SVOA Microbiology

ISSN: 2634-534X

Review Article

Cetacean Microbiota: Ecological Alterations and Their Impact on Health of These Mammals

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https://doi.org/10.58624/SVOAMB.2025.06.008

Received: March 16, 2025

Published: April 10, 2025

Citation: Gallego JC. Cetacean Microbiota: Ecological Alterations and Their Impact on Health of These Mammals. *SVOA Microbiology 2025,* 6:2, 66-70. doi:10.58624/SVOAMB.2025.06.008

Abstract

The microbiota of cetaceans plays a fundamental role in the health of these marine mammals and is influenced by various environmental factors. Pollution and changes in microorganism composition can lead to severe pathologies, including epizootics such as those caused by Morbillivirus. This study reviews the microbiota of free-ranging and captive cetaceans, highlighting differences between both environments and the effects of contaminants on microbial ecology. Additionally, conservation strategies based on microbiological surveillance are analyzed.

Keywords: *Microbiota, Cetaceans, Pollution, Epizootics, Conservation.*

1. Introduction

Cetaceans are sentinel species due to their long lifespans, their position in the marine trophic chain, and their exposure to environmental contaminants. Many species are long-term coastal residents, sharing habitats with humans, and they feed at a high trophic level, often consuming species that are also part of the human diet. Additionally, they have fatty deposits capable of accumulating anthropogenic toxins, making them valuable indicators of ecosystem health. (1)

The microbiota of cetaceans plays a crucial role in their physiology, contributing to digestion, metabolism, and protection against pathogens. However, various factors, such as heavy metal contamination and organochlorine compounds, can disrupt this microbial ecosystem, compromising cetacean health and facilitating the emergence of infectious diseases. (2,3)

Marine mammals are K-strategists, meaning they have slow reproductive rates and small population sizes, which makes them particularly vulnerable to environmental changes and anthropogenic pressures. Their microbial ecology is a key element in maintaining population balance, yet research on cetacean microbiota remains limited. Despite the special interest these charismatic animals generate among humans, significant knowledge gaps persist, particularly regarding the role of microbiota in their health and conservation. (4,5)

This study is divided into two main sections:

(1) A bibliographic review of cetacean microbial ecology and

(2) An analysis of the alterations occurring in the microbiota of cetaceans in captivity and the wild, followed by a discussion of the findings and their implications. Given the fundamental role of microbiota in cetacean health and conservation, this work aims to highlight its importance and address the current research gaps in this field.

2. Cetacean Microbiota in the Wild and Captivity

2.1 Microbiota in the Wild

Cetaceans living in natural environments have a diverse and stable microbiota, determined by food availability and water quality. The wild microbiota includes bacterial species from the genera *Pseudomonas*, *Vibrio*, and *Flavobacterium*, associated with a balanced ecosystem. The role of gut microbiota in maintaining health and preventing infections has been well documented in various species, including marine mammals (Guarner & Malagelada, 2003).

2.2 Microbiota in Captivity

Cetaceans in aquariums and dolphinariums experience significant alterations in their microbiota due to artificial conditions, restricted diets, and frequent administration of antibiotics. These modifications can induce dysbiosis, facilitating the proliferation of opportunistic pathogens such as *Mycobacterium marinum* and *Erysipelothrix rhusiopathiae*.

3. Impact of Pollution on Cetacean Microbiota

Marine pollution alters cetacean microbiota by inducing immunosuppression and changes in bacterial composition. Disruptions in the gut microbiome-host metabolic interactions have been shown to contribute to disease development in various organisms, including marine species (Holmes et al., 2011)

High concentrations of heavy metals and polychlorinated biphenyls (PCBs) have been identified in stranded cetacean tissues, suggesting a correlation between contaminant exposure and increased opportunistic infections.

3.1 Contaminants and Microbiological Alteration

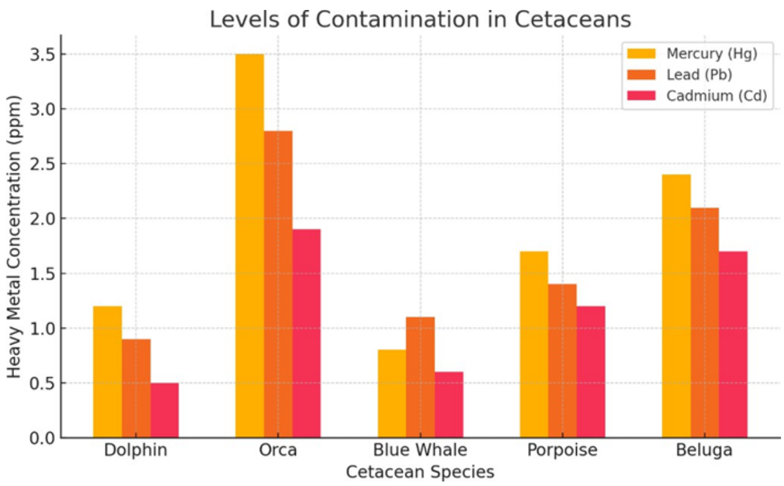

Figure 1. *Levels of pollution in cetaceans, showing Hg, Pb, and Cd concentrations in different species. (Own elaboration)*

- **PCBs and dioxins:** Related to immunosuppression and higher susceptibility to viral and bacterial infections.
- **Heavy metals (Hg, Pb, Cd):** Accumulate in adipose tissues, negatively impacting intestinal microbial diversity.
- **Organic waste:** Promotes pathogen growth in aquatic environments.

4. Emerging Diseases in Cetaceans

Emerging infectious diseases (EIDs) are those in which any of the following situations occur:

- A known infection spreads to a new geographic area or population.
- A new infection resulting from the evolution or change of an existing pathogen.
- A previously unknown disease or pathogen is diagnosed for the first time.
- The concomitant appearance of environmental changes that offer new opportunities for pathogens to thrive.

The factors that determine the emergence of an EID are largely unknown, but are known to be related to the adaptation of infectious agents to new species (Jiménez-Clavero MA. Climate change and arbovirus transmission). Three types can be identified among emerging diseases in wild species:

- Those that occur because host susceptibility has increased.
- Those that, due to environmental changes, favor the pathogen, making it more virulent.
- Those in which pathogens have recently invaded new hosts, with weakened immune systems due to adverse environmental conditions (Heide-Jorgensen y col 1992, Dobson y Foufopoulos 2001).

Emerging or re-emerging pathogens (viral, bacterial, fungal) cause a large number of diseases that may have epizootic potential, zoonotic implications, and a complex pathogenesis involving other cofactors, such as anthropogenic contamination, genetics, and individual immune dysfunction (Bossart, 2010 Marine Mammals as Sentinel Species for Oceans and Human H e a l t h). Several emerging and re-emerging diseases are of viral origin, such as Morbillivirus, Herpesvirus, and Poxvirus; of bacterial origin, such as brucellosis; of parasitic origin, such as toxoplasmosis; and of fungal origin, such as lobomycosis. Furthermore, the isolation of antibiotic-resistant bacteria from stranded or captive cetaceans has been of particular importance (Stewart et al, 2014. Survey of antibiotic-resistant bacteria isolated from bottlenose dolphins Tursiops truncatus in the southeastern USA). Some of the recognized adverse consequences (direct and/or indirect) of anthropogenic chemical pollution in cetaceans include: increased susceptibility to infectious diseases, immunosuppression, reproductive failure, endocrine disruption, and an increased incidence of neoplasia (Dietz, R., Riget, F., y Born, E. 2000. An assessment of selenium to mercury in Greenland marine animals. Sci Total Environ, 245:15-24).

Regarding diseases, sources include river discharges, such as untreated sewage and effluent from livestock farms. Several emerging or recurring infectious diseases are known or suspected to have a significant impact on marine mammal populations. Brucellosis has also been reported in marine mammals and can cause infertility. Specimens of grey and harbour seals off the east coast of England have tested positive for Salmonella. Parasitic, bacterial, fungal, and viral pathogens (most frequently pneumonia caused by bacterial infections or parasites) are common causes of death in stranded dolphins on European coasts. The high prevalence of skin lesions in bottlenose dolphins in the Moray Firth in Scotland, for example, is believed to be caused by environmental conditions that affect skin integrity or by increased physiological stress.

Changes in microbiota can predispose cetaceans to emerging infectious diseases. The most notable include:

- **Morbillivirus:** A single-stranded, negative-sense RNA virus containing six genes encoding eight proteins, two nonstructural and six structural, arranged in a 3'-5' direction (Figure 3): nucleoprotein (N), phosphoprotein (P), matrix protein (M), fusion protein (F), hemagglutinin protein (H), and large protein (L) (Rima et al. 2005. 'Rescue' of mini-genomic constructs and viruses by combinations of morbillivirus N, P and L proteins)
- Responsible for epizootic outbreaks in dolphins and porpoises.

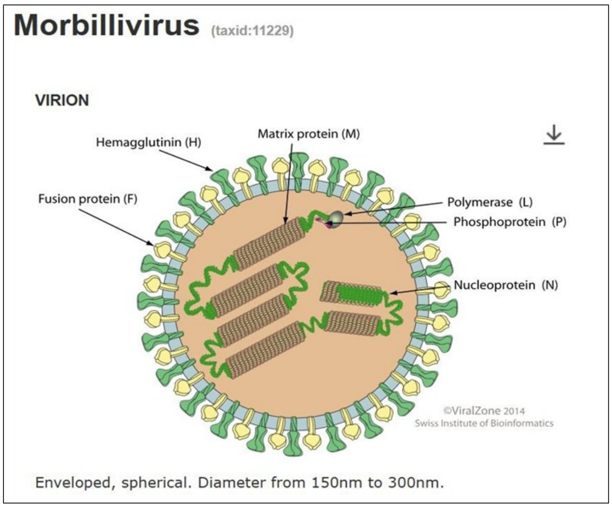

Figure 2. *Morphological diagram of the CeMV virion. Image taken from ©ViralZone 2014.*

Throughout the 1990s and continuing to the present, Cetacean Morbillivirus (CeMV) has emerged as the most important pathogen in wild cetaceans (Figure 3), responsible for major epidemics in the Atlantic, Pacific, and Mediterranean Oceans (Fowler y Miller, 2003. clinical pathology and assessment of pathogen exposure in southern and alaskan sea otters).

This virus, belonging to the Paramyxoviridae family, comprises three strains named after the species from which it was first isolated, thus distinguishing between Dolphin Morbillivirus (DMV), Porpoise Morbillivirus (PMV), and Pilot Whale Morbillivirus (PWMV) (Bellière et al., 2009. Estudio molecular de una nueva cepa de Morbillivirus de cetáceo aislada de un calderon tropical). Morbilliviruses such as distemper, believed to be terrestrial in origin, caused widespread mortalities in seals off the east coast of England in 1988 and 2002 and in striped dolphins in the Mediterranean.

Transmission is horizontal, spreading by direct contact or respiratory aerosols. There is no sex predisposition, but it has been observed that Mediterranean bottlenose dolphins are apparently more susceptible to the disease, in which it is believed to cause high mortality rates annually (Rojas, 2004. Morbillivirus en Cetáceos)

A. Dorsal lesions. *B. Ventral lesions.*

Figure 3. *Skin lesions caused by Morbillivirus on a male Indopacetus pacificus (Longman's beaked whale) found off the coast of Maui, Hawaii, on March 22, 2010. A. Dorsal lesions. B. Ventral lesions. Image taken and modified from the National Oceanic and Atmospheric Administration (NOAA) [Image from http://hpulamalama.com/wp/?p=1097].*

- **Marine brucellosis:** Caused by *Brucella ceti*, affecting the reproductive system.
- **Lobomycosis:** Chronic skin infection linked to polluted environments.

5. Conservation Strategies Based on Microbiota

To mitigate the impact of pollution and preserve cetacean health, conservation strategies based on microbiota monitoring must be implemented:

- **Microbiological surveillance programs:** Periodic analysis of intestinal and cutaneous microbiota.
- **Regulation of marine pollutants:** Implementation of policies to reduce industrial discharges and toxic waste.
- **Captivity management:** Designing balanced diets and reducing antibiotic use to prevent dysbiosis.

6. Conclusions and Future Directions

The microbiota of cetaceans is a key indicator of environmental health, and its alteration has significant consequences for species conservation. Chemical pollution of anthropogenic origin directly and indirectly impacts cetaceans, leading to increased susceptibility to infectious diseases and immunosuppression. Due to the bioaccumulation of persistent organic pollutants (POPs) and other contaminants, cetaceans serve as biological indicators of marine pollution levels.

However, research on the microbial ecology of captive cetaceans remains limited, making direct comparisons between wild and captive individuals challenging without sufficient data. Given the influence of both marine pollution and captivity on microbial composition and disease susceptibility, implementing surveillance and regulatory strategies is essential for the preservation of these marine mammals.

Conflict of Interest

The author declares that she has no conflict of interest.

Acknowledgement

To my daughters for being the driving force behind believing in myself.

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