Trajectory Analysis of the Impacts of Climate Change on the Pacific Great White Shark Population

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Introduction:

Drastic anthropological effects on the world's ecosystems have been magnified as marine apex predators are disproportionately affected by the alterations to their environment. The great white shark is among one of the most evasive predators for researchers to track, as their migration patterns and population statistics are difficult to consistently monitor. The drastic rise in greenhouse gas levels have shifted scientific terminology from "global warming" to "climate change." As a result, the adverse effects of ocean acidification and a drastic increase in ocean temperatures have begun to disproportionately affect the great white shark population. As the planet is warming, the ocean is absorbing roughly half of the carbon dioxide being emitted by the anthropological actions of industrialization (Boyd *et al*). The global average sea surface temperatures are predicted to rise due to the greenhouse effect by 1°–3 °C by 2100 and this is in addition to an increase of ~0.76 °C in the last 150 years (Pistevos *et al*).

White sharks are primarily concentrated in the Pacific Ocean along the west coast of North America in the summer and autumn and move west and south at the beginning of winter. The shark's migration offshore has been hypothesized to be due to foraging where recent tracking technology can trace the shark's location to a place called the "white shark Café." The "Café" is in the west Pacific Ocean, where sharks migrate west off the coast of North America (Carlisle *et al*).

As migration patterns displayed throughout the Pacific are being altered, researchers predict predator starvation, as the fish and marine life that serve as prey to white sharks are altering their consumption patterns and feeding locations. White sharks may have increased difficulty locating prey due to a vast change in location—higher latitudes—causing the sharks to travel greater

distances to feed and dramatically change their points of travel based on water temperature. The compounding effects of climate change on marine life has caused an inconsistency in migration across trophic levels, meaning with a change in location for the smallest prey, the entire food chain to relocate and travel to where cooler, more temperate water can be found (Pistevos *et al*).

Methods:

i. Migration Patterns

Great white sharks are global migrators, utilizing open water migration to forage and reproduce. As largely solitary predators—primarily eating and traveling alone—it is imperative for sharks to travel to common locations in order to mate and feed. The recent development of PAT (Pop-Up Satellite Archival Tracking) tracks the water pressure and temperature while the tagged shark swims and allows researchers to identify great white sharks' migration patterns. With the tagging study, the long-distance migration patterns tracked great whites spending August-January in offshore habitats off the coast of North America, between Mexico and Canada, and extending to Hawaii and as far west as Midway Island. White sharks are dispersed throughout this large area as a place for potential courtship for mating and foraging for food (Jorgensen *et al*). The consistency of the shark's migration varies, however, it is being altered with the changes in the ocean's water temperatures, as the entire oceanic ecosystem is being greatly impacted.

ii. Ocean Acidification

The ocean's elevated temperatures and gradual acidification has drawn researchers to analyze how this is affecting the food chain in its entirety. Studies have shown that the changes that are occurring in the ocean's water have caused fish's metabolic and respiratory rates to increase, which will impair aerobic scope and increase their need for food, which will be in a smaller demand. Studies have also seen that the increase in respiratory rates reduces a fish's scope to feed, digest, grow, reproduce, and avoid predators. However, these impacts will not affect all marine species, an increase in metabolism and limited aerobic scope have been observed in

temperate species. Larger predators, like the great white shark, have had interactive effects of elevated CO_2 and temperature, which has clouded their behavior and physiology, leading to disturbed predation tactics (Pistevos *et al*). The regions of the Pacific Ocean where temperatures are rising at relatively higher rates will have a positive correlation in the increase of CO_2 levels. The changes in the ocean's CO_2 will break down the marine food chain, where white sharks will be forced to adapt as their prey changes their feeding habits and location. White sharks are more susceptible to faster growth rates due to higher food intake and metabolic rates; therefore, this outcome will result in a high dependency on food availability (Nilsson *et al*).

iii. Change in Migration Patterns

Climate change is indefinitely altering predation for white sharks, as the elevated temperature of ocean water and CO_2 levels reduces the sharks' abilities to hunt and efficiently maintain control over the marine food chains. As their environment changes, the necessity for sharks to migrate to suitable climates will also directly impact the type of ecological influences these climatic stressors impose. White sharks are a migratory species that travel vast distances to feed and as their prey relocates, they will also change their migratory patterns. Sharks can relocate due to their ability to travel vast distances to a more temperate habitat in higher latitudes, however, this will affect the strength of their interaction within the systems they leave behind, which will introduce heightened pressures on the new habitats they occupy (Robinson *et al*).

Conclusion:

Although the findings on shark's patterns of migration have only been conclusive recently, the research completed is essential to compare with the changes in shark behavior as the ocean acidification and temperature rise. The global study CLIOTOP (Impacts on Oceanic Top Predators) has addressed the current trajectory of how marine ecosystems are evolving and utilizing current climate models in order to analyze the changes in biological patterns and how that will impact future marine ecosystems. The findings concluded, determined that shark's current measured body mass will fluctuate as they begin to travel to higher latitudes for feeding.

White shark consumption rates in waters offshore in the Pacific and near Hawaii were exponentially higher than the feeding rates in North Pacific waters (Hobday *et al*). Therefore, researchers are continuing to analyze how white sharks will adjust their feeding habits as they continue to migrate to new waters.

References:

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