

Occurrence Of Cetaceans Along The Cameroonian Atlantic Coast And The Importance Of Environmental Variables Of Oceanic Aquatic Resources

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Abstract: Biodiversity conservation thus addresses a growing global imperative, given the numerous challenges it faces. This ambition extends far beyond the mere protection of threatened species—such as cetaceans—which is already partially covered by various international conventions. Threats to marine and coastal ecosystems are primarily direct, stemming from industrial fishing, intensive aquaculture, the intentional or accidental introduction of invasive species, aggregate extraction, coastal tourism, and environmental modification (such as embankments). They are also indirect, resulting from various human activities that generate pollutants (heavy metals, organic matter, nutrients, herbicides, and fungicides) transported via diverse discharges and river systems. The study area (Figure 1) is located in the Gulf of Guinea, in southern Cameroon, encompassing the localities of Nlende Dibe (N02°46'42.9", E009°52'56.9"; elev. -4m), Mboro (N02°43'50.4", E009°52'17.4"; elev. 3m), and Lolabe (N02°41'39.2", E009°51'32.1"; elev. -5m). Key study methods include visual observation and photo-identification: scientists use photographs of dorsal fins or tails (flukes)—featuring unique patterns, scars, and nicks—to identify, census, and track individuals and populations over the long term. Cetacean sightings occur at a rate of 1 to 2 per month, covering both mysticetes and odontocetes. Variations in physicochemical parameters (CO₂, O₂, pH, temperature, suspended solids, salinity) during the study period indicate a deterioration in water quality.

Keywords: Biodiversity, mysticetes and odontocetes, physicochemical properties, Atlantic coast, Cameroon.

I. INTRODUCTION

Species conservation has taken on a very significant role today, given the disruptions and damage suffered by biodiversity as a whole, particularly that experienced by cetaceans. Biodiversity conservation thus reflects a growing global commitment, given the many challenges it faces. This ambition goes far beyond the mere protection of threatened species, such as cetaceans—a protection that is already partially ensured under various international conventions (Ayissi et al., 2013). These conventions provide a framework for biodiversity, requiring not only the inventorying of species and the development of conservation strategies for current and future uses, but also a comprehensive study of continental, coastal, and marine ecosystems. Marine ecosystems thus constitute a vast environment that provides numerous ecological services (GHG reduction, supply of seafood, multiple contributions to renewable energy, etc.), and whose full potential we do not yet seem to fully appreciate (Ayissi et al., 2007). The threats to marine

and coastal ecosystems are primarily direct, linked to industrial fishing, intensive aquaculture, the intentional or unintentional introduction of invasive species, aggregate extraction, coastal tourism, and land development (dikes, polderization); and secondly, indirect threats resulting from various human activities that generate pollutants (heavy metals, organic matter, nutrients, herbicides, fungicides) carried by various discharges, streams, and rivers. These pollutants pass through and/or accumulate in these areas, causing significant disruptions. These disruptions can also result from one-time catastrophic events such as oil spills or storm surges. Taken together, these hazards place significant pressure on coastal and marine ecosystems, leading to multiple conflicts of use and necessitating integrated management (Carranza et al., 2006). The Gulf of Guinea, along which Cameroon's coastline lies—and the town of Kribi in particular—is seeing the emergence of large-scale activities such as: mining and oil extraction, the construction of beachfront hotels, the extraction of sand from beaches for large-scale construction projects, and the generation of fishing waste (old nets), all of which disrupt marine and coastal ecosystems. This pollution exposes biodiversity—and cetacean diversity in particular—to changes in their metabolism and ecological behavior, putting their lives at risk (Tett et al., 2003). This study therefore represents a first step toward addressing the multiple threats affecting these species. To assess their ecological impact, it is necessary to distinguish natural variability at different time scales (seasonal, interannual, and cyclical variations) and correlate these with disturbances in these ecosystems. This variability thus serves as a good indicator of environmental changes. This preliminary study serves as a decision-making tool for the various stakeholders operating in the area (Héral, 1993). The main objective of this study is to determine the impact of environmental parameters on the presence of cetaceans along the Cameroonian coast. The specific objectives are: to determine the physicochemical parameters of the environment, to describe the dynamics of cetaceans along the Cameroonian coast, and finally, to identify possible links between these two variables.

II. MATERIALS AND METHODS

Study Area

The study area (Figure 1) is located in the Gulf of Guinea, in southern Cameroon, in the localities of Nlende Dibe (N02°46'42.9'' E009°52'56.9''; Altitude -4 m), Mboro (N02°43'50.4''; E009°52'17.4''; Altitude 3 m), and Lolabe (N02°41'39.2'' E009°51'32.1''; Altitude -5 m).

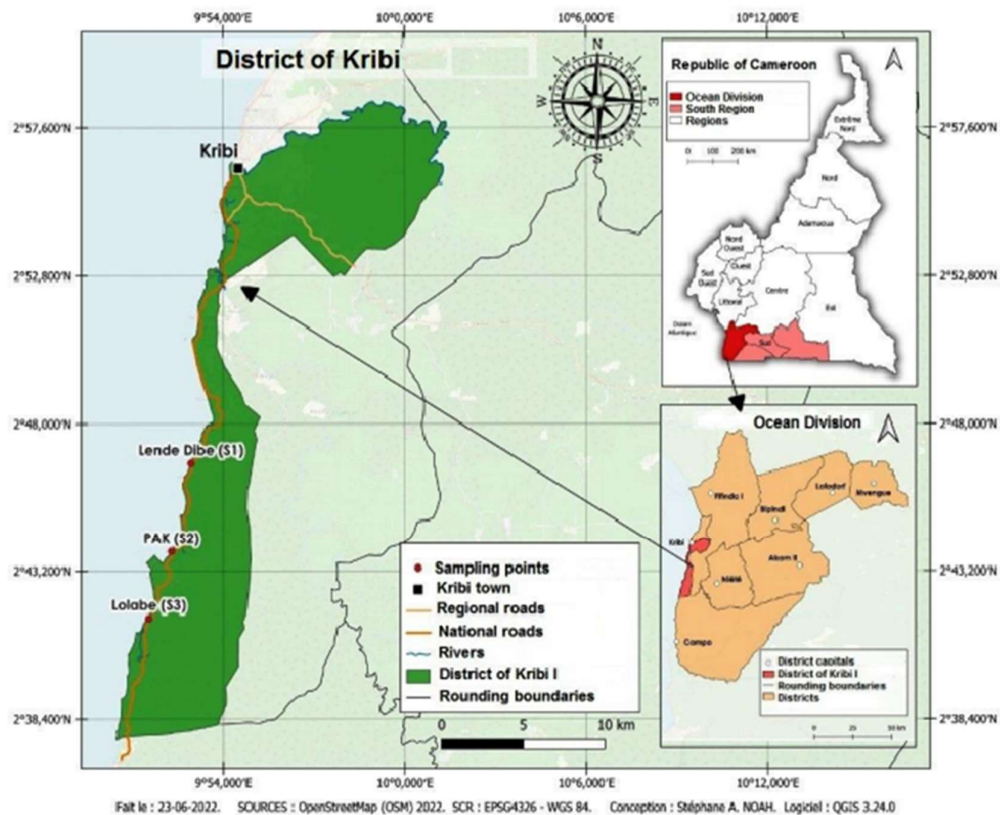


Figure 1: Map of the study area

Sample Collection

Water samples: Water samples for physicochemical analysis were collected using 1,000-ml polyethylene bottles with double caps (Rodier, 2009).

Biological samples: The presence of cetaceans was determined using the following methods:

- field surveys using non-invasive methods;
- Research observation is a method of collecting empirical data that involves observing, analyzing, and documenting behaviors or phenomena in their natural environment. It is essential for validating hypotheses or exploring topics without altering variables; it can be direct, participatory, or structured;

- Photo-identification: a non-invasive scientific method that allows for the tracking and recognition of individuals within an animal population (such as cetaceans) based on their unique physical characteristics (scars, markings, fin shape).

These methods are an ideal alternative to physical tagging and offer numerous advantages: they allow researchers to estimate population size, assess survival rates, birth rates, and migratory movements. These techniques are widely used in citizen science initiatives, where the data collected (photos and observation locations) are used to compile research catalogs. These photographic inventories are used, in particular, to guide efforts to protect endangered species.

Sample Analysis

Water samples: Physical variables (temperature, salinity, pH) were measured in situ using a multimeter via direct reading. Chemical parameters, such as dissolved carbon dioxide (measured volumetrically after in situ fixation) and dissolved oxygen (measured via direct reading), were also determined. Data Analysis and Statistical Tests: The results are presented in the form of graphs (physicochemical parameters) and tables. This was made possible by statistical software: Microsoft Office Excel 2010, which was used to create the tables and graphs; while SPSS version 2.0 was used to assess the relationships between the different variables.

III. RESULTS AND DISCUSSION

Results

Physicochemical Parameters

Figure 2 shows the variation in the physicochemical parameters we measured CO₂ had the highest average concentration at Station 1 (3.3 ± 1) mg/L, with a maximum value of 5.2 mg/L in September at Station 1 and a minimum value of 1.6 mg/L in February. Oxygen levels in aquatic systems indicate the degree of oxygenation of the water, which is very important for the respiration of organisms. The oxygen level was highest at Station 3, at (73.075 ± 7.4)%; its maximum value was 89% in March at Station 1, and its minimum value was 60% at Stations 1 and 2. pH was also measured; Station 3 had the highest average of all stations, at (7.6 ± 0.5) UC, with a maximum value of 8.4 UC in February at Station 2; while the minimum value was recorded in January, also at Station 2. total suspended solids (tss) measure water turbidity; the highest average was (10.7 ± 2.1) mg/L; the highest value occurred in January at Station 2, and the lowest value in November at Station 1. The highest average temperature among the three stations was recorded at Station 3, with a value of $27.7^{\circ}\text{C} \pm 2.5^{\circ}\text{C}$. The highest temperature during the study was measured in September at Station 3, while the lowest temperature was recorded at Station 1, also in September, at 20°C . Finally, regarding salinity: the maximum value was 31 uS, recorded in November at Station 1, and the minimum value was 21 uS, recorded in September at Station 1; the average at this station is (26.25 ± 3.1) uS.

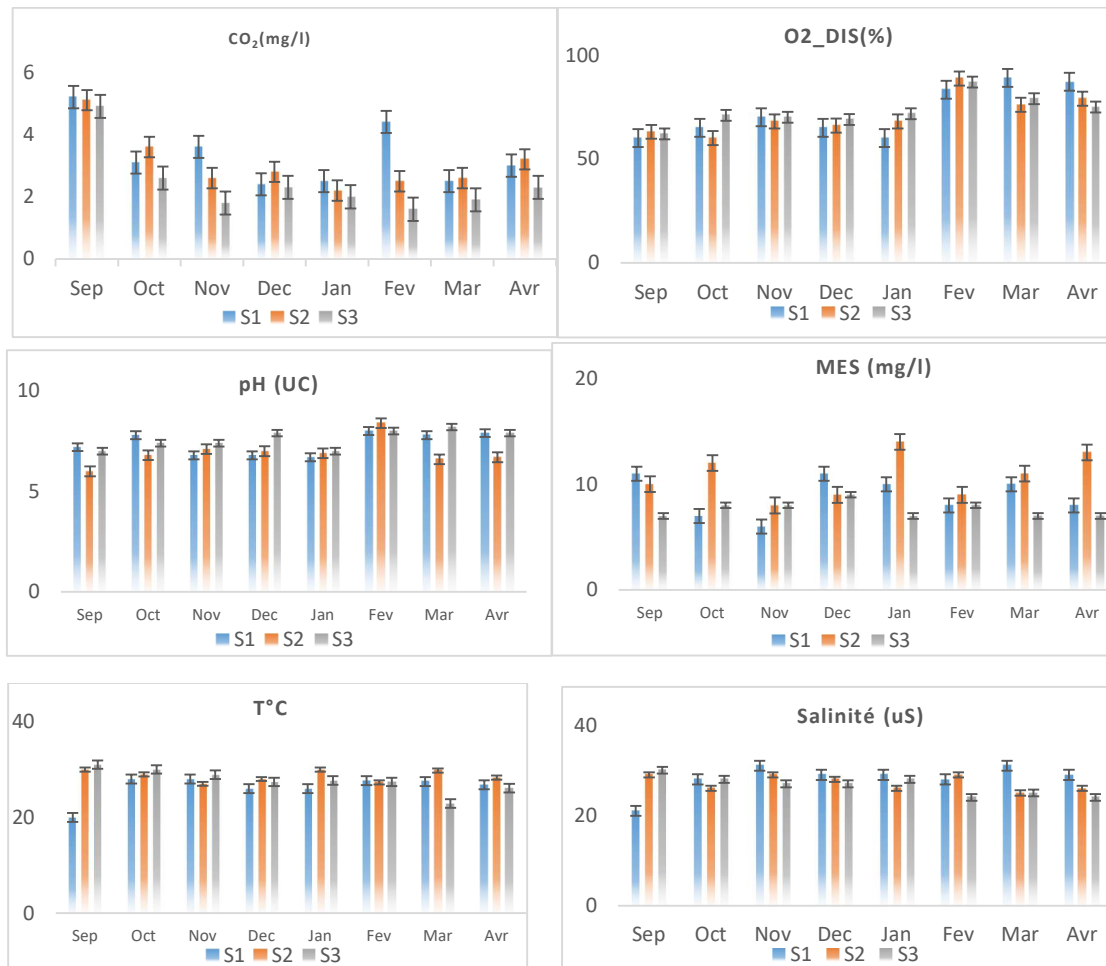


Figure 2: Changes in physicochemical parameters (CO₂, O₂, pH, T°, TSS, salinity) during the study period.

Biological Parameters

The occurrence of cetaceans is shown in Figure 3. A total of 41 specimens were recorded, comprising 28 odontocetes and 13 mysticetes during the study period. Station 2 proved to be the most frequented, with 16 specimens, followed by Station 1 with 15, and finally Station 3 with 10.

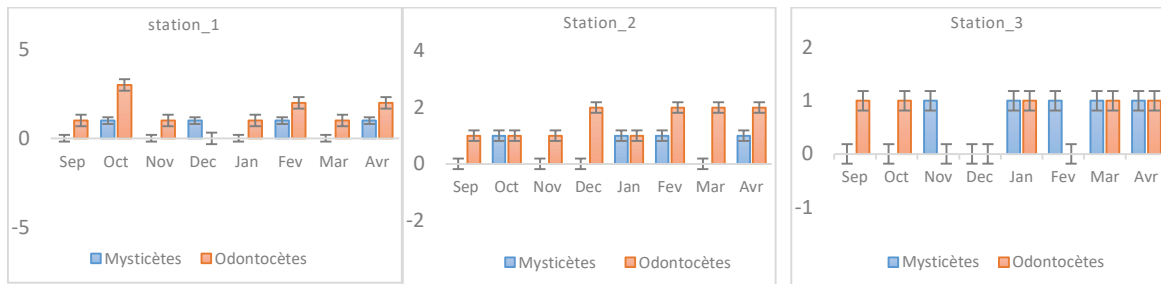


Figure 3: Changes in cetacean sightings during the study period

Table 1: Absolute abundance of cetaceans recorded during the study period

Stations		S1								S2								S3							
Months		S	O	N	D	J	F	M	A	S	O	N	D	J	F	M	A	S	O	N	D	J	F	M	A
Cetaceans	Odontocetes	0	1	0	1	0	1	0	1	0	1	0	0	1	1	0	1	0	0	1	0	1	1	1	1
	Mysticetes	1	3	1	0	1	2	1	2	1	1	1	2	1	2	2	2	1	1	0	0	1	0	1	1

The morphology and general appearance are shown in Figures 4.

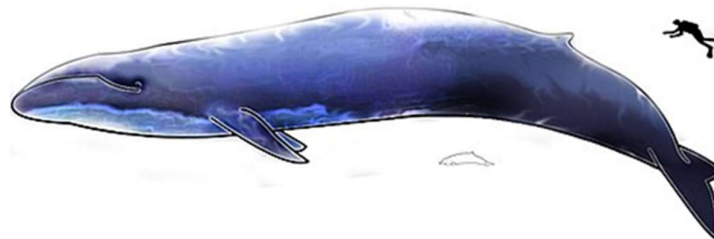


Figure 4A: Morphology of a blue whale (Size comparison between a blue whale, a Hector's dolphin, and a human.)

The blue whale is the largest animal alive today and the heaviest that has ever existed. Mysticetes are the largest animals on the planet living in our time. Only a few dinosaurs, such as Amphicoelias (whose uncertain size estimates range from 25 to 60 meters), are comparable or larger. Their size varies greatly, from five meters for the small pygmy whale to 33 meters for the southern blue whale. Their weight ranges from two metric tons for the pygmy whale to 200 metric tons for the blue whale, with an average of 50 metric tons. This most likely makes the blue whale the heaviest animal of all time. The various species are generally a more or less dark shade of gray. Their flanks are paler, their bellies are light, and their backs are dark, allowing the animal to blend into its surroundings whether viewed from the seafloor or the surface (the light color of the belly blends with the light from the sky, while the back resembles the color of the seafloor). Cases of leucism and, more rarely, albinism have been observed and affect 5% of southern baleen whales, but only in calves, which lose this pigmentation as they grow and take on a typical coloration. Rorquals, pygmy whales, and gray whales have baleen plates, ranging from just a few in gray whales to an average of more than fifty in

rorquals, except for the humpback whale, which has between 12 and 36. These baleen plates play an important role in feeding. Whales have two blowholes above their heads, which act as nostrils for breathing. Mysticetes are hydrodynamic, particularly rorquals, which are spindle-shaped. The head of a whale accounts for between two-fifths (baleen whales) and one-quarter (rorquals) of its body length. The eyes, which are small, are located just above the corners of the mouth. The short dorsal fin serves as a stabilizer. It is absent in baleen whales and the gray whale. The pectoral fins are used for steering and, to a lesser extent, also serve to stabilize the body. They account for only 7 to 9% of body size, except in the humpback whale, in which these fins are very large, ranging from 23 to 31% of the body. Finally, the caudal fin—the tail—which measures between one-tenth and one-third of the body length, propels the animal powerfully (Dauvin J.-C., 2002).

Nutritive Resources



4D: Two humpback whales feeding

Two humpback whales feeding. *Euphausia superba*, one of the main species that make up krill, which forms the basis of many whales' diet. Whales use three different hunting techniques, depending on the species and their location. "Swallowers" move through a school of fish, squid, or plankton with their mouths wide open. The immense mass of water (enough to double the animal's volume) fills the ventral grooves, creating a large pouch. The animal closes its mouth and expels the water. The food is trapped by the baleen plates. Fin whales use this technique, as do gray whales on occasion. Humpback whales enhance this method by expelling air through their blowholes to create bubble nets. This filter-feeding behavior, which is the most powerful biomechanical action in the animal kingdom, is made possible by a mechanoreceptor-type sensory organ that plays an essential role in the complex muscular coordination required by this strategy. "Skim feeders" or "filter feeders" lack ventral grooves (like baleen whales) and therefore cannot take in enormous quantities of water. They move slowly at or near the surface, with their mouths open. They lack baleen at the front, but the lateral baleen plates are very large, trapping food. Finally, "suckers" swim on their sides, seemingly upright, skimming along the seafloor, which they scrape with their mouths while sucking up mud and whatever is in it. This mud is expelled on the other side, but prey remains trapped in the baleen plates. This technique is used by the gray whale. Depending on the species, whales feed on plankton—particularly krill and copepods—fish (mackerel, herring, sardines, anchovies, capelin, smelt, sand eels, etc.), cephalopods (squid), or crustaceans. The polar regions in summer are particularly favorable for feeding, as melting ice triggers plankton blooms, which are in turn consumed by fish (the whale will therefore eat either the plankton itself or the fish that feed on plankton). Mysticetes, or literally "baleen whales," together with the suborder Odontocete (toothed whales), form the order Cetacea: whales, dolphins, porpoises, etc. These whales use their baleen plates—specialized filaments inside their mouths—to filter seawater and capture krill (small crustaceans), plankton, and fish (Carranza and Estrades 2006).

Diet, Behavior, and Ecological Role

The feeding strategy of mysticetes has shaped their behaviors and their place in ocean ecosystems. Primarily planktonivorous or microphagous, they consume enormous quantities of krill, copepods, small fish, and occasionally small crustaceans. Feeding techniques vary greatly by species: the humpback whale, for example, uses “bubble feeding” to trap and concentrate prey before swallowing the entire mass; others feed slowly near the surface, sweeping the water with their widely opened baleen plates. Their migratory lifestyle also involves strategies for building up body reserves, with significant fat accumulation to withstand long periods without food, particularly during gestation and lactation. Mysticetes also play a central ecological role as engineers of marine ecosystems. Through their excretions and the churning of water as they feed, they promote the redistribution of nutrients in the oceans, stimulating phytoplankton productivity and, in turn, the food chain. Their disappearance would have major consequences for the balance of ocean biodiversity, trophic interactions, and the health of marine habitats. The recovery of populations of certain species that were once threatened offers hope for a gradual restoration of these essential ecological functions (Kim S et al., 2007).

Odontocetes (Odontoceti), or toothed whales, constitute one of the two microorders of cetaceans. This group is characterized by the presence of teeth (as opposed to the baleen of mysticetes, or baleen whales). The suborder of odontocetes includes various species of belugas, sperm whales, orcas (or killer whales), dolphins, porpoises, narwhals, and pilot whales. Odontocetes are among the few animal species (along with bats, some birds, and certain shrews) capable of echolocation using ultrasound. They use this ability to locate their prey and navigate by analyzing the echoes of the sounds they emit—a function similar to a sonar system. Toothed whales are generally smaller than baleen whales. The sense of smell is believed to be rarely used in toothed whales, which lack an olfactory mucosa and an olfactory nerve. However, these animals still possess the vomeronasal organ, which is involved in the detection of pheromones. Odontocetes are homodont, meaning that their teeth—with exceptions such as the narwhal, which typically has only one tusk—are all identical. Dentition varies greatly among these species; the clade comprising the Ziphiidae and Monodontidae families has only two teeth, while some species of the Platanistidae family have more than 130. The baby teeth of odontocetes do not fall out; the second set remains atrophied. The teeth of odontocetes are used to grasp prey, and their shape depends on their diet. Thus, their number and shape allow specialists to identify the species. Some species, such as beaked whales and sperm whales, have teeth only on the lower jaw. Like all mammals, odontocetes have lungs and must periodically breathe at the surface. Odontocetes have only one blowhole, which distinguishes them from mysticetes, or baleen whales, which have two (Carranza et al., 2006).

Odontocetes have an asymmetrical skull, which is not the case with Mysticetes. Several researchers link this deformation to echolocation, which allows them to produce high-frequency sounds. However, although some scientists have already proposed this hypothesis, recent studies (2011) suggest that Archaeocetes—from which cetaceans are descended—already had an asymmetrical skull despite the fact that they did not use echolocation. These researchers therefore attribute the skull’s asymmetry to improved hearing for detecting the sounds made by their prey, rather than the echo of a sound emitted by the predator. Over time, mysticetes are thought to have reverted to a symmetrical skull. Further research will be needed to settle the matter. Many species are social. They form groups of individuals with a complex social structure, collaborating to hunt and defend one another. Numerous experiments in cognitive ethology have demonstrated their high intelligence. They can recognize themselves when placed in front

of a mirror as part of the mirror test. Currently, among mammals, aside from dolphins, this ability has been observed only in humans, certain primates, and elephants. This suggests that these animals possess self-awareness. Dolphins have also recently been observed using tools, a behavior rarely seen in the animal kingdom. For example, dolphins have been observed using sponges to protect their snouts while scraping the seafloor. It has since been demonstrated that this technique is passed down from mothers to daughters through learning; Dolphins are one of the few species that engage in sex for pleasure, without the intention of reproducing. They are considered to represent a case of evolutionary convergence with primates and hominids in particular due to their advanced cognitive abilities compared to other groups of marine mammals. Toothed whales use echolocation to avoid obstacles or to locate and analyze their prey. They emit a series of high-frequency whistles or clicks, then analyze the echoes produced by these signals as they bounce off obstacles, allowing them to determine the nature and distance of these objects (Ajeegah G. et al., 2018).

Threats and Protection

Although almost universally admired by humans, odontocetes face growing threats: ocean pollution and contamination of the food chains at the top of which they feed. Along with tuna, swordfish, and sperm whales, they are the marine animals with the highest levels of heavy metals, dioxins, and pesticide residues. Their meat, which is still consumed in Japan and the Faroe Islands[9], contains levels of toxic metals that exceed—often by a wide margin—international and national standards. Their mercury content alone would theoretically be sufficient to warrant a ban on their consumption in most cases; the disappearance of part of their food supply due to human overfishing is a second threat; injuries, suffocation, or stress from accidental entanglement in trawls or drift gillnets cause the deaths of many dolphins every year (Kim S et al., 2007) (Figure 5).

Classification

The microorder contains 6 families:

- Family Delphinidae Gray, 1821 — Oceanic dolphins and orcas
- Family Monodontidae Gray, 1821 — Beluga and narwhal
- Family Phocoenidae — Porpoises
- Family Physeteridae — Sperm whale (at a minimum)
- Family Platanistidae Gray, 1846 — Freshwater dolphins
- Family Ziphiidae Gray, 1850 — Beaked whales and hypodons



5B : Tursiops truncatus (Delphinidae)



5C : Phocoenoides dalli (Phocoenidae)



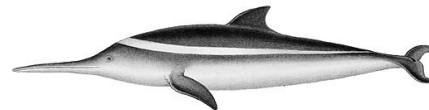
5D : Mesoplodon bidens (Ziphiidae)



5E : Kogia sima (Kogiidae)



5F : Lipotes vexillifer (Lipotidae)



5G : Pontoporia blainvillei (Pontoporiidae)

Discussion

Physicochemical parameters: Data from Station 1 show an average of $(26.25 \pm 2.6) ^\circ\text{C}$, $(28.6 \pm 1.2) ^\circ\text{C}$ at Station 2, and $(27.7 \pm 2.5) ^\circ\text{C}$ at Station 3; similarly, salinity was (28.5 ± 3.2) PSU at Station 1, (27.3 ± 1.7) PSU at Station 2, and (26.6 ± 2.1) PSU; these parameters describe the hydrology of the water body in the marine environment. They contradict the findings of the OCE (Corsican Environmental Office) (2019); The studies they conducted in the northwestern Mediterranean show a lower temperature of 13.6°C and a higher salinity of 38.5 PSU. These values can be explained by the fact that marine waters differ from one another overall. They are influenced by climate, ocean currents, and winds that occur at different times, thereby affecting the hydrology of each of these ecosystems. This value differs from that obtained by Ayissi et al. (2013) at Campo Ma'an, who were studying the ecological niches of sea turtles. The pH values at stations 1, 2, and 3 are (7.2 ± 0.6) , (6.9 ± 0.6) , and (7.6 ± 0.5) , respectively, consistent with

the values found during the assessment of the marine environment in the Bay of Biscay subregion (2012). Furthermore, when comparing these values to those in the marine water quality guidelines, it can be said that they fall within a good water quality range. However, the high values recorded during January and February were likely due to unforeseen circumstances that occurred during that period. The oxygen saturation percentage is satisfactory at $(71.1 \pm 9.4)\%$, particularly at Station 2; this value falls within the same range as that obtained in the waters of three Tensift sub-basins by Mimouni (2020) during his work on the assessment of the physicochemical water quality.

Biological parameters: Table 1 shows cetacean sightings during the study period. The results indicate that mysticetes were the most abundant infraorder during the study period, with 36 specimens, distributed among stations 1, 2, and 3 as follows: $n=3$, $n=4$, and $n=5$, respectively; Based on these figures, we can conclude that Station 3 is the most frequented in this area; this may be due to physicochemical parameters that could support the development of food webs favorable for cetacean feeding (Gasmi and Bahri, 2008).

Rank correlation test “r”: pH is negatively correlated with salinity, with a value of $(r = -0.41)$; As we saw in the results, pH remains virtually stable throughout the study period, suggesting that it has a specific effect on organisms in the environment; Odum (1986) states that it is the most decisive environmental parameter in the adaptation of organisms, second only to temperature. Mysticetes show no correlation with temperature $(r = 0.09)$; Temperature is a key factor in the adaptation and ecology of organisms; this could explain why odontocetes are abundant, simply because they are within their thermal range.

IV. CONCLUSION

At the conclusion of this study—whose primary objective was to demonstrate the importance of physicochemical parameters in the occurrence of cetaceans along the Cameroonian coast—the specific aims were to determine the physicochemical parameters of the environment, to present the occurrence of cetaceans in this area, and finally, to establish possible links between the various parameters studied. The study reveals that these waters are neutral and have a temperature favorable to marine life. The measured parameters for organic pollution are low, suggesting that the environment is in good ecological condition. Salinity is also within acceptable limits, with good oxygenation of the environment. We also observed the presence of cetaceans, although their abundance is likely low: a total of 53 species, comprising 36 odontocetes and 17 mysticetes. pH shows no correlation with salinity; odontocetes exhibit a strong correlation with temperature.

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