Connecting Microbiomes: From Soil to Human Health across Ecosystems

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Abstract: - Microbiomes by definition provide the foundational ecosystem for sustaining life, while also permitting negative impacts on the health of any system. Human health is closely linked to the gut microbiome, metabolism is supported by nutrient absorption, influencing multiple pathways including brain function, immune system performance, organ function, and circulatory health. In parallel, agricultural production relies heavily on the health of the soil microbiome. This article delves into the benefits of healthy microbiomes both in humans and within the soil and the connections between. Optimizing these microbiomes can lead to improved human health—which manifests as longevity and enhanced productivity—and better soil health, which correlates with increased agricultural productivity and resilience. The use of Electrocide, for example, has demonstrated improvements in immune system function and nutrient absorption, thus enhancing overall metabolism and reducing the negative impacts of pathogens. This article also updates readers on the latest research related to Electrocide applications on agricultural and human microbiomes, along with their health implications. Investigating the interactions among soil, plant, and human microbiomes can reveal critical insights into mitigating some adverse impacts of agricultural practices on human health. Examples of these correlations will be explored. Healthy soils emerge from the application of the best sustainable agricultural practices, while human health can be improved through better food choices, regular exercise, and proper hydration. Land-to-sea ecosystems have their own biomes and pathogenicity magnified by agri-inputs, industrial pollution, and natural and other dramatic inputs to the downstream equation. Policymakers must acknowledge this synergy and invest in interdisciplinary strategies that foster more resilient agricultural systems, ecosystems, and healthier human populations. As we continuously delve into the complexities of these interrelations, proactive action is necessary for minimizing environmental pollution, safeguarding public health, and promoting sustainable practices that will benefit future generations.

Key-Words: - Health Interconnections, Microbial communities, Ecosystem health, Gut microbiome, Pollution, Microbial transmission, Pathogenicity, Human health, Biotic and abiotic habitats, and Land-to-Sea ecosystems.

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1 Introduction

Microorganisms are found almost everywhere on our planet where they play a pivotal role in the establishment and functioning of marine, terrestrial, and freshwater environments, [1]. Additionally, eukaryotes, including plants and animals, are naturally associated with complex microbial communities that are crucial for the health and functioning of their host. These microbial communities what is called microbiomes, which are an assemblage of bacteria, protozoans, fungi, archaea, viruses, plus other microeukaryotes, with respective activities in the context of a given biotic or abiotic habitat. Microbiomes occupy and shape the vast array of ecological niches available in natural and engineered environments, [2]. Microbiomes are associated with the digestive tract of humans and other animals, in the treatment of domestic, agricultural, and industrial waste streams, in fermentative food production, and in the biotechnological production of bulk and fine chemicals. Microorganisms are transmitted between ecosystems, the potential and extent of more positive aspects of microbial transmission have not been addressed with equal attention, even though their impact and importance were recently emphasized, [3], [4]. Such knowledge, however, and particularly quantitative aspects of microbial transmission routes as well as the conditions that determine these, would be essential for the optimization and/or *de novo* design of microbiome-inspired intervention strategies that can allow safer, more sustainable, and healthier food and feed production, [5].

Microbiome equilibriums are affected by nutrients, microorganisms, temperature, and other factors such as pathogenicity. The nature of each microbiome whether soil in an agricultural field, an aquatic ecosystem, or the gut of a human or other animal with a gastrointestinal system creates the crucible for the positive, negative, or neutral influence within the system and also downstream effects. The connection between microorganisms and human health can be traced back to Koch's postulates, introduced in the late 19th century by Robert Koch, the founder of the field of Medical Microbiology, [6], [7]. There are four hypotheses fronted by Koch. Foremost, certain disease pathogens can be isolated from patients; secondly, the pathogen can not be detected in patients with other diseases; thirdly, in experimental animals, the pathogen can cause similar diseases, and finally, from experimental animals, the pathogen can be isolated. The hypothesis provides a criterion for validating the relationship between diseases and pathogens, hence an advanced approach that scientifically guides the epidemic aetiologies exploration, [7].

2 Human Health

A healthy microbiome affects nutrient absorption and there is a direct functional relationship between the gut and brain health. Pathogens like bacteria, viruses, and parasites can have significant health effects as shown in Figure 1 (Appendix).

Pathogens have substantial effects on the body’s blood flow. Whenever pathogens invade the body, a series of events are triggered by the immune system leading to changes in blood flow. Pathogens trigger the immune system to release inflammatory mediators in response to infection, [8]. Inflammation can cause blood vessels to dilate and become more permeable, leading to increased blood flow to the affected area as white blood cells and other immune cells are recruited to fight off the pathogen. Some pathogens can directly or indirectly induce a hypercoagulable state, leading to the formation of blood clots within blood vessels (thrombosis). Blood clots can disrupt normal blood flow, potentially causing blockages that can lead to tissue damage or even organ failure. Pathogens like certain bacteria and viruses can directly damage blood vessels, leading to impaired blood flow. The damage leads to weaker blood vessel walls that are unable to regulate the blood flow leading to increased risks from complications such as hemorrhage or reduction of blood supply to tissues. Severe infections, particularly from bacterial pathogens, can trigger a systemic inflammatory response known as sepsis. In septic shock, blood flow to vital organs may be compromised due to widespread vasodilation, reduced vascular tone, and abnormal clotting, leading to multiorgan failure and poor tissue perfusion. Pathogens may also affect blood flow by modulating the immune response. Some pathogens can evade immune surveillance or manipulate immune cells to their advantage, impacting the inflammatory response and blood flow regulation in the infected tissues. Overall, the effects of pathogens on blood flow changes are complex and can vary depending on the type of pathogen, the site of infection, and the host's immune response. Proper diagnosis, treatment, and management of infections are essential in preventing severe complications that may impact blood flow and overall health. Early recognition of signs and symptoms of infection and prompt medical intervention are crucial in addressing potential blood flow disturbances caused by pathogens, [9], [10].

3 Soil Health

The soil-plant system represents a continuum of microorganisms, which are able to survive both in the plant and in the soil environment and may be exchanged between the two as shown in Figure 2 (Appendix), [11]. Because of this close relationship, the type of vegetation, soil management practices, or environmental conditions greatly influence microbiome diversity and composition of soil as well as of plant-associated microbiomes, [12], [13]. Soils serve as major reservoirs of plant-associated microbiota encompassing plant-beneficial, neutral, or pathogenic microorganisms. Common is the symbiosis of plants with mycorrhizal fungi or of legumes with nitrogen-fixing rhizobia. Other beneficial microorganisms may have direct effects, such as by mobilizing and providing important plant nutrients, alleviating plant stress (in cases of drought), or protecting plants from pests and pathogens through competition, antibiosis, or the production of enzymes or metabolites. Indirect benefits include the induction of plant responses leading to improved resistance to pathogens. The soil microbiome, the environmental parameters, as well as the physiology of plants all determine which microorganisms are transferred to and established within and upon plants, [14].

Research reported in [15], [16], [17], there are multiple niches within the plant that enable the growth of diverse microbial communities. In the roots, a microbial continuum extends from the rhizosphere soil to the rhizoplane and different niches within the endosphere. Microorganisms colonizing the plant endosphere can comprise obligate or facultative endophytes. Depending on the plant microbial properties, species, genotype, and environmental conditions, different subsets of rhizosphere microbial communities enter and colonize roots as endophytes. A range of formal interactions and opportunistic events enable rhizosphere microorganisms to reach inner root tissues. These include intricate “chemical dialogues” between the plant and compatible microorganisms (e.g., legumes and rhizobia) that lead to modification of the host and microorganisms, colonization of root hairs, and formation of new organs. Compatible or opportunistic microbes can enter root systems through cracks (e.g., when lateral roots form) or by cell wall degradation. Once inside the plant, microorganisms can disseminate to below- and above-ground tissues by colonizing the apoplast or the vascular system. A plethora of opportunities exist for members of the soil microbiome to enter and colonize plant root systems, spread within the plant, and even be disseminated to new environments and generations of plants by movement of pollen, seed, or other tissues. [18], [19], [20], [21], reported that the endophytes colonize reproductive organs that are flowers, fruits, and seeds, the seeds being increasingly recognized as habitats for functionally important microorganisms. Microorganisms colonizing seeds and the spermosphere (the area around the germinating seed), can improve germination and increase seedling vigour, but also protect seeds against rotting or the emerging seedling against disease, [19], [20], [21]. Seed microorganisms are horizontally acquired, as many of them derive from the soil environment [22], where soil microorganisms colonize and then enter roots and then systemically colonize plant tissues and seeds.

Fundamental to crop production is the soil health. Healthy soil microbiomes are resistant to pathogens. Activities, such as heavy tillage, nutrient depletion, and excessive use of pesticides, lead to soil health degradation and increase crops susceptibility to diseases. Promoting sustainable soil management practices is key to enhancing soil biodiversity and fertility which is crucial in suppressing pathogenic organisms, [23]. The use of antimicrobial agents and antibiotics in agriculture systems leads to antimicrobial resistance (AMR) leading to the emergence of resistant pathogens that spread to crops either through contaminated water or soil. This poses a high risk to human health via the food chain. Organisms that are pathogenic in the soil contaminate crops at different stages of production which may lead to various foodborne illness outbreaks. Pathogens like E. coli, Listeria, and Salmonella present in produce are raising concerns thus the need for food safety protocols and agricultural practices that are proper. The shift to an integrated approach towards chemical, biological, and cultural controls to improve the soil microbiome health and downstream effects. There is a need to increase awareness and education on the importance of soil health and sustainable agricultural practices among the stakeholders especially consumers, farmers, and agronomists in comparing pathogenicity. An understanding of the connection between soil health and crop vitality is key to the development of resilient agricultural systems. The need of a collaborative effort is required among consumers, researchers, policymakers, and farmers in addressing pathogenicity in soils and crops. Enhancing soil health, utilizing integrated management strategies in addition to emphasizing sustainable agricultural practices can ensure safe, resilient food systems as well as mitigate risks associated with soilborne pathogens. Global population growth necessitates the need to tackle the challenges through innovative approaches and commitment to action from all stakeholders involved.

4 Electrocide

"Electrocide™" is a novel nature-based dietary supplement that has been previously administered over 500,000 times without any adverse effects. It has been tested for efficacy of anti-pathogenesis with the combination of trace minerals, [24], [25], [26], activation complex which allows for an increased solubility across cell membranes. Scanning and transmitting electron microscopic images show that the pathogens are degraded from the electrical interface of negatively charged pathogens in response to the positively charged active minerals from the surfaces disintegrating the negatively charged pathogens. The inactive disintegrating pathogens could be associated with immune improvement, [27]. An oxygen-rich environment is created through the electrolyte balance water in the Electrocide (liquid and capsules), which significantly increases and maintains higher dissolved oxygen content. This higher oxygen concentration increases oxidation/reduction cellular function (mitochondrial), creating energy elevation, increasing circulation and other organelle function protein metabolism, including hormone production, and other beneficial cellular actions, including mitochondrial and gut-brain activation, [27], [28], [29].

Previous studies indicated "Electrocide™" mechanisms supported claims related to improved general wellness, including fatigue, energy, diarrhea, and faster recovery towards COVID-19, [27]. Studies have also shown that cancer cells with a negative charge on the exterior surface [30], [31] and internally may allow "Electrocide™" to destroy negatively charged cancer cells effectively and stimulate a natural immune response to the neoplasm. Additionally, it has been postulated that using an enhanced delivery system for chemotherapeutics may provide greater effectiveness to be achieved with chemotherapy without the high number of side effects due to the lower quantity of the products used while improving the resulting efficiency at the same time. Recent studies in immunotherapy have shown that many patients have a chronic level of inflammation when being treated can be made more efficient when moving the body toward an acute inflammatory metabolism, which may allow for synergistic effects from the immune support treatment, cell treatments, and chemotherapeutics, furthermore, if radiation is being used the combined healing effects from the immunotherapy treatments may not only further enhance the recovery from the radiation but also aide in additional healthy cell regeneration in the patient.

[10], conducted a study that compared the antimicrobial efficacy of Electrocide with Ceftriaxone, a third-generation cephalosporin antibiotic, a well-known antibiotic, against several pathogens. Ceftriaxone inhibits bacterial cell wall synthesis by binding to penicillin-binding proteins (PBPs). This leads to the lysis of the bacteria. It is effective against a broad range of Gram-negative bacteria including many strains of E. coli, as well as some Gram-positive bacteria. The results, as shown in Table 1 (Appendix), indicate that Electrocide demonstrated superior performance in inhibiting the growth of Staphylococcus aureus, Streptococcus pyogenes, and Escherichia coli, with inhibition zones significantly larger than those of Ceftriaxone. For example, the area of inhibition for Staphylococcus aureus with Electrocide was 452.6 mm², compared to 95.1 mm² for Ceftriaxone, [7].

The effectiveness of the Electrocide is compared with known drugs such as Ceftriaxone shown in Table 1 (Appendix).

4.1 Proven Effectiveness Over Time

In Appendix Table 2 and Table 3 highlight the temporal effectiveness of Electrocide in reducing Staphylococcus aureus populations over 48 hours, showing a dramatic decrease in colony-forming units (CFU/ml) compared to Ceftriaxone. In contrast, Escherichia coli populations (Table 4, Appendix) were similarly suppressed by Electrocide over time, with a greater reduction in pathogen numbers compared to Ceftriaxone, as demonstrated in Table 5 (Appendix), [7].

Electrocide showed a very significant effect on the *Staphylococcus Aureus* population over time as shown in Table 3 (Appendix).

Table 4 (Appendix) shows that Electrocide is more effective than the Ceftriaxone in clearing the bacteria over time.

Electrocide showed a very significant effect on the Electrocide on Escherichia coli in the BHI population over time as shown in Table 5 (Appendix).

5 Soil Studies and Implications of Improved Microbiome

In the study conducted, [10], three soil samples were collected from different locations within Mbarara Referrals Hospital field, in South Western Uganda. The soils were collected from different parts of the hospital fields and samples were labeled based on their attributes: Soil Sample 1: Moist from the garden field; Soil Sample 2: Semi-arid type from the area between the garden and dry area, and Soil Sample 3: Arid and sandy on the dry area of the water terrace. Electrocide was also tested in agricultural soil, where it demonstrated promising effects on soil microbiomes. As shown in Appendix in Table 6, Table 7, Table 8 and Figure 3, Figure 4 and Figure 5, Electrocide effectively targeted pathogenic bacteria, including an E. coli spike, while leaving the natural microbiome relatively unaffected, particularly in moist, semi-arid, and arid soils from the Mbarara Referral Hospital region.

6 Correlation of Health along the Food Chain

6.1 Overview of Ecosystems

Keystone ecosystems that link land-to-sea environments play a crucial role in maintaining ecological balance and facilitating energy transfer across different ecosystems, [32]. Major keystone ecosystems and their associated positive and negative forces are shown in Appendix in Table 9 and Figure 6.

Respectively, keystone ecosystems play a key role in the health of the terrestrial and marine environments. They provide immense ecological and economic benefits; whereas they are also susceptible to various threats resulting from human activities and environmental changes. Protecting and restoring these ecosystems is important for maintaining biodiversity, supporting livelihoods, and mitigating climate change impacts, [33].

6.2 How are each Ecosystem is Affected by Pathogens?

Keystone ecosystems that link land to sea environments are critical for maintaining ecological integrity and facilitating interactions between terrestrial and aquatic systems. These ecosystems are susceptible to various pathogens, which can impact their health, biodiversity, and functionality, [34]. The overview of key land-to-sea ecosystems, the pathogens that affect each, and their impacts are shown in Table 10 (Appendix).

Pathogens play an important part in the health and stability of keystone ecosystems linking terrestrial and marine environments. The interaction of pathogens in these ecosystems has profound implications for biodiversity, ecosystem services, and community resilience. Monitoring and managing pathogen outbreaks, along with addressing the underlying environmental stressors, is key to the conservation of the ecosystems. Effective management strategies also require understanding the dynamics of pathogen spread and infection processes, which are influenced by climate change, pollution, and habitat degradation, [34]. The role pathogens play in biodiversity and how those roles can change across different ecosystems is shown in Table 11 (Appendix).

6.3 Variations Across Ecosystems

When looking at the Terrestrial Ecosystems; In forest ecosystems, pathogens can have substantial impacts on tree diversity. For instance, fungal pathogens like Phytophthora can lead to tree mortality, affecting the composition and structure of plant communities. In grasslands, pathogens can regulate herbaceous plant populations and influence grazing by herbivores, thereby affecting the overall biodiversity and community dynamics. In Aquatic Ecosystems; In freshwater ecosystems, pathogens can impact fish populations, leading to shifts in species composition. For example, outbreaks of fish diseases can reduce dominant fish species, allowing for the proliferation of other species and thus altering biodiversity. While in Marine ecosystems, such as coral reefs, are significantly affected by pathogens. Coral diseases can lead to declines in coral cover, which not only impacts coral biodiversity but also affects the entire reef ecosystem and the myriads of species that depend on coral habitats. In wetland ecosystems, pathogens impact the plant species that contribute to the structural complexities of the ecosystem. Pathogen outbreaks can lead to the loss of key species leading to changes in the habitat availability of various organisms further influencing overall biodiversity. Pathogens in ecosystems or in urban settings can thrive leading to changes in native species composition and hence the introduction of non-native species that may come with new pathogens. Pathogens also play a complex role in biodiversity shaping across different ecosystems by influencing species interactions, population dynamics, evolutionary processes, and community structure. The impacts of the pathogens are based on the organisms involved, ecosystem type, and the context of the environmental stressors or human activities. The understanding of these roles is key for effective ecosystem management and biodiversity conversation as it guides the understanding of the interconnectedness of pathogens and ecological health. To maintain ecosystem function and resilience, mitigation of pathogens impacts is crucial in vulnerable ecosystems and biodiversity hotspots.

There is a renewed effort among researchers to look at the roles played by healthy microbiomes and ecosystems in degrading and provision protection against pathogens. [35], emphasized the role of soil microbiomes in disease suppression by looking at how diversity within communities enhances resilience against pathogens. It has been demonstrated that pathogens affect nutrient cycles in human health and also in various ecosystems. According to [36], unprecedented population growth is being experienced globally and there is low food production that is unable to meet the demand due to population growth. The Agricultural Production System since the 1950s has become heavily dependent upon chemical inputs and the land and sea have been significantly affected by this buildup of chemicals including the rise of dead zones around the world. This opinion article points to the harsh realities of this overworked system and how it affects us all. There is a conclusion about what the future holds and where the Agriculture Industry needs to go towards greater sustainability. Agriculture contaminants from previous years affect soil health and the future sustainability of crop production not to mention the deleterious effects on streams, lakes, and ocean areas that are being polluted and species dying to support the faster growing. Plants are currently not producing to their optimal potential to provide for adequate global food security. It is our opinion that soil health is the key to the success of improving crop production. Recent research will show the overall effects on the very culture of soil health, on runoff effects on cyanobacteria, the devastation of biological systems both in the soil and water that support life and decontaminate the downstream pollutants of phosphorous and nitrogen that come from the agriculture inputs and the lack of efficiently reining in the effects of the unused products that wash away. New products are contemplated to decrease the use of fertilizer, increase the growth of plants, increase the nutritional density of the foods being raised, and increase product awareness at all levels of the food chain to help drive better choices about what we eat and how it affects ecosystems all over the world. Also, there are bright spots in how to use trees to help soil restoration. The agricultural sector is primarily responsible for excess nitrogen in the form of ammonia, nitrite and nitrate, phosphorus, pesticides, and pathogen pollution of water bodies in agricultural zones. Nitrogen and phosphorous are causal to eutrophication in water bodies and affect aquatic life, [37].

Many third-world developing countries' agricultural systems are on the verge of collapse due to a number of failed schemes. The residues of pesticides, herbicides, fertilizers, and over-use of soil have led to an inability for production to reach optimized levels, [38]. The structures for financing and subsidizing the farmers are broken and have proved to be less effective and unsustainable. The effects of climate change have further marginalized productivity due to changes in soil conditions and relative cropping equations. The effluents from the farm fields are toxifying streams and residues are being built up into oceanic areas in the form of new eutrophic zones, [39]. Further to these factors are the insufficiencies of education, marketing, transportation, and the growing lack of nutritional value of the crops raised. To all of these crises, there is a need to reinvent the agriculture system towards natural and organic sustainability - economically, environmentally, for food security and eco-safety as shown in Figure 7 (Appendix). Independent field trials using the food-safe nature-based products produced by Salvation Farming Solutions have shown seed and soil treatments led to over 250% increase in corn production compared to Control and 100% pest control by comparison. The control corn had 1.5 cobs per stalk with each cob having corn borer infestation with the experimental group having 3.5 cobs per stalk with no pests present. Nutritional analyses showed g/100g percentage change of 400%, 374%, and 257% for protein, carbs, and fat respectively. Overall, this systemic approach allows for a reduction in fertilizer by up to 80% while decreasing costs of production by over 50% while doubling the crop yield hence with the potential to quadruple the income of the farmer and also enhance soil health.

7 Conclusion

It is well documented that microbial communities play vital roles across ecosystems, influencing soil fertility, plant growth, aquatic balance, and human health. The health of soil, aquatic ecosystems, and humans are deeply interconnected through microbiome exchanges and shared environmental impacts. Pathogens disrupt microbiome balance, causing diseases in humans, plants, and ecosystems, exacerbated by human pollution, antimicrobial resistance, and poor management practices. There is a need for policymakers to recognize the synergy between environmental health, agriculture, and human health. Strategies like sustainable soil management, pollution mitigation, and microbiome-inspired technologies (e.g., Electrocide™) are vital for resilience and health restoration. There is a call for interdisciplinary strategies promoting resilient agricultural systems and healthier populations. Emphasis should be on proactive measures to mitigate environmental pollution and promote sustainability for future generations.

Acronyms:

AMR	Antimicrobial Resistance
BHI	Brain Heart Infusion
CFU/ml	Colony-Forming Unit Per Milliliter
HABs	Harmful Algal Blooms
PBPs	Penicillin-Binding Proteins
SCTLD	Stony Coral Tissue Loss Disease

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Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this work the authors used index medicus in order to improve the readability and language of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

APPENDIX

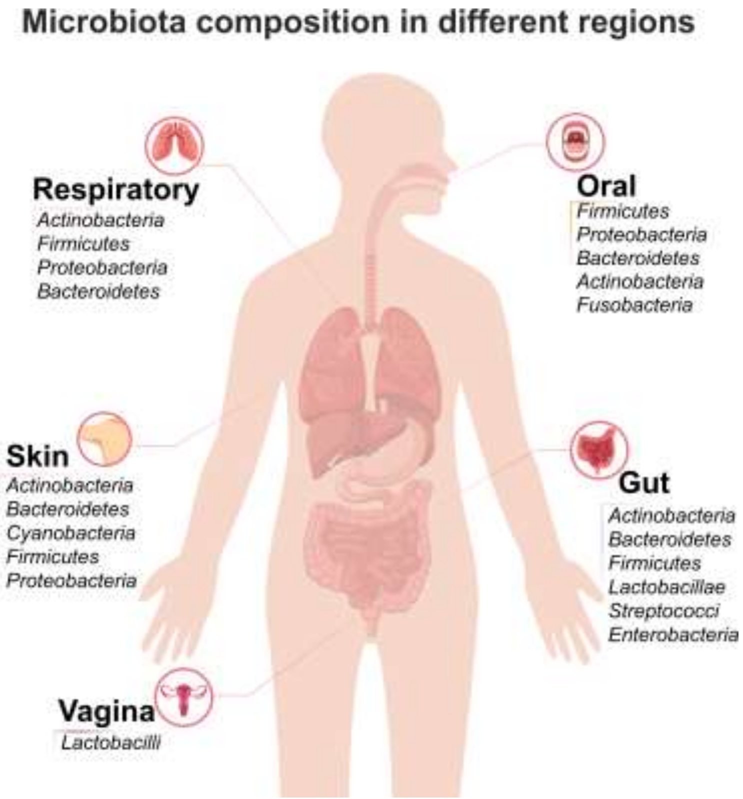

Fig. 1: Microbiota composition in different regions of human body, [8]

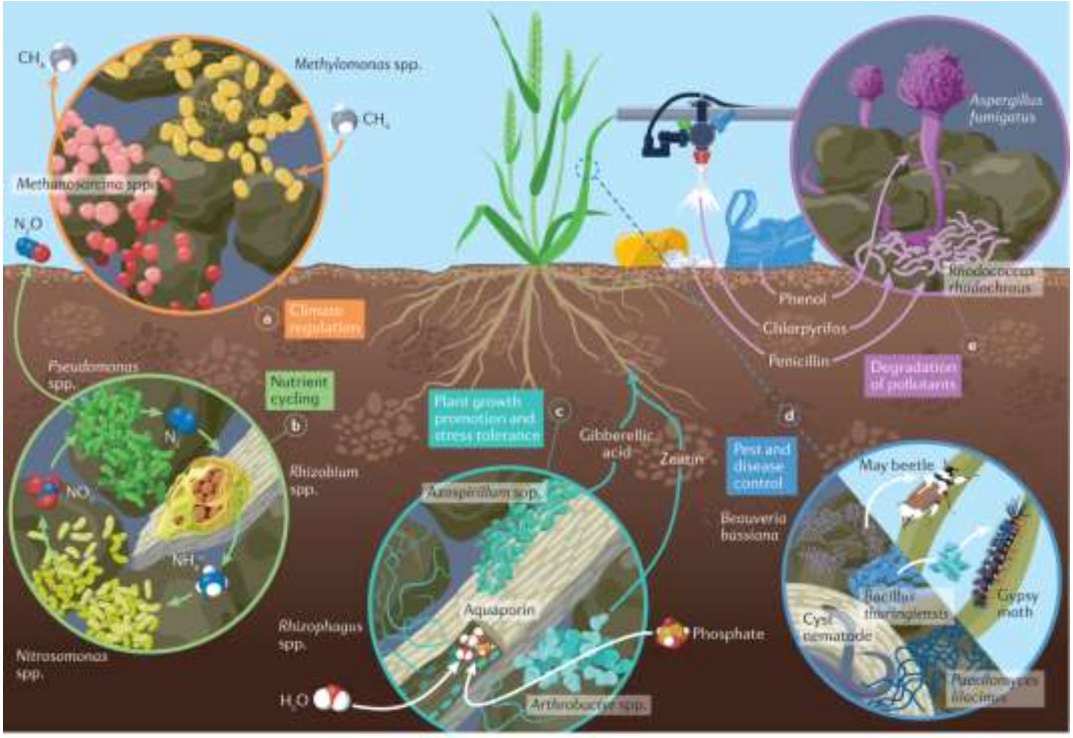

Fig. 2: Soil structure and microbiome functions in agroecosystems, [11]

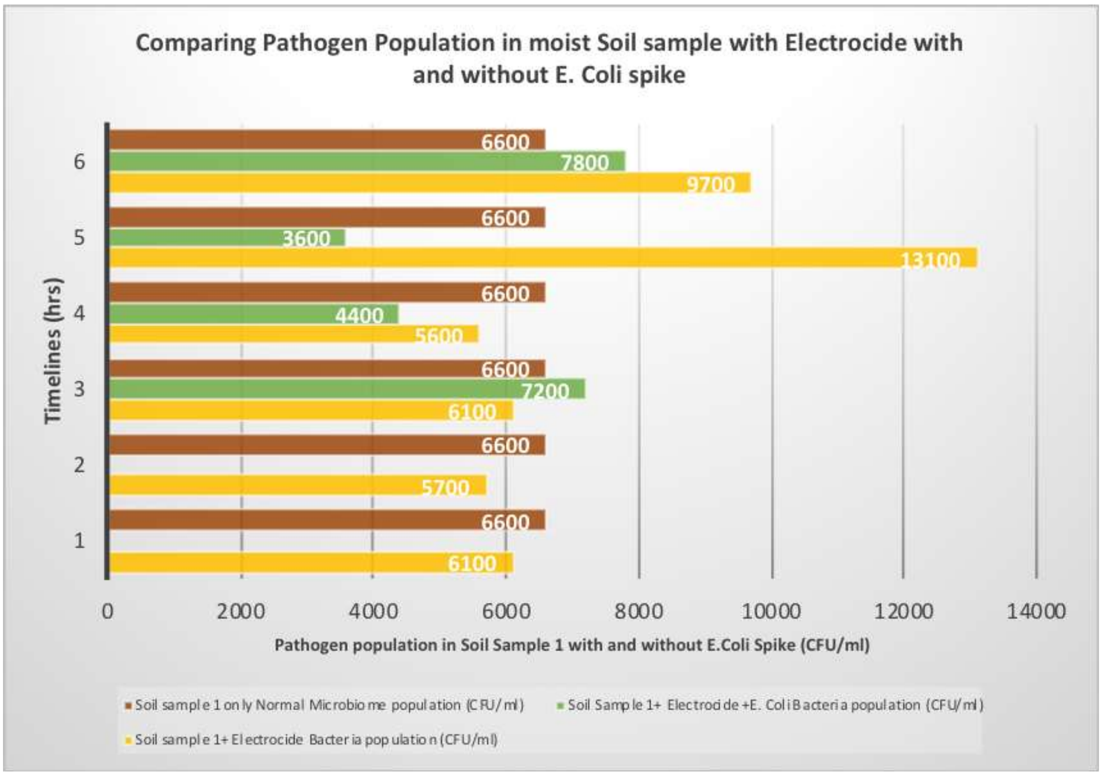

Fig. 3: Comparing Pathogen Population in moist soil sample with Electrocide with and without E. Coli spike

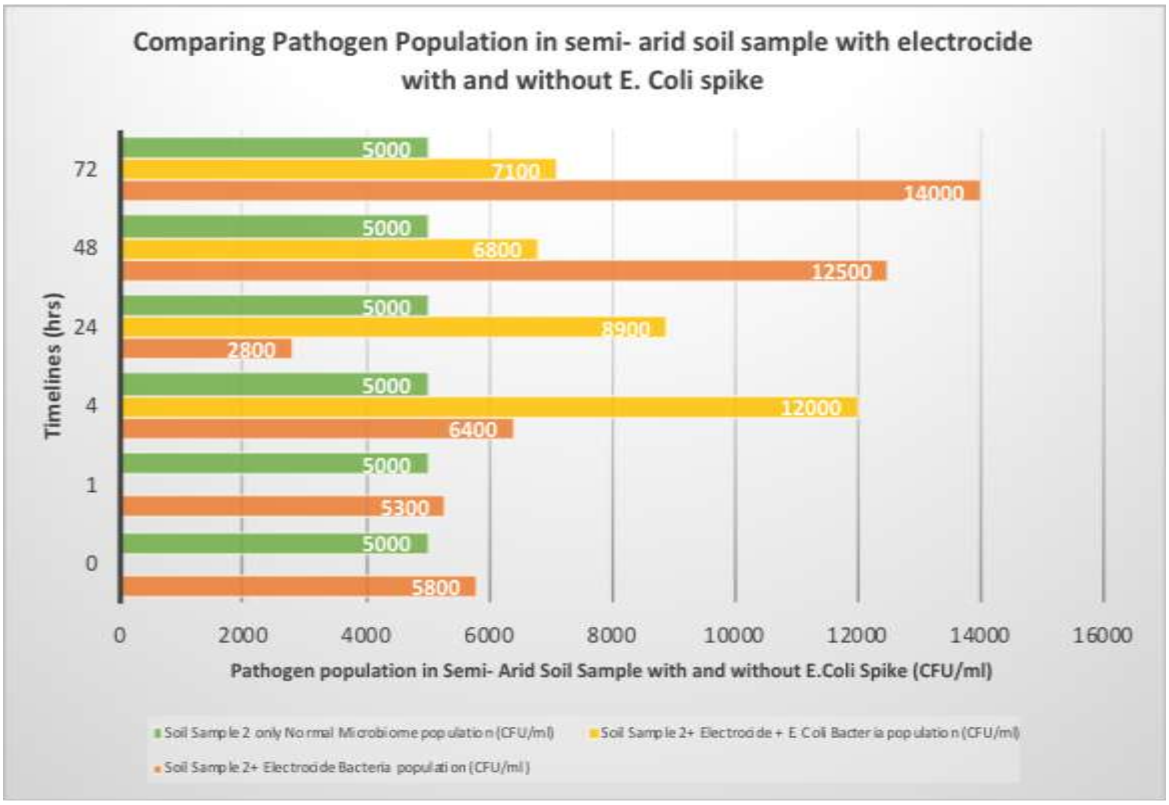

Fig. 4: Comparing Pathogen Population in Semi-Arid soil sample with Electrocide with and without E. Coli spike

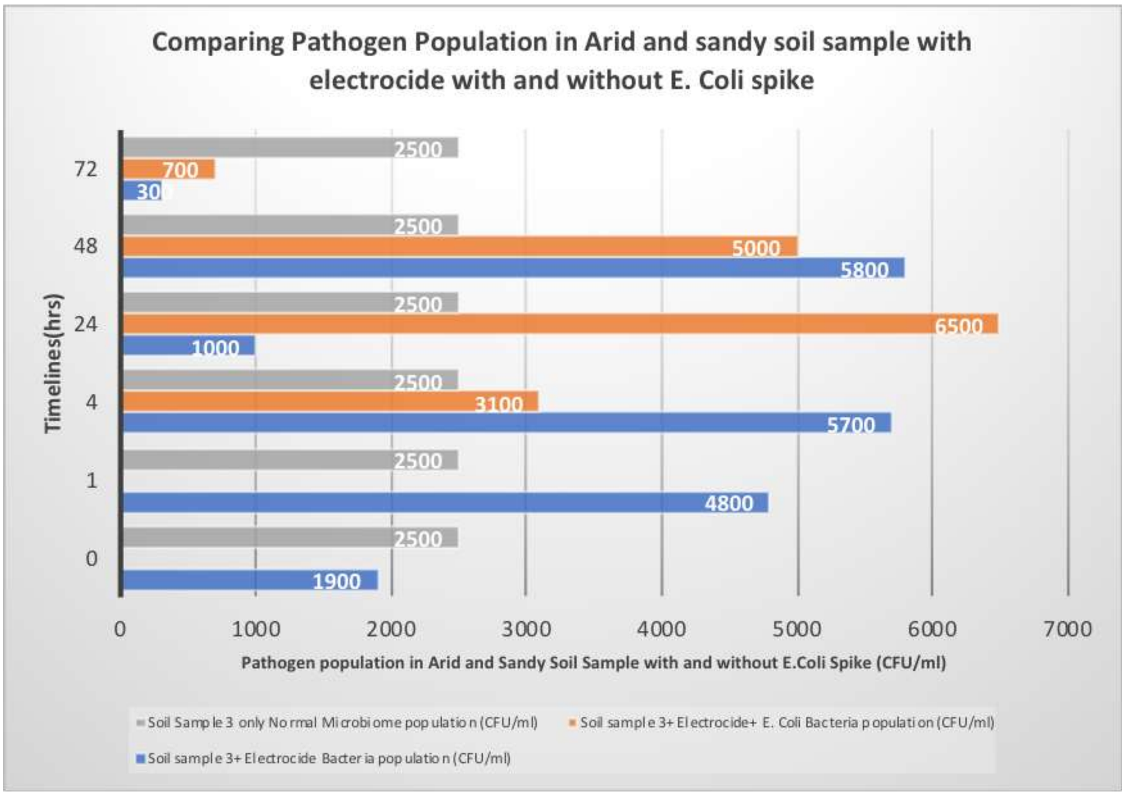

Fig. 5: Comparing Pathogen Population in Arid and sandy soil samples with Electrocide with and without E. Coli spike

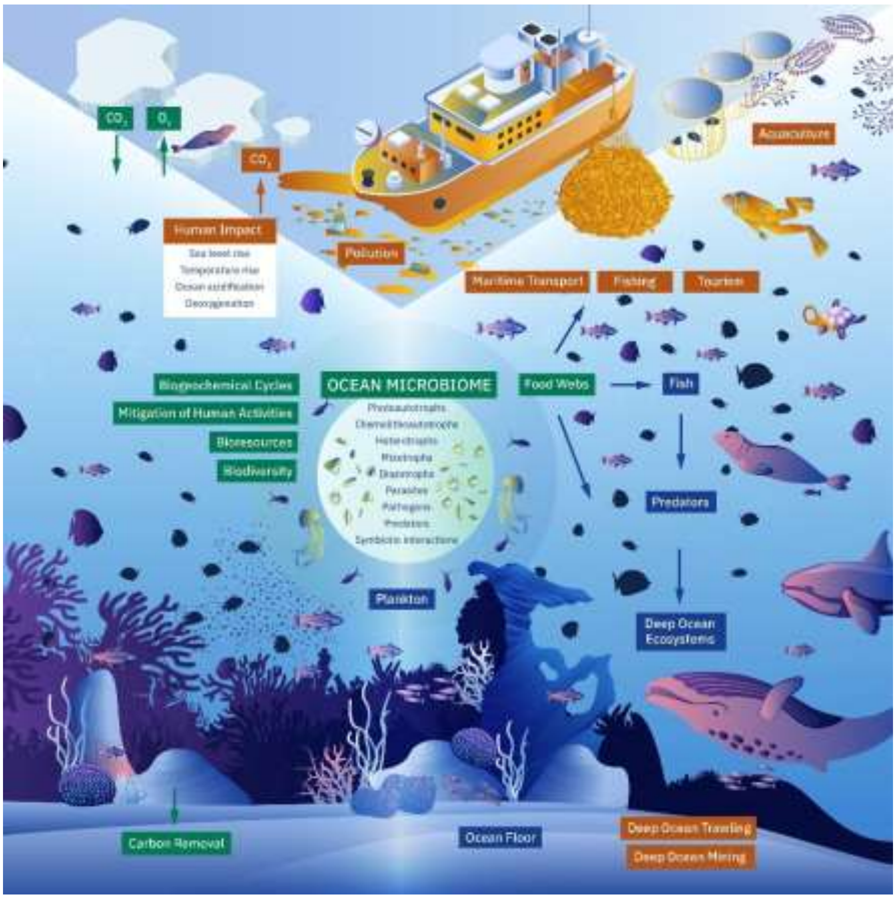

Fig. 6: Priorities for ocean microbiome research, [33]

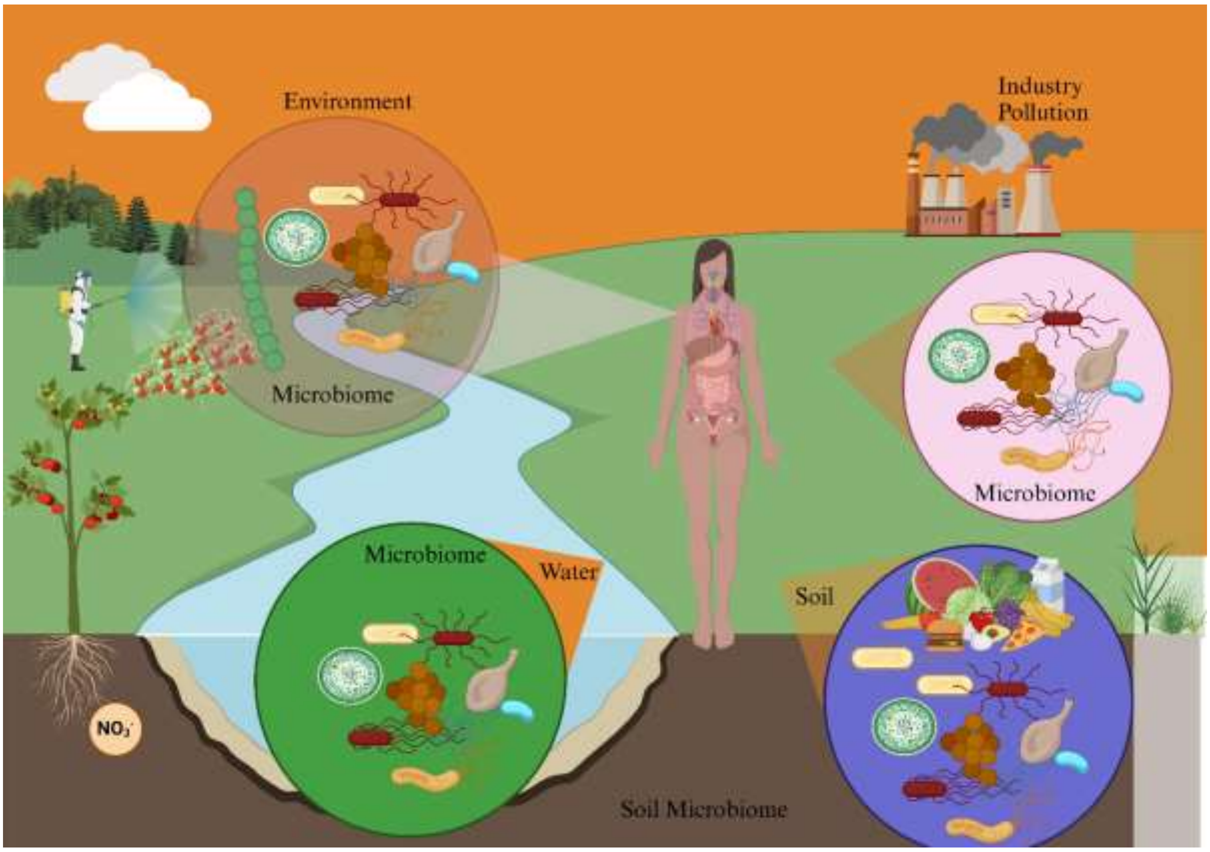

Fig. 7: Review of Applied Applications of Microbiome on Human Lives, [40]

Table 1. Comparison of pathogen disablement between Electrocide and Ceftriaxone (known drug) over 24 hours

Pathogen	**Area of inhibition (mm^2)**	
	Ceftriaxone	**Electrocide**
Staphylococcus aureus	95.1	452.6
Streptococcus pyogenes	616.0	531.1
Escherichia coli	804.6	452.6
Klebsiella pneumoniae	531.1	380.3
Pseudomonas aeruginosa	314.3	201.1
Proteus mirabilis/vulgaris	201.1	314.3

Table 2 Comparing the action of the Electrocide with Ceftriaxone on Staphylococcus Aureus

Timelines(hrs)	**Staphylococcus Aureus in BHI +Electrocide population (CFU/ml)**	**Staphylococcus Aureus in BHI +Ceftriaxone population (CFU/ml)**
0	Uncountable	Uncountable
1	38600	Uncountable
2	Uncountable	24400
4	24600	24700
24	700	Uncountable
48	400	32400

Table 3. Comparing the effectiveness of the Electrocide on Staphylococcus Aureus in the BHI population over time

Comparing the effectiveness of the Electrocide on Staphylococcus Aureus in the BHI population over time

1 vs 4hrs	
1 vs24hrs	5.4x10^3
1 vs 48hrs	9.6 x10^3

Table 4. Comparing the action of the Electrocide with Ceftriaxone on Escherichia Coli

Timelines(hrs)	E. Coli BHI +Electrocide population (CFU/ml)	E. Coli BHI + Ceftriaxone population (CFU/ml)
0	29100	Uncountable
1	Uncountable	Uncountable
2	28200	Uncountable
4	15800	Uncountable
24	2300	1100
48	2200	35800

Table 5. Comparing the effectiveness of the Electrocide on Escherichia coli in the BHI population over time

Effectiveness of Electrocide on Escherichia coli in BHI population over time

0 vs 2hrs	
0 vs 4hrs	
0 vs 24hrs	1.2x10^3
0 vs 48hrs	1.2 x10^3

Table 6. Comparing Electrocide action with soil sample 1 with and without E. Coli Spike

Timelines(hrs)	Soil sample 1+ Electrocide Normal Bacteria population (CFU/ml)	Soil Sample 1+ Electrocide +E. Coli Normal Bacteria population (CFU/ml)	Soil sample 1 Normal Microbiome population (CFU/ml)
0	6100	Uncountable	6600
1	5700	Uncountable	6600
4	6100	7200	6600
24	5600	4400	6600
48	13100	3600	6600
72	9700	7800	6600

Table 7. Comparing Electrocide action with semi-arid soil sample with and without E. Coli Spike

Timelines(hrs)	Soil Sample 2+ Electrocide Normal Bacteria population (CFU/ml)	Soil Sample 2+ Electrocide + E. Coli Normal Bacteria population (CFU/ml)	Soil sample 2 Normal Microbiome population (CFU/ml)
0	5800	Uncountable	5000
1	5300	Uncountable	5000
4	6400	12000	5000
24	2800	8900	5000
48	12500	6800	5000
72	14000	7100	5000

Table 8. Comparing Electrocide action with Arid and Sandy soil samples with and without E. Coli Spike

Timelines(hrs)	Soil sample 3+ Electrocide Normal Bacteria population (CFU/ml)	Soil sample 3+ Electrocide+ E. Coli Normal Bacteria population (CFU/ml)	Soil sample 3 Normal Microbiome population (CFU/ml)
0	1900	Uncountable	2500
1	4800	Uncountable	2500
4	5700	3100	2500
24	1000	6500	2500
48	5800	5000	2500
72	300	700	2500

Table 9. Major keystone ecosystems and their associated positive and negative forces

Ecosystem	Description	Positive Forces	Negative Forces
Estuaries	Estuaries are coastal areas where freshwater from rivers meets and mixes with saltwater from the ocean. They serve as nurseries for many aquatic species.	Biodiversity: Provide habitat for a wide variety of organisms, including fish, birds, and invertebrates. Nutrient Cycling: High nutrient influx from rivers supports rich biological productivity Flood Mitigation: Act as natural buffers against storm surges and flooding	Pollution: Runoff from agriculture and urban areas can lead to nutrient loading and contamination. Habitat Loss: Urban development and industrialization threaten estuarine habitats. Climate Change: Rising sea levels and changing salinity affect the delicate balance of these ecosystems.
Mangroves	Mangroves are coastal forests found in tropical and subtropical regions, characterized by salt-tolerant trees and dense root systems.	Plays a significant role in carbon sequestration as it stores substantial amounts of carbon, helping to mitigate climate change It further provides a critical habitat for marine and terrestrial life thus a biodiversity hotspot including endangered species. It provides coastal protection by acting as a buffer against storms leading to reduced erosion and thus protecting coastal environments.	Deforestation due to land clearing for agricultural purposes, aquaculture, and urban development leads to significant habitat loss. Pollution due to industrial runoff coupled with waste can degrade water quality and harm mangrove ecosystems. Non-native species lead to the disruption of the local ecosystems threatening native flora and fauna
Coral Reefs	Coral reefs are complex underwater ecosystems formed by coral polyps that provide a habitat for marine life diversity.	Coral reefs provide biodiversity support to a diverse number of species by providing shelter and food. They further support local economies through fishing and also tourism They provide coastal protection by reducing wave energy and protecting the shorelines from erosion.	Coral bleaching results from rising ocean temperatures and pollution, leading to the loss of coral cover. Overfishing is an unsustainable fishing practice that disrupts the balance of reef ecosystems. Coastal development such as construction and pollution leads to habitat destruction and water quality degradation.
Salt Marshes	Salt marshes are coastal wetlands flooded and drained by salt water brought in by the tides.	Salt marshes serve as habitat for several species of birds and fish. It also acts as a natural filter leading to the improvement of water quality by trapping pollutants. Salt marshes also store carbon in the soil thus helping in climate change mitigation.	Sea-level rise such as waves can lead to the loss of marshland hence change in plant communities. Pollution due to nutrient surplus from agricultural activities and also urban runoff results in eutrophication. Development pressures arising from land conversion for development purposes reduce marsh area plus ecological functions.
Riparian Zones	This is the zone that usually interfaces between land and a stream or a river and it is often rich in biodiversity.	The zones help with controlling erosion through vegetation stabilization of the banks. Act as a link between aquatic and terrestrial habitats allowing for species movement Nutrient Cycling: Play a role in filtering out pollutants before they enter waterways.	Agricultural runoff especially from pesticides and fertilizers can pollute water bodies. Urbanization and development lead to habitat destruction and fragmentation. Invasive species such as non-native plants can outcompete native vegetation, resulting in changing ecosystem dynamics.

Table 10. Overview of key land-to-sea ecosystems, the pathogens that affect each, and their impacts

Ecosystem	Pathogen Impacts	Common Pathogens	Impacts
Estuaries	- Estuaries are often affected by a range of pathogens, including bacteria, viruses, and protozoa, primarily due to nutrient runoff and human activities.	Vibrio spp.: These bacteria can be pathogenic to humans and aquatic organisms, particularly during warmer temperatures, and can lead to illnesses such as vibriosis. Enterococcus spp.: Often used as indicators of fecal contamination, elevated levels can indicate the presence of pathogens affecting human health. Pfiesteria piscicida: A dinoflagellate that causes fish kills and can lead to harmful algal blooms (HABs).	Pathogens can lead to disease outbreaks in fish and shellfish, impacting both ecological balance and fisheries.
Mangroves	Mangroves are affected by pathogens that can weaken trees, making them more susceptible to environmental stress.	Phytophthora spp.: This water mold can cause root rot and affect mangrove health. Ceratocystis manginecans: A fungus that causes wilting and dieback of mangrove trees. Bacterial pathogens: Various bacteria can infect mangrove species and contribute to decline.	Mangrove trees that are infected have reduced growth and reproductive success, resulting in habitat loss and diminished ecosystem services.
Coral Reefs	- Coral reefs are particularly vulnerable to pathogens, which can lead to coral diseases that threaten entire reef communities	Stony Coral Tissue Loss Disease (SCTLD): Affects various coral species, leading to widespread tissue loss and mortality. Vibrio corallilyticus: A bacterium that can lead to bleaching and disease in corals. White Band Disease: Caused by a combination of microbial pathogens, affecting key coral species like Acropora.	Coral diseases lead to coral bleaching, loss of biodiversity, and decreased reef resilience which affects fish populations and other marine life that depend on coral habitats.
Salt Marshes	Salt marshes can suffer from pathogens that affect the vegetation and the fauna relying on these habitats.	Necrotic Ring Spot Fungus: Affects salt marsh plants like Spartina alterniflora. Bacterial pathogens: Such as Pseudomonas spp., can infect marsh plants and lead to reduced growth and health. Parasitic nematodes impact plant roots, causing stress leading to reduced marsh resilience.	Pathogens result in a reduction of key plant species thus disrupting the ecosystem's functionality.
Riparian Zones	Riparian zones face threats from pathogens that can affect both plant health and water quality.	Phytophthora spp. causes root rot in riparian vegetation. Hyaloperonospora spp. is a downy mildew that affects various plant species in riparian zones. Coliform bacteria are indicator organisms that signify fecal contamination thus affecting water quality and aquatic life.	Diseases in riparian vegetation reduce bank stability and habitat complexity hence affecting water quality and contributing to erosion.

Table 11. Overview of the role pathogens play in biodiversity and how those roles can change across different ecosystems

Roles of Pathogens in Biodiversity	Mechanism	Ecosystem Impact
Population Control	Pathogens regulate the population of the host by causing disease outbreaks, which may prevent any single species from becoming overly dominant.	Controlling the population promotes species richness and diversity as it balances species interactions and prevents monopolization of resources.
Selective Pressure	Pathogens exert selective pressure on host populations, leading to evolutionary changes such as increased resistance or adaptive traits.	This evolutionary response can enhance overall genetic diversity within species, as genetically diverse populations may be better equipped to withstand pathogen pressure.
Species Interactions	Pathogens can alter species interactions, such as predator-prey dynamics, competition, and mutualism.	Such changes can reshape community structure and function, thus influencing biodiversity. For example, a disease that disproportionately affects one species might allow other species to thrive.
Disease Spillover	Pathogens can spread between species (spillover), affecting a wider range of organisms than just the primary hosts.	This can lead to changes in community composition and dynamics, positively or negatively affecting biodiversity depending on the roles of the affected species.
Nutrient Cycling	Pathogens can influence the decomposition process by affecting the health of primary producers and decomposers.	This, in turn, influences nutrient availability and cycling, which can affect the richness and productivity of the ecosystem.