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Evaluation of the Incidence of Candida yeasts in Coastal Lagoon Ecosystems Puerto Rico: Ecological and Pathogenic Implications

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Abstract:
Coastal lagoons, located at the terrestrial-marine interface, are exposed to a series of environmental changes due to anthropogenic activity. This study evaluated the water quality of seven lagoons in Puerto Rico: Tortuguero in Vega Baja, Condado in San Juan, San José in San Juan, Torrecilla in Carolina, Piñones in Loíza, Aguas Prietas in Fajardo, and Laguna Grande in Fajardo, between February and March 2024. The objectives were to isolate yeasts from the water of each lagoon, identify the genus and species, estimate the number of yeasts through colony-forming unit (CFU) counting, and compare the isolated species among the seven water bodies. Samples were collected using sterile bags, filtering 100 mL of water in triplicate. The membranes were placed on plates with Hardy CHROM™ Candida. The incubation period for the samples was 24 to 48 hours at 35-37 °C. The colonies were counted, isolated, and macroscopically identified. The average for each lagoon was 218 CFU in Laguna Grande followed by 125 CFU in Tortuguero, 84 CFU in Piñones, 68 CFU in Condado, 50 CFU in San José, 45 CFU in Aguas Prietas, and the least was 37 CFU in Torrecilla. The yeast species identified were *Candida tropicalis, Candida krusei* except in Laguna Piñones, and *Candida glabrata*, *Candida parapsilosis*, *Candida auris*, and *Candida albicans* except in Laguna Tortuguero, Laguna Grande, and Laguna Piñones. The results revealed a variation in yeast types in response to environmental changes. Understanding these findings is crucial to prevent potential health risks for those who use these waters. Most of the species isolated in this study are responsible for opportunistic fungal infections. The studies indicate that patterns are being observed in the epidemiology of Candida species, such as variations in prevalence and antibiotic resistance based on geographic location.

INTRODUCTION

The Candida genus comprises a diverse group of yeasts that are part of the microbiota of humans and other animals, but that can also become opportunistic pathogens, causing infections in immunocompromised individuals. Fungal infections cause an estimated 1.7 million deaths worldwide each year, primarily in immunocompromised individuals with two or more underlying conditions (Calderone *et al.,* 2014). This genus includes well-known species such as *Candida albicans, Candida tropicalis, Candida glabrata, Candida krusei*, among others, which are responsible for various infections, such as oral, vaginal, systemic, and mucocutaneous candidiasis (Lockhart *et al.,* 2012). Although these species are primarily known for their impact on human health (Alhamzi and Al.Maqtari, 2018; Carvalho *et al.,* 2018; Iqbal *et al.,* 2021; Echevarría, 2022), Candida is also found in natural environments, including soil, water, and vegetation (Ashraf and Iqbal, 2022; Echevarría and Bello, 2023; Echevarría, 2025). Its presence in aquatic ecosystems, such as coastal lagoons, is an underexplored area that presents an important field of study, especially in places with high biodiversity, such as Puerto Rico.

Puerto Rico, with its rich biodiversity and diverse coastal ecosystems, such as lagoons, estuaries, and mangroves, represents a unique environment where fungi, including those of the Candida genus, can thrive. The island's coastal lagoons, in particular, are habitats prone to the accumulation of organic matter and the interaction of various environmental factors, such as salinity, water temperature, and nutrient load, creating favorable conditions for the growth of microorganisms, including Candida sp. (Varela *et al.,* 2016). The study of Candida in these aquatic ecosystems could offer relevant information about their ecology, their possible role in compound biogenesis, and potential risks to public health. In a context where fungal infections are a growing public health concern (Iqbal *et al.,* 2019; Ashraf and Iqbal, 2021; Aernan *et al.,* 2023; Iqbal and Ashraf, 2023; 2025), understanding how Candida species survive and spread in these environments could provide clues to new sources of infection, resistance mechanisms, and control strategies.

Tortuguero Lagoon, located on the northeast coast of Puerto Rico, is a complex coastal ecosystem rich in biodiversity. This lagoon is known for being an important habitat for diverse species of flora and fauna, especially migratory birds and sea turtles. Its water is a mixture of fresh and salt water, which favors the existence of a diversity of aquatic organisms, including different species of yeast (Kiernan *et al.,* 2008). However, human activity in its surroundings has altered the water quality, which could impact the microbial communities present, including yeasts. The lagoon, located in the town of Vega Baja, is an estuary that plays an important role in water filtration and protection against coastal erosion. This lagoon has been the subject of water quality studies due to its susceptibility to nutrient pollution, primarily from agricultural and urban sources. Yeasts that inhabit the Vega Baja Lagoon can influence the nutrient cycle and the decomposition of organic matter in the water (Martínez-Rodríguez *et al.,* 2015).

The Condado coastal area in San Juan, which includes several bodies of water near the beach, has been intensely modified by urban development. Despite its urbanization, the area remains a refuge for diverse marine and freshwater species. Recent studies have revealed that Condado waters contain a variety of microscopic organisms, including yeasts, that may be adapted to changing salinity conditions and urban pollution (González-Ramos *et al.,* 2019).

San José Lagoon is a coastal ecosystem surrounded by urban areas and natural parks. Its function as an urban wetland allows it to receive a mixture of stormwater, domestic waste, and industrial waste, creating an ideal environment for the growth of yeasts that can influence the biogeochemical processes in the water. The microbial biodiversity in this lagoon is subject to the effects of climate change and urban pollution

(Pérez-Villalona *et al.,* 2015; Imaz-Lamadrid *et al.,* 2019).

Torrecilla Lagoon, located on the north coast of Puerto Rico, is a saltwater lagoon that has historically been an important resource for fishing and tourism. Torrecilla's waters are exposed to contamination by industrial and agricultural waste, which has altered its microbiological characteristics. The presence of yeasts in this environment is essential for the decomposition of organic matter and the regulation of water quality (Hernández-Ruiz *et al.,* 2014).

The Piñones area in Loíza is a coastal system that includes a series of wetlands and coastal lagoons directly connected to the marine environment. This ecosystem provides refuge for a variety of migratory and local species. Studies on aquatic microorganisms in Piñones have identified a high diversity of yeasts that play an important role in nutrient cycling but are also sensitive to alterations caused by plastic and other debris pollution (González *et al.,* 2020).

The Aguas Prietas Lagoon in Fajardo, located on the northeast coast of Puerto Rico, is a wetland system influenced by tourism and agriculture. The waters of Aguas Prietas contain a variety of yeasts that are part of the lagoon's ecological cycle, including their participation in the biodegradation of organic matter (Torres-Rodríguez *et al.,* 2018). However, the high load of nutrients and pollutants has altered the microbial composition, which can affect the lagoon's ecological balance.

Laguna Grande in San Juan, part of the San Juan Wetland System, is a critical coastal ecosystem that has been the subject of various investigations due to its high concentration of organic and inorganic contaminants. The yeasts found in its waters are not only involved in nutrient recycling but have also been documented to influence biofiltration processes, a vital process for ecosystem health (Méndez *et al.,* 2021).

Furthermore, Puerto Rico's coastal lagoons are key sites for environmental research due to their ecological importance and vulnerability to pollution, eutrophication, and the effects of climate change. Previous research has documented the presence of diverse microorganisms, including fungi, in Puerto Rico's coastal waters, although less attention has been paid to the Candida genus in these environments (Díaz *et al.,* 2019). This article aims to explore the Candida species present in the waters of the coastal lagoons of northern Puerto Rico, describing their biodiversity, their relationship with environmental conditions, and the potential associated risks to public health.

MATERIALS AND METHODS

Figure 1 shows the location of the all lagoons on the map. Water samples were taken from 7 different lagoons, totaling 21 samples. Each sample consisted of 300 mL of water. Samples were taken between February and March 2024. 100 mL of each sample were filtered in triplicate from each lagoon, and filter membranes were placed in Petri dishes with Hardy CHROM™ Candida medium (Echevarría, 2022). This medium facilitates the detection and differentiation of Candida species through the appearance of colonies of different colors. The dishes were incubated at 35-37 °C for 24-48 hours. The positive control was inoculated by inoculating a plate with Hardy CHROM™ Candida culture medium, using *C. albicans* as the indicator organism, to demonstrate the growth capacity of the medium. The negative control was a plate without any species to ensure the sterility of the medium. Colonies were counted, and the average was calculated for each sample (Echevarría, 2019; Echevarría and Iqbal, 2021). Samples were isolated in tubes containing Hardy CHROM™ Candida and incubated for 24 to 48 hours at 35–37 °C. The genus and species of each sample were identified.

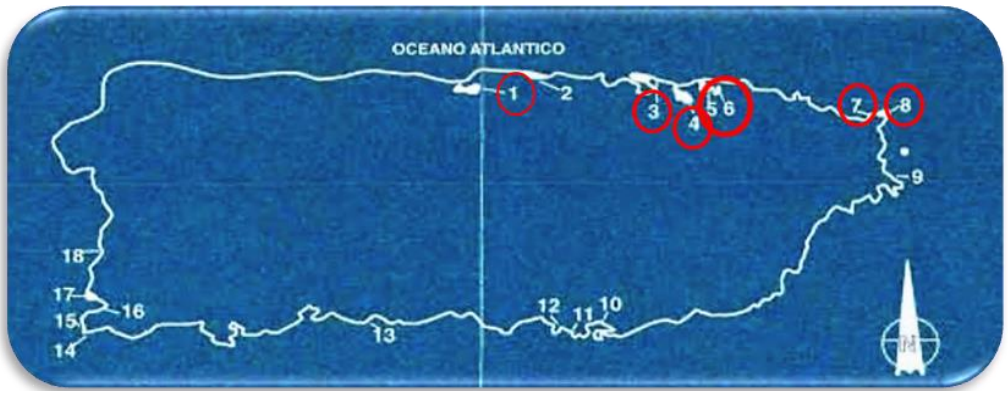

Fig. 1. Location of the lagoons (Grillo and Grana, 1986). (1) Tortuguero (3) Condado (4) San José (5) Torrecilla (6) Piñones (7) Agus prietas (8) Laguna grande.

RESULTS AND DISCUSSION

Species of the genus Candida are a group of ubiquitous yeasts found in a variety of environments, including aquatic ones. Their presence in coastal lagoons in Puerto Rico, such as Tortuguero in Vega Baja, Condado in San Juan, San José in San Juan, Torrecilla in Carolina, Piñones in Loíza, Aguas Prietas in Fajardo, and Laguna Grande in San Juan, raises serious questions both in terms of human and animal health and their effects on the environment. The study of these species in these coastal ecosystems has implications for public health, ecology, and aquatic biodiversity.

The results of the positive control were as expected: *C. albicans* grew. The negative control did not grow, so the controls fulfilled their purpose of measuring the efficiency of the medium and verifying its sterility. Figure 2 (Candida species in total lagoon water) summarizes all the lagoons in the three sampling sessions. Tortuguero Lagoon had the highest species count. The presence of Candida species in these aquatic environments can pose a significant risk to human health. In particular, species such as *Candida albicans, C. tropicalis*, and *C. glabrata* are known pathogens that can affect humans, especially those with compromised immune systems. Infections associated with these species include mucocutaneous candidiasis, urinary tract infections, systemic candidiasis, and invasive candidiasis, which can be serious and even fatal if not treated properly (Lockhart *et al.,* 2012; Kuhn *et al.,* 2015). These Candida species can colonize the skin or mucous membranes of people who come into contact with contaminated water, particularly if they have open wounds or if their immune system is weakened due to chronic illness or immunosuppressive treatments.

In Figure 3 (average CFU yeast Candida water gaps), we can observe the average CFU for each sample and the overall average for all samples. Tortuguero Lagoon had the highest CFU across all three samplings. In particular, *Candida auris*, an emerging Candida species, has proven resistant to multiple classes of antifungals, representing a significant challenge for treating the infections it can cause. Exposure to *C. auris* in these aquatic environments could lead to new outbreaks of hospital-acquired infections due to its ability to survive on aquatic surfaces and in the environment (Tsay *et al.,* 2017). Coastal lagoons in Puerto Rico, such as Tortuguero and Piñones, which receive both fresh and salt water, could be accumulation points for these pathogens due to contamination from human activities and the decomposition of organic matter.

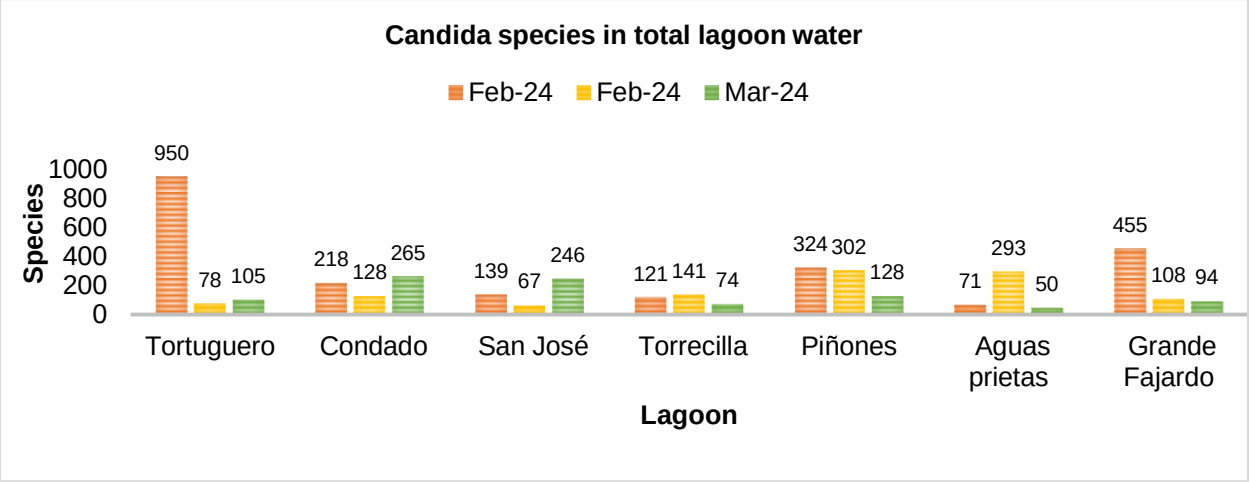

Fig. 2. Candida species in total lagoon water.

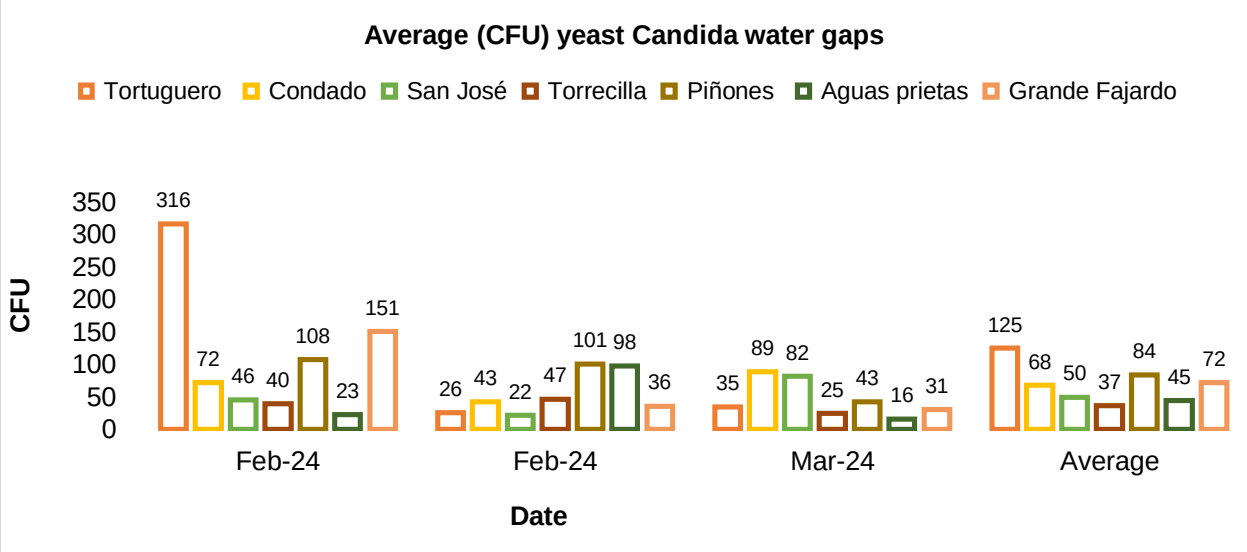

Fig. 3. Average (CFU) yeast Candida water gaps.

As we can see in Figure 4 (Candida species isolated from lagoon water), the presence of these species is evident. If you look at the graph, *C. auris, C. glabrata*, and *C. parapsilosis* are present in the Tortuguero lagoon, Condado, San Juan, Torrecilla, Piñones, Aguas Prietas, and the large lagoon in Fajardo. However, *C. krusei* and *C. tropicalis* were not found in the large lagoon in Fajardo, and *C. albicans* were not found in Totuguero, Piñones, and the large lagoon in Fajardo (Martínez-Rodríguez *et al.,* 2015; González-Ramos *et al.,* 2019; Hernández-Ruiz *et al.,* 2014; González *et al.,* 2020; Torres-Rodríguez *et al.,* 2018). Studies indicate that these species are resistant to antibiotics depending on geographic location (De Bedout and Gómez, 2010).

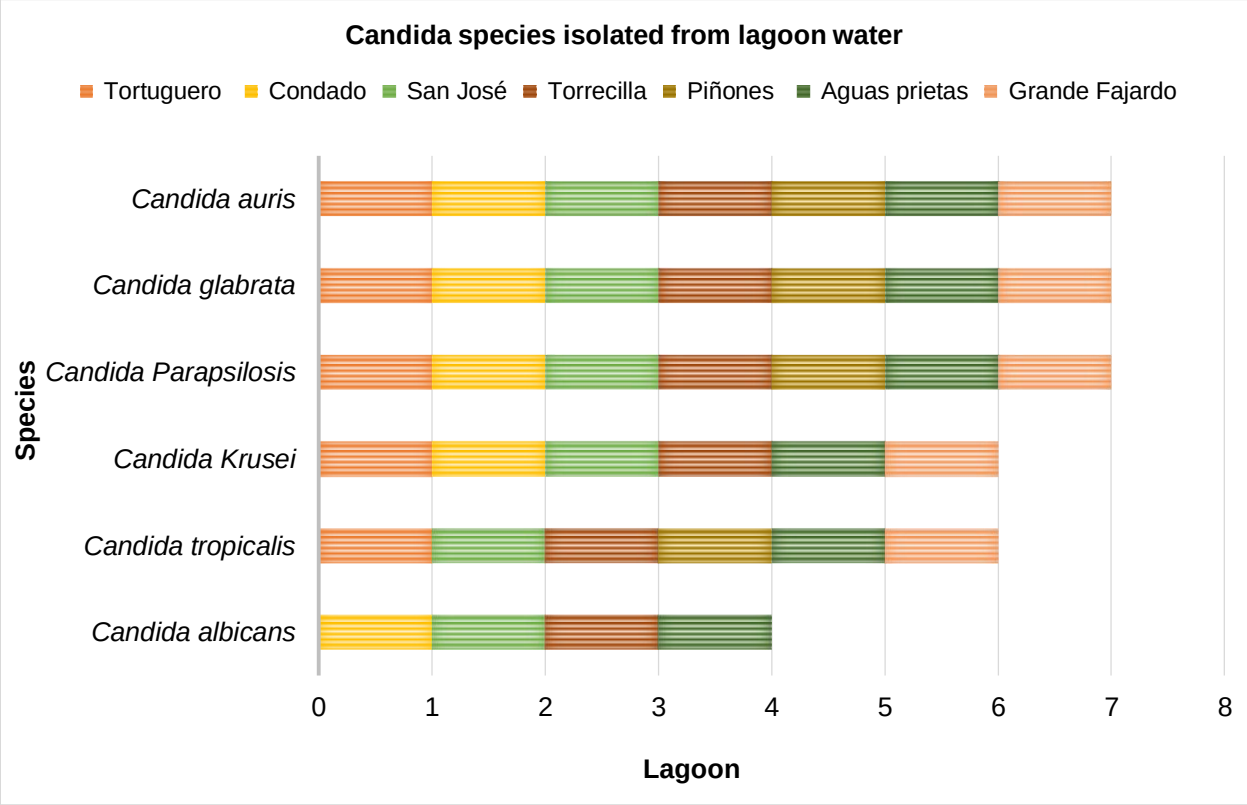

Fig. 4. Candida species isolated from lagoon water.

Aquatic animals can also be affected by the presence of Candida species in the waters of these lagoons. These yeasts have the ability to colonize the tissues of marine animals, including fish and mollusks, affecting their health. Candida infection in aquatic animals could result in alterations in their behavior, growth, and reproduction. While research on fungal infections in Puerto Rico's aquatic fauna is limited, the ecology of Candida suggests that its presence in the water could negatively affect local species, especially in areas with high pollution and eutrophication (Souza and Mendes, 2021). The alteration of aquatic habitats by the presence of these yeasts could also modify ecological interactions between species, affecting biodiversity and the balance of aquatic ecosystems. Candida species are known to form biofilms, complex structures that can adhere to aquatic surfaces such as rocks, sediments, and aquatic plants. These biofilms not only alter the aquatic microbiota but also hinder water purification, which can create conditions conducive to the proliferation of pathogens (Ben-Ami *et al.,* 2014).

Tables 1 through 7 show the number and species found in each sample. The presence of Candida species in Puerto Rico's coastal lagoons is not only concerning for human and animal health, but also for the environment in general. Coastal lagoons, such as Condado, San José, and Laguna Grande in San Juan, are sensitive ecosystems that harbor rich biodiversity. Candida species can contribute to the alteration of the aquatic microbiota, which could impact the ecological functions of these environments.

Table 1. Total isolated Tortuguero Lagoon Vega Baja.

	Total isolated Tortuguero Lagoon Vega Baja		
Species	**5 February 2024**	**26 February 2024**	**11 March 2024**
Candida tropicalis	900	5	11
Candida glabrata	11	2	0
Candida Krusei	30	0	2
Candida Parapsilosis	3	47	7
Candida auris	6	24	85
Candida albicans	0	0	0

Table 2. Total isolated San Juan Lagoon Condado.

	Total isolated San Juan Lagoon Condado		
Species	**5 February 2024**	**26 February 2024**	**11 March 2024**
Candida tropicalis	0	10	9
Candida glabrata	40	24	64
Candida Krusei	44	3	0
Candida Parapsilosis	32	8	108
Candida auris	102	82	85
Candida albicans	0	0	2

Table 3. Total isolated San Jose lagoon San Juan.

	Total isolated San Jose lagoon San Juan		
Species	**5 February 2024**	**26 February 2024**	**11 March 2024**
Candida tropicalis	16	21	15
Candida glabrata	36	5	31
Candida Krusei	1	1	2
Candida Parapsilosis	8	4	115
Candida auris	29	35	82
Candida albicans	0	1	0

Table 4. Total isolated Torrecilla lagoon Carolina.

	Total isolated Torrecilla lagoon Carolina		
Species	**5 February 2024**	**26 February 2024**	**11 March 2024**
Candida tropicalis	22	7	7
Candida glabrata	11	37	16
Candida Krusei	1	3	0
Candida Parapsilosis	58	13	34
Candida auris	29	77	17
Candida albicans	0	24	0

Table 5. Total isolated Piñones lagoon Loíza.

	Total isolated Piñones lagoon Loíza		
Species	**5 February 2024**	**26 February 2024**	**11 March 2024**
Candida tropicalis	231	200	27
Candida glabrata	37	63	0
Candida Krusei	0	0	0
Candida Parapsilosis	38	39	37
Candida auris	18	0	64
Candida albicans	0	0	0

Table 6. Total isolate taguas prietas lagoon fajardo.

	Total isolated aguas prietas lagoon Fajardo		
Species	**5 February 2024**	**26 February 2024**	**11 March 2024**
Candida tropicalis	19	40	14
Candida glabrata	21	29	5
Candida Krusei	1	0	6
Candida Parapsilosis	22	42	13
Candida auris	4	137	12
Candida albicans	0	45	0

Tabla 7. Total isolated Grande lagoon Fajardo.

	Total isolated Grande lagoon Fajardo		
Species	**5 February 2024**	**26 February 2024**	**11 March 2024**
Candida tropicalis	397	23	6
Candida glabrata	15	14	10
Candida Krusei	37	3	8
Candida Parapsilosis	3	24	55
Candida auris	3	44	15
Candida albicans	0	0	0

Candida contamination, particularly in areas with high nutrient loads, such as the Fajardo and Torrecilla lagoons, could contribute to water eutrophication, favoring the growth of pathogenic organisms and affecting water quality (Méndez *et al.,* 2021).

Table 8 shows a summary describing the yeast species, effects on human health and effects on the aquatic ecosystem. The ability of Candida to form biofilms also represents a risk to aquatic ecosystems, since these microbial structures can alter water flow dynamics, modify oxygen conditions and disrupt biological interactions between native species. Under conditions of high salinity and temperature, such as those found in the coastal lagoons of Loíza and Vega Baja, Candida species can adapt and proliferate, affecting aquatic biodiversity and the self-healing processes of these ecosystems (Del Pozo and Cantón, 2016; Kiernan *et al.,* 2008).

Table 8. Health Effects and Description of Candida Species in Aquatic Environments (Coastal Lagoons).

Species Description	**Effects on Human Health**	**Effects on the Aquatic Ecosystem (Coastal Lagoons)**	**References**
Candida albicans is a dimorphic yeast commonly found in the human microbiota. In aquatic environments, it can form biofilms on surfaces such as rocks and sediments.	It causes mucocutaneous infections such as oral and vaginal candidiasis. In immunocompromised individuals, it can cause serious systemic infections (invasive candidiasis) affecting internal organs such as the kidneys and lungs.	In coastal lagoons, their presence not only indicates organic pollution but can also disrupt natural microbial interactions. Their ability to form biofilms could alter the microbial ecology of the water.	(Kuhn *et al.,* 2015; Lockhart *et al.,* 2012)
Candida tropicalis is a common pathogenic yeast found in hospitals and water environments. It is frequently found in contaminated water bodies.	It primarily affects immunocompromised patients, causing systemic infections such as peritoneal and soft tissue candidiasis. It is known for its resistance to some antifungals.	Its presence in coastal lagoons could be an indicator of pollution and eutrophication. It can contribute to microbial imbalance in these ecosystems, affecting their diversity.	(Hedayati *et al.,* 2007)
Candida krusei is a yeast	This species is capable of causing	Although less common, its	(Kullberg and

species that has been increasingly recognized for its intrinsic resistance to fluconazole treatments.	systemic infections, especially in immunocompromised individuals. Antifungal resistance limits treatment options.	presence in bodies of water such as lagoons could contribute to antifungal resistance in the aquatic ecosystem, interfering with native microorganisms and altering the ecological balance.	Arendrup, 2015; Pfaller *et al.,* 2019)
Candida glabrata is known for its resistance to fluconazole and is frequently found in hospital environments, but also in fresh and coastal waters.	It can cause urinary tract infections, invasive candidiasis, and is associated with candidemia in immunocompromised patients. Its resistance to antifungals makes treatment challenging.	In aquatic environments, it can contribute to increased antifungal resistance in local microorganisms, affecting water quality and surrounding ecosystems.	(Chagas *et al.,* 2015; Ben-Ami *et al.,* 2014)
Candida parapsilosis is a yeast found in the environment and on surfaces, especially in moist and aquatic environments. It is known for its ability to form biofilms.	It causes systemic and cutaneous infections, particularly in newborns and immunocompromised patients. It is associated with infections in medical devices.	The presence of *C. parapsilosis* in coastal lagoons can affect aquatic microbiota and contribute to biological contamination, since this species has the ability to adhere to substrates and form biofilms, altering ecosystem conditions.	(Al-Fattah *et al.,* 2016; Colombo *et al.,* 2017)
Candida auris is an emerging yeast species that has caused hospital outbreaks worldwide. Its resistance to multiple antifungals poses a treatment challenge.	It is known to cause serious invasive infections, including systemic candidiasis, which can be fatal in individuals with compromised immune systems. Its ability to resist antifungal treatments represents a growing public health problem.	In aquatic environments, *C. auris* is an emerging threat due to its ability to survive on surfaces and in water for extended periods. Its presence can impact public health, especially in densely populated coastal areas.	(Arens *et al.,* 2019; Tsay *et al.,* 2017)

The presence of Candida species in Puerto Rico's coastal lagoons, such as Tortuguero, Vega Baja, Condado in San Juan, San José in San Juan, Torrecilla in Carolina, Piñones in Loíza, Aguas Prietas in Fajardo, and Laguna Grande in San Juan, highlights the importance of monitoring and controlling aquatic pathogens in these vulnerable ecosystems. These species not only pose a risk to human health but also have the potential to affect aquatic fauna and alter ecological processes in coastal lagoons (Almeida and Santos, 2020). Studying the distribution and ecology of Candida in these aquatic environments is crucial to understanding its role in coastal ecosystems and to developing management strategies that protect both public health and aquatic biodiversity.

The presence of Candida species in the waters of Puerto Rico's coastal lagoons and other aquatic ecosystems poses significant risks to both human health and aquatic ecosystems. Exposure to these species, particularly those resistant to antifungals, can result in serious infections, especially in immunocompromised individuals (Varela *et al.,* 2019). Furthermore, the proliferation of Candida in these aquatic environments could alter microbial biodiversity and contribute to the ecological imbalance of coastal lagoons, highlighting the need for continuous water quality monitoring in high-traffic coastal areas. Changes related to anthropogenic activities are directly reflected in the environment and, consequently, in water resources (Ríos *et al.,* 2017).

Yeasts of the genus Candida and other yeast species play an essential role in aquatic ecosystems, especially in coastal lagoons, where they act as decomposers and participate

in nutrient cycles, such as nitrogen and phosphorus (Ghosh, 2015; Ashraf and Iqbal, 2022). However, their presence can also have implications for human and animal health. The waters of Puerto Rico's coastal lagoons, which are influenced by terrestrial and marine sources, create conditions conducive to the colonization of pathogenic yeasts, which increases the risk of infections in humans and aquatic fauna, particularly in immunocompromised individuals. Furthermore, changes in the microbial composition of these environments due to pollution can affect water quality and alter the ecosystem services provided by these wetlands (González *et al.,* 2018).

CONCLUSION

Candida colony growth in the samples ranged from 16 to 316 CFU/mL. Taxonomic analysis revealed six species: *C. albicans, C. tropicalis, C. krusei, C. parapsilosis, C. glabrata*, and *C. auris*. The species found in greatest abundance was *Candida tropicalis*. The lagoon with the second highest number of colonies was Piñones Lagoon in Loíza, preceded only by Tortuguero Lagoon in Vega Baja. The study of yeasts in Puerto Rico's coastal lagoons is essential to understand not only the local aquatic microbiota but also the potential risks to public health and ecosystems. The presence of yeasts in these aquatic environments, such as those in the Tortuguero, Vega Baja, Condado, San José, Torrecilla, Piñones, Aguas Prietas, and Laguna Grande lagoons, requires continuous monitoring to assess the effects of pollution and climate change on water quality and biodiversity.

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CONFLICT OF INTEREST

The author declares that this article content has no conflict of interest.

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