution is closely related to the changing marine environment due to climate change, particularly in areas with rising sea temperatures or changing ocean currents. These shifts have caused whale sharks to adapt their foraging and migration behaviors, which may lead to population declines in regions more heavily affected by climate change.The results from this study emphasize the need for proactive management and conservation measures to protect vulnerable marine species like the whale shark from the impacts of climate change. Integrated coastal zone management and community-based adaptation strategies will be critical in addressing the complex challenges posed by climate change to the marine environment and the communities that depend on it (Ahmed & Diana, 2015) (Sequeira et al., 2014) (Islam et al., 2018) (Mullins et al., 2024).The data suggest that climate change has a clear impact on the behavior and distribution of whale sharks in Thailand. Statistical data and survey results indicate a decline in whale shark sightings in certain areas, aligning with studies that suggest whale sharks are likely to relocate due to environmental changes in marine habitats. Additionally, the public's interaction with whale sharks serves as an important indicator of changes in the species' distribution in the studied regions. (Whitehead et al., 2019), (Djunaidi et al., 2019)

The correlation analysis was conducted in accordance with the second research objective. This research was found that climate change has had a significant impact on marine ecosystems, particularly on the distribution of whale sharks, which are highly sensitive to changes in sea temperature. These temperature shifts force whale sharks to migrate to cooler waters, which may affect their migration patterns and food sources, especially the availability and distribution of plankton and small fish that constitute their diet. Additionally, the increased absorption of CO_2 in the oceans has led to greater ocean acidification, which impacts the health and reproduction of whale sharks and other marine species. This could potentially lead to a decline in whale shark populations and affect their distribution along Thailand's coasts.

To mitigate the effects of climate change on whale sharks, policymakers should consider implementing place-based conservation strategies that take into account the species' sensitivity to environmental changes. Evidence-based decision-making, as well as a deeper understanding of the impact of climate change on marine megafauna, will be crucial for developing effective conservation plans (Rosa et al., 2017) (Sequeira et al., 2014). Furthermore, the effects of climate change on coastal fish populations, such as bull sharks, must also be considered, as these species are already at risk due to overfishing and habitat degradation. (Mullins et al., 2024)

The analysis of key variables revealed that OE (Respondent Demographics and Experience), representing the demographic and experience data of respondents, showed a statistically significant positive correlation with PE (Perceived Climate Change Effects) at 0.389. PE, which reflects the respondents' perceptions of the effects of climate change, had a strong positive correlation with MA (Mitigation and Adaptation), with MA5 having a high

correlation with MA (r = .732**) and a strong positive correlation with PE (r = .344**). (Parganiha et al., 2019), (Ma et al., 2022)(Lee, 2018), (Akhtar et al., 2018).

These findings indicate that climate change has a significant effect on the distribution of whale sharks in Thailand. The changes in sea temperature and ocean acidification have forced whale sharks to alter their migration and feeding behaviors, potentially leading to a population decline. Furthermore, the relationship between the variables suggests that respondents with experience and knowledge about the effects of climate change are more likely to perceive and understand these impacts. The positive correlation between OE and PE demonstrates that knowledge and experience in marine environments can enhance understanding of climate change impacts, leading to greater support for mitigation and adaptation measures to sustain whale shark populations in the long term (Mendoza et al., 2019), (Cooley et al., 2023), (Legaspi et al., 2020).

In conclusion, individuals with marine experience and knowledge about the impacts of climate change tend to have greater awareness and understanding of these issues. This leads them to support mitigation and adaptation measures aimed at conserving whale sharks. Climate change has a significant impact on the distribution and population of whale sharks in Thailand, making conservation and adaptation efforts essential to protect this species in the future.

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