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Investigating the Influence of Physiographic Factors on Habitat Selection by Cetacean Species in Marine Environments

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Abstract

Habitat selection in marine environments is a critical aspect of understanding the behavior, distribution, and survival of marine species. As marine ecosystems are diverse and complex, the habitats offer varying resources, conditions, and ecological riches that influence the choices of organisms. The aim of the research is to investigate the influence of fisheries and physiographic factors on habitat selection by cetacean species in marine environments (Frouin et al., 2023). Habitat use of six different species of cetaceans using summer shipboard survey data. A total of 528 cetacean species were collected from marine environments. The habitat characteristics, such as bathymetric depth and seabed slope, were used as covariates in the analysis, with depth and slope data gathered from geospatial datasets. The presence or absence of each species at specific survey locations was recorded, and environmental data were organized into structured formats for analysis. Results revealed that depth and slope significantly affect cetacean habitat selection. Fin whales prefer depths >200 m and steep slopes; striped dolphins favor shallower waters <100 m depths. For the fin whale, the absence rate was 68.3%, while the presence rate was higher at 89.5%. In contrast, the striped dolphin showed a higher absence rate of 72.3% with the presence rate at 67.6%. The sperm whale demonstrated a notable pattern, with an absence rate of 72.7% and a presence rate of 82.8%. These findings highlight the depth, slope, and temporal factors that significantly influence the presence or absence of cetacean species and offer important insights for conservation and habitat management strategies.

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Introduction

Cetacean species in fisheries, which include dolphins and whales as well as porpoises, select their habitats based on multiple physiographic traits (Stanković & Ćurĉić, 2020). Mosquera-Guerra et al., (2022) explain that these features determine which marine environments these species can inhabit (Tokur & Korkmaz, 2017). The important aspects of undersea surveys consist of ocean floor morphology as well as underwater depression levels as well as geological formations ranging from ridges to canyons (Mawer et al., 2023). Water depth stands out as the main environmental factor that determines where cetaceans choose to reside. Whenever cetaceans seek food sources, they mostly inhabit deep ocean regions with ample resources in fisheries even though dolphins usually stay near coastal waters (Reisinger et al., 2022). Various species rely on different levels in the water column; some feed in deep water, while others use nutrient-rich shallow coastal zones in fisheries (Saidova et al., 2024). Dolphin habitats are distributed according to the shape of the seafloor, which includes features like seamounts, subduction trenches, and continental slopes (Sanganyado & Liu, 2022). Large concentrations of prey, including fish and krill, are typically produced by these underwater structures, which also form upwelling areas or places where nutrient-rich waters are pushed upward toward the proximity of the marine environment of fisheries (Kerfouf et al., 2023; Ranganathan, 2019). The organisms that are drawn to these biologically rich locations are cetaceans, specifically the ones that feed directly on these prey items (Hucke-Gaete et al., 2024). The formation of natural migration corridors between hills and valleys can provide cetaceans with paths for seasonal travels. The water's currents and temperature gradient are conditioned by numerous additional physiographic elements (Campana et al., 2022). It is necessary to have favorable oceanic conditions before choosing a particular dolphin habitat of fisheries. Temperature, salinity, and current patterns are some of the aforementioned variables that impact the distribution of prey in the environment and the eating behavior of cetaceans (Méndez-Fernandez et al., 2022). Cetaceans commonly inhabit areas where warm and cold-water produces an abundance of prey species (Teixeira et al., 2023). Cetacean habitats are strongly affected by human-made fishery grounds together with shipping lanes. Human activities, unfortunately, push cetacean habitats out of their best locations in sea areas where marine animals face death due to boat noises and collisions (Ham et al., 2023). Habitat choices of cetaceans depend on knowledge about which physiographic elements influence their habitat selection, including water depth and sea floor topography (Ahmed et al., 2021). Scientific information related to cetacean habitats facilitates habitat preservation because it safeguards populations from damaging human influences and ensures their future survival (Paul et al., 2024).

An animal’s habitat preference varies by population and geographic location, according to machine learning (ML) algorithms. 168 humpback whales' satellite telemetry data from the Southern Ocean (Santos et al., 2023) was used to demonstrate how multiregional ensemble techniques enhanced the predictive performance, which enabled more precise forecasts across populations or regions with different habitat preferences assessed by (Reisinger et al., 2021). Areas surrounding the seamount features that could provide appropriate habitats for eight common cetacean taxa using six years' worth of cetacean data from cargo ship routes were evaluated by (Correia et al., 2021). The creation of priority regions, monitoring schedules, and conservation initiatives could benefit from 842 sightings used to investigate the distribution of Cuvier's beaked whale, Risso's dolphin, and Sperm whale in the western Mediterranean Sea (García et al.,2022). The findings

indicated that its occurrence could influence the factors of sea surface temperature stability, distance to towns, reduced salinity, and higher concentrations of chlorophyll A utilized by (Torreblanca et al.,2022).

The five species were found in a survey of marine cetaceans in Andaman waters, with spinner dolphins as the most prevalent. Positive relationships between species presence and environmental factors were discovered, along with no discernible variation in species distribution, as suggested by Purkayastha et al., (2024). The migratory patterns, abundances, and metabolic rates of tiny cetaceans, such as dolphins, porpoises, and small-toothed whales, have a substantial impact on ecosystems. However, other factors continue to affect its limited effects on prey populations and behaviors (Kiszka et al., 2022). Climate-resilient management techniques for marine animals require an understanding of the social and environmental signals that control the migrations of marine species, such as salinity and temperature, as determined by L-A & PJ (2024). The dangers of habitat simplification and human interference indicated a trade-off between profitable and well-structured otter habitats in strongly anthropogenic river basins, and recommended incorporating ecological criteria for successful conservation (Tolrà et al., 2024). Ecological interactions, not physiological limitations, determine the vertical habitat usage of adult Chinook salmon, with the most important factors being bathymetric depth ratio, season, maturation stage, and geographical position, as shown in Freshwater et al., (2024).

Research Contributions

- **Understanding Cetacean Habitat Preferences:** The research ascertains how bottom slopes and bathymetric depths, among other physiographic features, impact the habitat choices of the six distinct cetacean species of fisheries. To better understand the spatial distribution of marine ecosystems, the research presents the habitat preferences analyzed through the habitat preferences of fin whales, striped dolphins, and sperm whales.
- **Contribution to Ecological Knowledge:** The results of the research are useful in expanding the understanding of how these marine animals adapt to varying environmental situations. The research advances understanding of marine biodiversity by illustrating how physical oceanographic factors affect cetacean behavior, which advances ecological research.
- **Implications for Conservation Strategies:** These findings emphasize the need to incorporate depth, slope, and temporal factors into marine conservation planning. The research provides valuable insights that can inform habitat management strategies, help reduce the impact of human activities on cetacean populations and support the long-term conservation of these species in evolving marine environments.

Methodology

Habitat selection by cetacean species in marine environments investigates how physiographic features, like seabed slope and bathymetric depth, affect the choice of habitat for cetacean species in marine settings of fisheries. By identifying its existence or absence, it attempts to pinpoint distinct environmental factors that facilitate the dispersal of different cetacean species. Figure 1 shows the methodological flow.

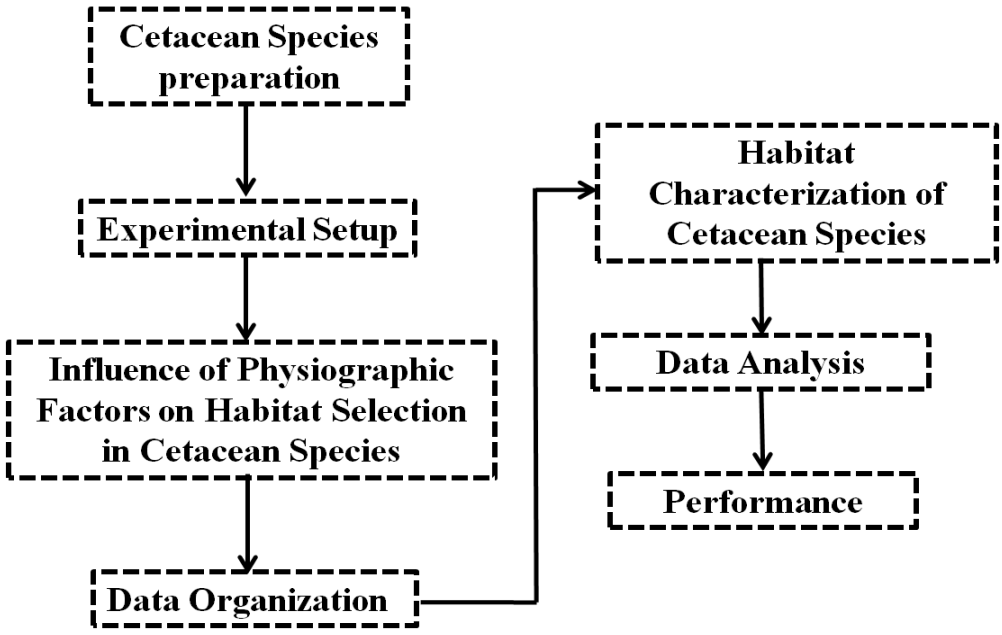

Figure 1. Flow of methodology

Cetacean Species Preparation

The preparation of cetacean species draws attention to the variety of oceanic habitats where cetacean species were discovered during summer cruise surveys. A range of open oceans is used for surveys, from shallow coastal waters. These zones contain unique physiographic features, which include the seabed slope, bathymetric depth, and other elements that determine the distribution of the marine environment. Survey zones include areas with different oceanographic characteristics, such as salinity, water temperature gradients, and currents that affect the ecological characteristics of the habitats. Because cetaceans can be found in a wide range of environments, focus on determining preferences across habitat physiographic categories throughout the whole survey range. Consequently, it provides significant analyses that elucidate how these features emphasize the variations in species ranges among marine zones of fisheries.

Experimental Setup

Six species of cetaceans, including the fin whale, striped dolphin, sperm whale, common bottlenose dolphin, humpback whale, and blue whale, use different habitats in open waters, which can be observed during cruise surveys of the experimental design. Habitat selection by cetacean species in marine environments included 528 recorded cetacean sightings. At different survey locations, each species was recorded as either occurring or not, depending on differences in variables. With this setup, it was possible to assess the physiographic traits of cetacean dispersal in its marine habitats of fisheries.

Influence of Physiographic Factors on Habitat Selection in Cetacean Species

The observations recorded complete information about confounding variables, including bathymetric depth and seabed slope in detail. The Research personnel performed geospatial data analysis of survey points to determine accurate results of seabed slope and bathymetric depth. The collected environmental information such as seabed slope and bathymetric depth data came from geographic databases for additional research analysis. The discovery of dataset patterns became viable through the structured relations between environmental variables and species presence-absence data. The well-organized structure enables to detect

relevant environmental impact factors on habitat preferences by removing variables that potentially affect the research. The analysis of statistical models depends upon easy data examination alongside complete data sets, which the structured format enables, thereby enabling their construction and analysis success. Research methods using structures yield better knowledge about how depth and slope affect where cetaceans reside. The development of conservation plans for crucial marine environments becomes more effective through acquired knowledge in fisheries.

Data Organization

Cetacean favorite habitats function as fundamental components to execute maritime protection and management plans. This research utilized observation techniques to check for the existence or absence of particular cetacean species at multiple survey sites. Through this method receive a complete evaluation of environmental factors, which influence both range patterns and habitat selection behavior of fisheries.

Habitat Characterization of Cetacean Species

Characterizing the habitats of cetacean species is necessary due to the environmental factors, influencing their distributions; require this data for the investigation of distribution patterns and behavior. Dolphin and other cetacean habitat preferences steer toward particular physical environmental aspects, especially differences in slope and water level and seabed structure shapes. These marine animals determine their distribution zones based on environmental factors that directly offer access to protective locations and necessary food sources. While dolphins prefer mild slopes in shallow depths, blue whales and other baleen whale species seek copious food sources in deep seas with steep gradients. Field survey procedures combine environmental data with species detection techniques to produce assessments of cetacean habitat in fisheries.

Statistical Data

Valuable statistical analysis occurred through the utilization of IBM SPSS software version of 29. The selection of aquatic habitats by cetacean populations depends heavily on natural geographical elements, which quantifies regression analysis helps through environmental variable measurements. Regression analysis models verify that sea floor topography, water depth, and features like ridges and canyons continue to be the primary determinants of cetacean species' habitat preferences. The statistical method controls other measured variables while creating evaluations of individual influencing factors that impact habitat selection. Regression analysis can predict where marine cetaceans can live based on recorded information about physical features. The statistical examination identifies optimal habitats for marine species via factual data, which constructs a properly structured model to intricate natural arrangements in fisheries.

Results

Habitat selection by cetacean species in marine environments investigates how physiographic elements, like water depth, seafloor topography, and underwater features such as ridges and canyons affect the choice of habitat for cetacean species. The research attempts to identify the environmental conditions that sustain dolphins, whales, and porpoises by assessing how these elements influence their distribution and behavioral response. The findings provide valuable insights into marine management and conservation tactics of fisheries.

Presence/Absence Rate of Cetacean Species

Each cetacean species showed its distribution patterns through Table 1 and Figure 2 shows preferred depth levels and slope types. The fin whale exists at a rate of 89.5% in water areas, exceeding 200 meters in depth

along slopes above 15°. The sperm whale exists at 82.8% frequency in deep waters over 500 meters deep, showing a 72.7% rate of absence. The blue whale shares similar tendencies with this cetacean because its onsets absence at 60.0% and persists at 85.0% in deep waters.

Striped dolphins continue to prefer mild slopes of less than 5° in shallow waters below 100 meters, but their presence rates average 67.6%, with higher absence rates of 72.3%. The common bottlenose dolphin thrives in depths of less than 200 meters and on very low slopes, with 75.0% prevalent and 65.0% absent. Humpback whales favor moderate slopes of 5°-15° from 100 to 500 m, with an 80.0% presence and 70.0% absence rate, demonstrating selected habitat choice. The data show significant disparities in how different cetacean species use their habitats.

Table 1. Quantitative values of presence/absence rate of cetacean species

Cetacean Species	Preferred Depth Range	Preferred Slope	Presence Rate (%)	Absence Rate (%)
Fin Whale	>200 m	Steep (>15°)	89.5(%)	68.3(%)
Striped Dolphin	<100 m	Shallow (<5°)	67.6(%)	72.3(%)
Sperm Whale	>500 m	Steep (>15°)	82.8(%)	72.7(%)
Common Bottlenose Dolphin	<200 m	Shallow (<5°)	75.0(%)	65.0(%)
Humpback Whale	100-500 m	Moderate (5° −15°)	80.0(%)	70.0(%)
Blue Whale	>200 m	Steep (>15°)	85.0(%)	60.0(%)

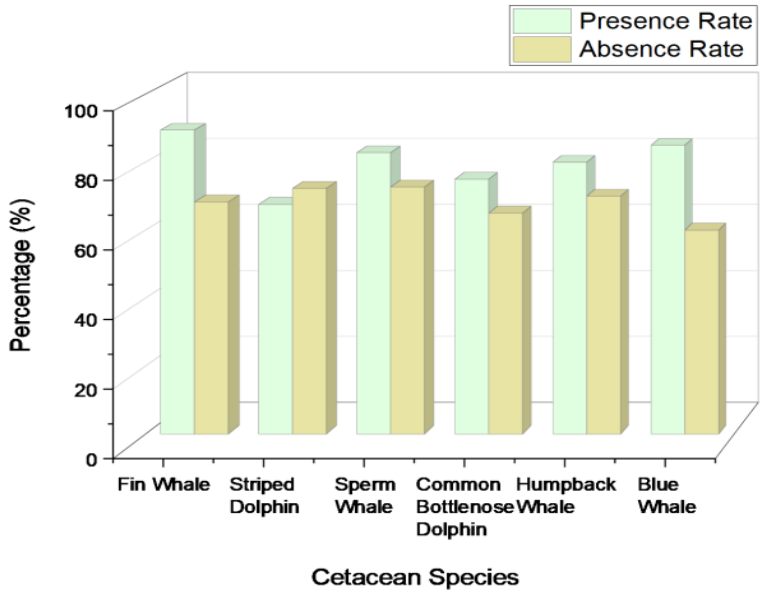

Figure 2. Graphical representation of presence/absence rate of cetacean species

Table 2 combines several whale species' habitat preferences based on depth and slope. Observed and missing data were included. Fin whales are typically found at depths of more than 200 m, however, it has high slope, with 124 presences and 56 absences. Striped dolphins, in contrast, prefer shallow water less than 100m deep and a gradual slope, with the same 104 presences and 104 absences reported of fisheries. Sperm whales live in depths greater than 500 meters and on the sharpest hills. Only 98 presences were reported in its absence, which is only 37, making such data meaningful. As a result, the species' preference for deep-water environments is most likely one of its advantages. Under 200 meters, with a gradual slope, the common bottlenose dolphin prefers to report presence at a substantially higher medium: 150 presences and 75 absences as tagging, emphasizing its versatility in coastal settings. Humpback whales are most commonly found in depths of 100

to 500 meters, with 110 presences and 40 absences, indicating a moderate predilection for mid-depth environments. Finally, blue whales prefer depths more than 200 m and steep slope conditions, as evidenced by 90 observed presences and 30 absences, indicating an inclination for deep offshore settings.

Table 2. Quantitative values of habitat preferences of cetacean species by depth and slope

Cetacean Species	Depth Preference (m)	Slope Preference	Observed Preference (n)	Observed Absence (n)
Fin Whale	>200 m	Steep	124	56
Striped Dolphin	<100 m	Gentle	104	104
Sperm Whale	>500 m	Steep	98	37
Common Bottlenose Dolphin	<200 m	Gentle	150	75
Humpback Whale	100-500 m	Moderate	110	40
Blue Whale	>200 m	Steep	90	30

Habitat Selection by Cetacean Species

Table 3 summarizes all aspects of cetacean habitat selection, with a focus on overall sightings, presence and absence rates, depth preference ranges, and slope types. For example, there have been 180 sightings of fin whales, with an 89.5% presence rate, and have a strong affinity for deeper locations >200 m and steep slopes >15°. An absence rate of 10.5% indicates that it is very particular about its habitat. Striped dolphins, with 208 sightings, favor shallow waters (<100 m) and easy slopes (<5°). The presence and absence percentages are 67.6% and 32.4%, respectively.

The sperm whale was sighted 135 times and preferred deep seas exceeding 500 meters as well as steep. The 82.8% presence rate and 17.2% absence rate show a significant preference for offshore, steep situations. While common bottlenose dolphins have been sighted 150 times, they prefer to stay under 200 meters and on mild slopes less than 10 degrees; their presence rate is thus 75%, while their absence rate is 25%. Humpback whales have been sighted 220 times and prefer depths between 100 and 400 meters, as well as moderate slopes between 5° and 15°. This species was found to be present 80% of the time. Blue whales, which have been sighted 180 times, also favor deep waters and steep slopes. The species are 85% present and 15% absent.

Table 3. Quantitative values of habitat selection by cetacean species

Cetacean Species	Total Sightings (n)	Presence Rate (%)	Absence Rate (%)	Depth Range (m)	Slope Type
Fin Whale	180	89.5	10.5	>200 m	Steep (>15°)
Striped Dolphin	208	67.6	32.4	<100 m	Shallow (<5°)
Sperm Whale	135	82.8	17.2	>500 m	Steep (> 15°)
Common Bottlenose Dolphin	150	75.0	25.0	<200 m	Moderate (<10°)
Humpback Whale	220	80.0	20.0	100-400 m	Moderate (5° – 15°)
Blue Whale	180	85.0	15.0	>200 m	Steep (>15°)

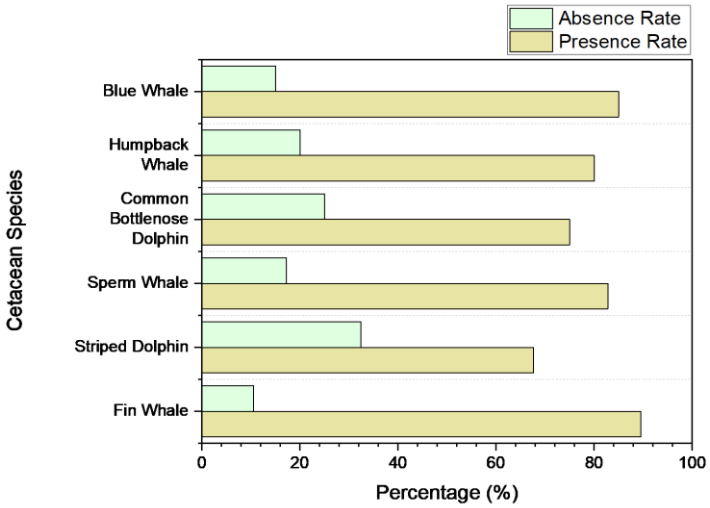

Figure 3. Graphical representation of habitat selection by cetacean species

Regression Analysis

Table 4 shows the findings of a regression analysis of habitat selection in cetacean species, which used depth and slope as predictor variables. The fin whale prefers deep (>200m) and steep (>15°) slopes, with significant regression coefficients in fisheries (β = 1.34, p = 0.001, OR = 3.82 for depth; β = 1.52, p = 0.001, OR = 4.56 for slope), indicating a higher likelihood of this type of environment. Striped dolphins prefer shallow (<100 m) and gently sloping (<5°) waters, as indicated by negative coefficients (β=-1.27, p=0.003, OR=0.28 for depth; β=-0.92, p=0.025, OR=0.40 for slope).

Sperm whales were most common at depths (>500 m) and steep slopes, with significant coefficients (depth: β = 1.45, p < 0.001, OR = 4.26; slope: β = 1.63, p = 0.001, OR = 5.09). Common Bottlenose Dolphin at Depth (>200 m) with: β = 1.12, p = 0.004, OR = 3.07, Slope (Steep>15°, β = 1.34, p = 0.001, OR = 3.82), Humpback Whale at (Depth >200 m, β = 1.25, p = 0.002, OR = 3.49) and Slope (Moderate 5- 15°, β = 1.14, p = 0.008, OR = 3.13), and Blue Whale at Depth (>500 m) with: β = 1.48, p = <0.001, OR = 4.41, Slope (Steep>15°, β = 1.72, p = <0.001, OR = 5.63).

Table 4. Quantitative values of regression analysis

Cetacean Species	Variable	Regression Coefficient (β)	Standard Error (SE)	z-vale	P-value	Odds Ratio (OR)
Fin Whale	Depth (>200 m)	1.34	0.42	3.19	0.001	3.82
	Slope (Steep>15°)	1.52	0.45	3.38	0.001	4.56
Striped Dolphin	Depth (<100 ml)	-1.27	0.43	-2.95	0.003	0.28
	Slope (Shallow <5°)	-0.92	0.41	-2.24	0.025	0.40
Sperm Whale	Depth (>500 m)	1.45	0.39	3.72	<0.001	4.26
	Slope (Steep>15°)	1.63	0.18	3.39	0.001	5.09
Common Bottlenose Dolphin	Depth (>200 m)	1.12	0.39	2.87	0.004	3.07
	Slope (Steep>15°)	1.34	0.42	3.19	0.001	3.82
Humpback Whale	Depth (>200 m)	1.25	0.41	3.05	0.002	3.49
	Slope (Moderate 5- 15°)	1.14	0.43	2.65	0.008	3.13
Blue Whale	Depth (>500 m)	1.48	0.38	3.89	<0.001	4.41
	Slope (Steep >15°)	1.72	0.46	3.74	<0.001	5.63

Discussion

The analysis results provide plausible inferences about the association between cetacean habitat choices and physiographic parameters like depth and seabed slope. Fin whales have a strong preference for deep waters (more than 200 m) and steep slopes (greater than 15°), with high regression coefficients ($\beta = 1.34$, $p = 0.001$ for depth; $\beta = 1.52$, $p = 0.001$ for slope), indicating that these features are significant predictors of species habitat choices. Furthermore, the high odds ratios (OR = 3.82 for depth and OR = 4.56 for slope) suggest that characteristics are better at predicting species presence in any environment. The observed predilection for deeper and steeper areas corresponds to species' behavioral representations, resulting from the need for offshore habitats with better access to available food. Striped dolphins favored shallow waters (less than 100 m) with moderate slopes (less than 5°), as demonstrated by negative regression coefficients ($\beta=-1.27$, $p =0.003$ for depth; $\beta=-0.92$, $p=0.025$ for slope). The decreased odds ratios (OR=0.28 for depth and OR=0.40 for slope) show significant reductions in the likelihood of dolphins being in deeper or steeper locations. Thus, this predilection for shallow and moderate conditions can be linked to the utilization of coastal environments, which are ideal for eating and socializing, because similar physiographic characteristics are widespread in such habitats.

Conclusion

The findings shed light on the fisheries in habitat preferences of six cetacean species regarding physiographic variables such as seabed slope and bathymetric depth. It is an ecological determinant, along with depth and slope, in the distribution of these marine species. Fin whales, sperm whales, and blue whales are most often caught in deep waters with steeply sloping slopes, indicating that they live in open-sea habitats that are ideal for feeding and migrating. In contrast, the striped dolphin and common bottlenose dolphin favor shallower, smoother slopes, which are their distinguishing qualities. Interestingly, humpback whales have such delicate depths and slope ranges, implying that other species of cetaceans can require very different habitats. The regression model quantifies habitat preference variables, with significant coefficients corresponding to the degree of the correlation of physiographic features with species occurrence. This is critical when developing strategies that account for the specific habitat requirements of many species as a growing danger to human activities, including shipping, fishing, and climate change. Contributes to the knowledge based on cetacean ecology while advancing the argument for incorporating physiographic variables such as depth and slope into marine conservation planning. Such insights can aid in prioritizing habitat protection areas, improving marine protected area management, and guiding future research into the long-term effects of environmental changes on cetacean populations.

Author Contributions

All Authors contributed equally.

Conflict of Interest

The authors declared that no conflict of interest.

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