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CASE REPORT
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Postmortem Pathology of a Cuvier's Beaked Whale: Evidence of Environmental and Traumatic Stress in a Deep-Diving Cetacean

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ABSTRACT

A female Cuvier's beaked whale (*Ziphius cavirostris*), approximately 6.4 meters long, was found stranded and subsequently deceased on Tanakeke Island, South Sulawesi, Indonesia. Necropsy was performed, and tissue samples from the muscle, liver, spleen, and intestine were collected for histopathological analysis. Microscopic evaluation revealed peripheral hemorrhages in muscle tissue, extensive hepatic autolysis with vacuolation, bacterial presence, and sinusoidal disruption in the liver. The spleen exhibited total red and white pulp loss, accompanied by heavy macrophage infiltration and bacterial colonization. Intestinal samples showed villi degradation and the presence of rod-shaped bacteria, which are likely to reflect systemic stress and microbial imbalance. These findings suggest that a combination of trauma, infection, and possible environmental or decompression-related stressors contributed to the whale's deterioration and stranding. This case highlights the value of histopathology in diagnosing health conditions in deep-diving cetaceans and underscores the importance of rapid response to marine mammal strandings for pathological evaluation.

Keywords: Ziphius cavirostris, Histopathology, Stranded whale, Organ lesions, Cuvier's beaked whale, Marine mammal pathology.

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INTRODUCTION

Cuvier's beaked whale (*Ziphius cavirostris*) is a deep-diving marine mammal that typically inhabits offshore waters, tends to avoid vessels, and remains submerged for extended periods (Baird, 2019). These whales are frequently observed at depths of around 500 meters, with a particular preference for waters ranging between 1000 and 2000 meters (Karaa et al., 2021). Their elusive behavior and deep-sea habitat significantly hinder researchers' ability to observe and study them in their natural environment. Consequently, much of the current understanding of this species has been derived from postmortem examinations of stranded individuals (Ijsseldijk et al., 2019). When separated from their social group, Cuvier's beaked whales face considerable challenges, including difficulty in foraging and an increased vulnerability to predation (Alcázar-Treviño et al., 2021). Furthermore, the loss of acoustic communication may impair their ability to navigate complex underwater environments (Feyrer et al., 2024).

Cuvier's beaked whale (*Ziphius cavirostris*) exhibits a specialized foraging strategy primarily within the mesopelagic and bathypelagic zones, typically ranging between depths of 600 and 3000 m, with recorded dives exceeding 2900 m and lasting over two hours, the deepest and longest ever documented for any mammal (Visser et al., 2022). Dietary analyses from stranded and bycaught specimens across the North Pacific have demonstrated that cephalopods constitute the dominant prey, accounting for approximately 98% of all prey items and nearly 88% of dietary biomass. Among these, squids of the families *Gonatidae*, *Octopoteuthidae* and *Cranchiidae* are particularly important, with *Gonatopsis borealis*, *Gonatus onyx*, *Octopoteuthis deletron* and *Taonius borealis* representing key species. Although less frequent by

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number, teleost fishes, notably the giant grenadier (*Albatrossia pectoralis*), contribute substantially to dietary mass in some regions, particularly along the eastern Pacific. Crustaceans, including members of the families *Pasiphaeidae* and *Oplophoridae*, occur in nearly one-third of examined stomachs but contribute minimally to overall biomass. Regional differences are apparent, with crustaceans more prevalent in the western Pacific and fish more frequently consumed in the eastern Pacific. Globally, comparative studies confirm that Cuvier's beaked whales consistently rely on deepwater cephalopod families such as *Cranchiidae, Gonatidae, Histioteuthidae*, and *Octopoteuthidae*, highlighting the species' dependence on mesopelagic and bathypelagic prey assemblages. These dietary patterns not only reflect the ecological role of *Ziphius cavirostris* as a deep-diving cephalopod specialist but also emphasize the importance of oceanic slope habitats as critical foraging grounds (West et al., 2017).

This case report presents a histopathological investigation to identify potential causes of stranding in a Cuvier's beaked whale. The examination focuses on tissue and organ damage to detect abnormalities contributing to the animal's beaching.

History

A female Cuvier's beaked whale was found stranded along the coast of Tanakeke Island, Takalar Regency, South Sulawesi (Fig. 1). The whale measured approximately 6.4 meters in body length with a chest circumference of around 3.2 meters. Residents discovered it on October 9, 2023, at approximately 15:00 Central Indonesia Time (WITA). Upon discovery, the whale was still alive but in critical condition, unable to move and exhibiting multiple wounds covering most parts of its body (Fig. 2). Unfortunately, the animal did not survive long after being found. The emergency response to the stranding event commenced on October 11, 2023. The response was carried out by a Rapid Response Team comprising representatives from the Marine and Fisheries Resources Surveillance Unit (PSDKP) Takalar, the Makassar Coastal and Marine Resources Management Center (BPSPL Makassar), a team of veterinary professionals from Hasanuddin University, and members of the local community. By the time the team arrived on site, the whale had already died and showed signs of decomposition, corresponding to Code 3 carcass condition. The exact coordinates of the stranding location were recorded at -5° 31′ 17.99″ S and 119° 15′ 14.55″ E.

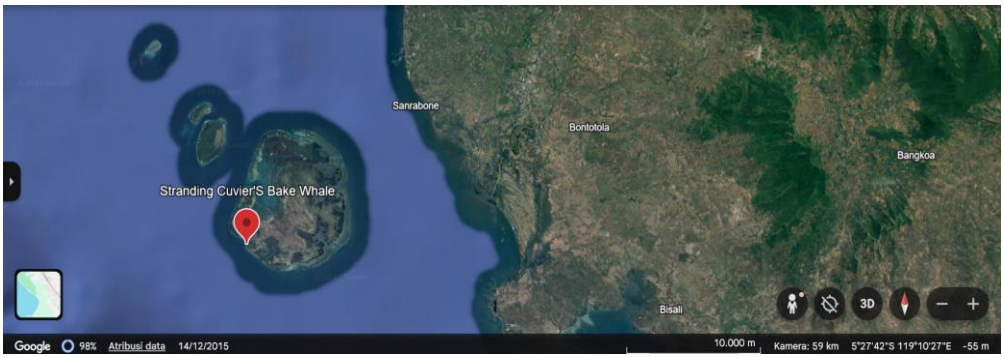

Fig. 1: The location was found stranded along the coast of Tanakeke Island, Takalar Regency, South Sulawesi

Fig. 2: (A) A stranded Cuvier's beaked whale (*Ziphius cavirostris*) on the coast of Tanakeke Island, Takalar Regency; (B) Visible lesions on the right side of the whale's head; (C) Measurement of the whale's body diameter; (D) Measurement of the whale's total body length.

Postmortem Findings

Key biological parameters, including stranding characteristics (type, location, and date), life history traits (species, age class, and sex), and body condition and decomposition stage, were systematically recorded. Age classification (neonate, calf, juvenile, or adult) was determined based on total body length and the degree of gonadal development. The stranded individual was identified as a female Cuvier's beaked whale (*Ziphius cavirostris*). Key morphometric data were recorded on-site; the total body length was measured at approximately 6.4 meters, with a chest circumference of 3.2 meters. Based on the total body length, which is a standard indicator for this species, the whale was classified as an adult. Due to the logistical challenges of the remote stranding location and the size of the animal, it was not feasible to obtain the body weight. Decomposition status was evaluated using a five-tier classification: Code 1 (recently deceased or euthanized animal), Code 2 (fresh carcass), Code 3 (moderate decomposition), Code 4 (advanced decomposition), and Code 5 (mummified or skeletal remains) (Ijsseldijk et al., 2019). Macroscopic lesions identified during necropsy were documented and photographed for diagnostic purposes.

Tissue samples for histopathological analysis were collected during the necropsy and fixed in 10% neutral-buffered formalin. These samples were subsequently trimmed, routinely processed, embedded in paraffin wax, sectioned at a thickness of 5µm, and stained with hematoxylin and eosin (H&E) for examination under light microscopy (Nagpal, 2023).

Differential Diagnosis

Based on the gross and microscopic findings, including focal muscle hemorrhages, hepatic degeneration with bacterial presence, and the absence of ingesta, the likely causes of morbidity and mortality include trauma and systemic bacterial infection. Differential diagnoses considered include gas embolism due to decompression, environmental toxicity, and advanced autolysis, confounding interpretation.

The presence of bacteria was noted during histopathological examination of the liver, spleen, and intestinal tissues. However, further definitive identification through bacterial culture or molecular methods such as PCR was not performed. This limitation was due to the advanced decomposition, which was classified as Code 3. In cetacean carcasses with this level of autolysis, significant postmortem bacterial translocation occurs, where commensal bacteria from the gastrointestinal tract proliferate and invade other tissues (Romani-Cremaschi et al., 2023). This process makes it exceedingly difficult to distinguish between antemortem pathogens that may have contributed to the cause of death and postmortem bacteria that are merely agents of decomposition (Lennon et al., 2025). Given these confounding factors and the logistical constraints of performing sterile sampling for microbiology in a remote field setting, the analysis was restricted to the morphological observation of bacterial colonies within the tissue sections.

• Histopathological examination of the skeletal muscle revealed that the general architecture of the myocytes was well-preserved, with intact and orderly muscle fibers (Fig. 3). However, distinct focal areas of hemorrhage were observed, characterized by the extravasation of erythrocytes into the interstitial space between the muscle bundles (Fig. 3). No significant necrosis or inflammatory infiltrate was detected in the examined sections.

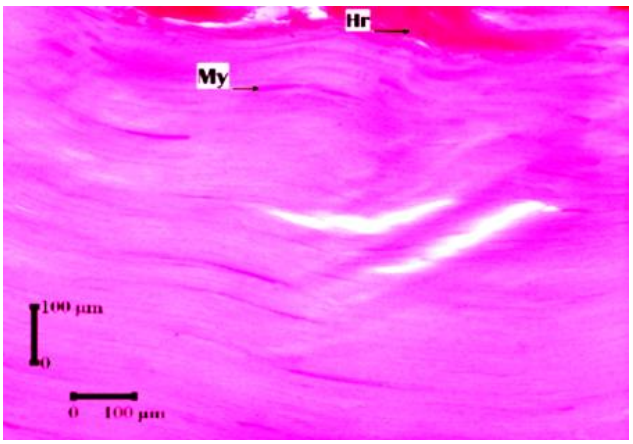

Fig. 3: Histopathology of the skeletal muscle. The section shows well-preserved muscle fibers with organized myocytes (My). A distinct area of focal hemorrhage (Hr) is visible, characterized by the extravasation of erythrocytes into the interstitial space. H&E stain.

• The liver tissue exhibited significant pathological alterations consistent with systemic stress and postmortem change. There was evidence of widespread autolysis, resulting in a loss of the normal hepatic cord structure (Fig. 4). The hepatic sinusoids were markedly dilated, suggesting significant vascular congestion (Fig. 4). Many hepatocytes displayed prominent cytoplasmic vacuolation, indicative of hydropic degeneration or steatosis (Fig. 4). Furthermore, multifocal aggregates of a golden-brown pigment, consistent with hemosiderin deposits, were noted. Aggregates of rod-shaped bacteria were also scattered throughout the parenchyma (Fig. 4).

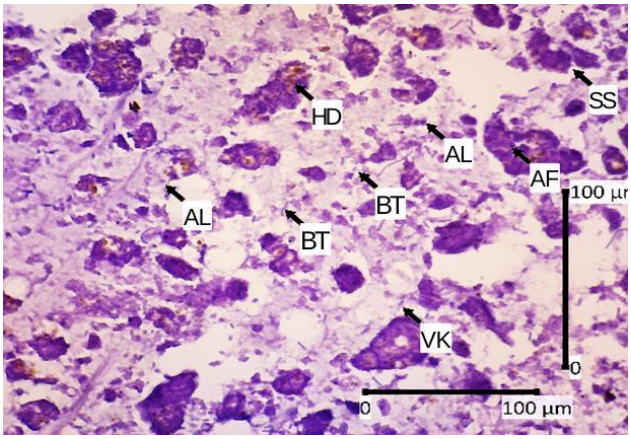

Fig. 4: Histopathology of the liver showing severe autolysis (Al), dilated sinusoids (Ss), and prominent cytoplasmic vacuolation (Vk) in hepatocytes. Note the presence of hemosiderin deposits (HD) and aggregates of bacteria (Bt).

• Examination of the splenic tissue revealed severe autolysis, resulting in a complete loss of the distinguishable red and white pulp architecture. The

normal lymphoid structure was effaced and replaced by a predominance of resilient fibroconnective stromal tissue, indicating advanced tissue degradation (Fig. 5). Despite the autolysis, a heavy infiltration of large mononuclear cells consistent with macrophages was still identifiable. Numerous bacterial aggregates were also scattered throughout the tissue (Fig. 5).

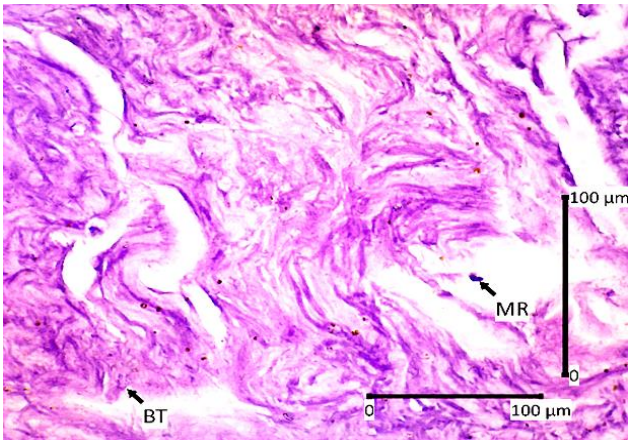

Fig. 5: Splenic tissue showing advanced autolysis with loss of normal architecture. Macrophages (Mr) and scattered bacteria (Bt) are visible within the remaining fibroconnective stroma.

• The intestinal sections showed pathological changes primarily affecting the mucosal layer. There was a widespread loss of epithelial cells (enterocytes) along the intestinal villi, a condition often described as villous sloughing or attenuation (Fig. 6). This resulted in blunted and exposed villous structures. In contrast, the underlying tunica submucosa and tunica muscularis appeared structurally intact with only minimal disruption (Fig. 6). Bacteria were also observed within the intestinal lumen and adhered to the degraded mucosal surface (Fig. 6).

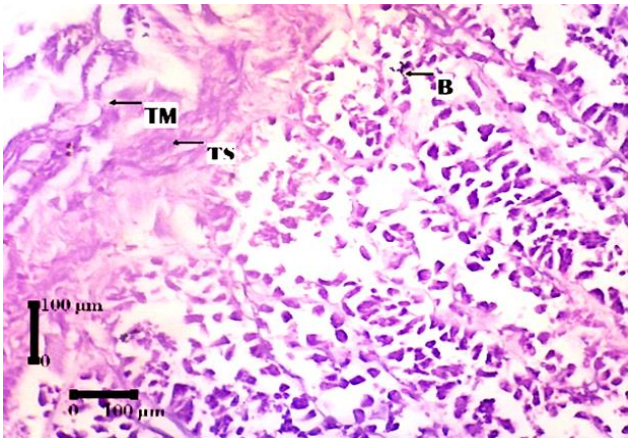

Fig. 6: Intestinal tissue exhibiting widespread loss of the villous epithelium due to advanced autolysis. The underlying tunica submucosa (TS) and tunica muscularis (TM) are preserved, and bacteria (B) are visible within the lumen. H&E stain.

DISCUSSION

A necropsy was performed on the stranded Cuvier's beaked whale, revealing no evidence of food remnants or plastic debris in the stomach or intestinal tract. This finding suggests that the whale had likely not ingested any substances for several days before stranding. Such an observation raises several hypotheses regarding possible pathological processes or environmental stressors that may have contributed to the stranding event (Suárez-González et al., 2024).

The presence of gas within the whale's body can originate from two primary sources: antemortem accumulation and postmortem decomposition. The ante-mortem gas buildup may occur due to pressure-related changes during deep dives (Puig-Lozano et al., 2020). Cuvier's beaked whales possess physiological adaptations that regulate nitrogen levels in the bloodstream, helping to prevent gas embolism during routine diving behavior. However, anthropogenic disturbances, such as acoustic interference or vessel traffic, can force whales to ascend rapidly. This abrupt ascent may cause nitrogen bubbles to form due to rapid decompression, potentially leading to decompression sickness a condition characterized by the formation of gas emboli in blood vessels and tissue, which can result in severe internal trauma (Fahlman et al., 2020). In contrast, postmortem gas is typically produced by microbial decomposition of soft tissues. Gases such as methane, hydrogen sulfide, and ammonia tend to accumulate in body cavities, particularly the gastrointestinal tract, and other soft tissues and are generally unrelated to any pathological condition preceding death (Cloyed et al., 2023).

It is important to acknowledge several inherent limitations in this study that may influence the interpretation of the findings. The primary constraint was the advanced state of decomposition (Carcass Code 3) of the whale at the time of examination. The interval between the animal's discovery on October 9, 2023, and the necropsy performed by the response team on October 11, 2023, allowed for significant postmortem autolysis to occur.

This autolytic process directly compromised the quality of the histopathological preparations. The integrity of the cellular and tissue architecture was diminished, particularly in organs susceptible to rapid decay, such as the spleen and intestine. This resulted in difficulty identifying characteristic structures, such as the red and white pulp of the spleen, and may have introduced technical artifacts, including the expansion of intestinal tissue during processing. Furthermore, advanced autolysis can mask or even mimic true antemortem lesions, thus necessitating a cautious interpretation of the microscopic findings.

A further limitation was present in the microbiological analysis. Massive postmortem bacterial proliferation within a decomposed carcass makes it unfeasible to distinguish between primary pathogens that may have contributed to mortality and opportunistic microbes that flourish after death. Consequently, definitive bacterial identification via culture or molecular methods was not pursued. Finally, conducting the necropsy at a remote location on Tanakeke Island presented logistical challenges, including the inability to obtain the animal's body weight and difficulties in preserving optimal samples.

Despite these limitations, this report provides valuable

baseline pathological data for a Cuvier's beaked whale (*Ziphius cavirostris*), a species for which stranding events are infrequently documented in Indonesian waters.

Histopathological examination of the muscle tissue of the Cuvier's beaked whale revealed predominantly normal findings. The muscle sections showed clearly defined myocytes with intact and orderly muscle fibers (Fig. 3). However, densely stained red regions identified focal areas of hemorrhage. No evidence of necrosis was detected in the muscle tissue. The localized hemorrhages are likely attributable to trauma associated with external injuries. Additionally, physiological stress may have contributed to impaired muscle perfusion, leading to vascular dysfunction that could exacerbate tissue damage during episodes of blood loss.

Histological analysis of the liver tissue revealed multiple pathological alterations, including autolysis, sinusoidal distortion, vacuolization, and bacterial colonies (Fig. 4). The hepatic sinusoids appeared dilated, suggesting vascular congestion or disrupted blood flow. This vascular congestion may result from elevated pressure within the portal system, potentially linked to metabolic stress or physical trauma experienced before death. Cytoplasmic vacuoles in hepatocytes indicate hydropic degeneration or lipid accumulation (*steatosis*), suggesting metabolic disturbances associated with exposure to environmental pollutants such as heavy metals or hydrocarbons. This stress response may trigger vacuolar membrane invagination as an adaptive mechanism to compartmentalize un-processable materials (Jarc and Petan, 2019).

Histopathological evaluation of the spleen tissue from the Cuvier's beaked whale revealed a predominance of connective tissue, with an absence of distinguishable red and white pulp structures (Fig. 5). This condition indicates advanced autolysis, a postmortem tissue degradation process mediated by hydrolytic enzymes released from lysosomes. As a result of this degradation, the characteristic splenic architecture, including the red and white pulp, was entirely lost, leaving only the more resilient connective or stromal tissue, which is less susceptible to autolytic breakdown (Mattioda et al., 2024). The absence of these key histological components signifies a high degree of tissue autolysis, which can introduce bias and limitations in interpreting histopathological findings for forensic investigations.

Histopathological examination of the intestinal tissue of the Cuvier's beaked whale revealed abnormalities, specifically in the intestinal villi. Notably, there was widespread loss of epithelial cells along many sections of the villi (Fig. 6). Other intestinal layers, including the tunica submucosa and tunica muscularis, appeared largely intact with only minimal structural disruption. Villi are composed predominantly of enterocytes metabolically active cells responsible for nutrient absorption (Kiela and Ghishan, 2016). Due to their high turnover rate, these cells are particularly susceptible to autolytic degradation (Anna et al., 2020).

The histopathological changes observed in the muscle, liver, spleen, and intestinal tissues of the stranded whale are suspected to be associated with trauma and gas embolism occurring during rapid surfacing (Puig-Lozano et al., 2020). Such conditions may have triggered gas accumulation within tissues, metabolic dysfunction, and cellular injury, ultimately accelerating autolytic processes. This pathological state was likely exacerbated by the prolonged interval between stranding and necropsy, allowing for significant tissue decomposition before optimal fixation.

DECLARATIONS

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Conflict of Interest: Conflict of Interest: The authors declare no conflict of interest.

Data Availability: Data are available upon request from the corresponding author.

Ethics Statement: Ethical review was not required as the study was conducted on a stranded animal carcass found dead.

Author's Contribution: All authors made the diagnosis. MAN was the leading researcher and supervised this study. ARA carried out the histopathological diagnosis. MRB performed species identification and morphometric measurement. FA and ASR also performed a necropsy sample collection on Tanakeke Island and wrote the manuscript.

Generative AI Statement: The authors declare that no Gen AI/DeepSeek was used in the writing/creation of this manuscript.

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