Evaluation of the use of Wastewater Based Epidemiology as a Surveillance Tool and the Potential effects of Vaccines and Students' Beliefs and Practices in Mitigating the Spread of COVID-19 Among Students at East Carolina University

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December 2022

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Abstract

Worldwide, newly emerging and re-emerging infectious diseases and pathogens have led to increases in the number and frequency of disease outbreaks. Although these disease outbreaks are not new, increases in outbreaks have led to the need for public health agencies to effectively monitor disease spread. It has been estimated that 25% of 60 million deaths occurring yearly are the result of infectious diseases (Fauci et al., 2005; Nii-Trebi, 2017). Thus, disease monitoring tools are of utmost importance. The outbreak and spread of a severe acute respiratory illness in China alerted the world to a potentially new or re-emerging pathogen. As the virus rapidly spread, it was named "Severe Acute Respiratory Syndrome 2" (SARS-CoV-2) by the World Health Organization (WHO). The SARS-CoV-2 virus was deemed a public health emergency and later declared a pandemic as people across the world contracted COVID-19. The rapid spread of the COVID-19 pandemic underscored the need for disease monitoring and surveillance to mitigate spread. SARS-CoV-2 causes fever, dry cough, shortness of breath and in some instances loss of taste and smell. However, some persons, particularly those with pre-existing conditions, may experience severe symptoms of high fever, severe cough pneumonia, and even death (WHO,

2020). In the United States alone, an estimated 88,044,073 cases have occurred since the start of the epidemic (Worldometer, 2022).

Early strategies to handle the epidemic included temporary sheltering in-place orders, and many institutions including schools and universities shifted to online strategies to ensure continuity in learning. As these entities later sought to fully re-open and regain a sense of normalcy, many were tasked with establishing monitoring systems to help detect potential outbreaks. The use of wastewater-based surveillance was evaluated as a tool in helping to identify when and where student polymerase chain reaction (PCR) testing should be conducted. Here, we utilized wastewater-based epidemiology by sampling dormitory wastewater thrice weekly during Spring and Fall 2021. Data obtained from this sampling was used to help identify potential cases of COVID-19 in dormitories. Additionally, as vaccines were developed and distributed, the relationship between vaccination rates and COVID-19 cases on campus was investigated. Lastly, students' attitudes and behaviors toward the virus were also evaluated by administering an online survey tool designed through REDCAP systems. This survey utilized a Likert scale where possible to aid in analysis and comparison of student responses between Spring 2021 and Fall 2021 semesters.

Results from this study found significantly higher concentrations of SARS-CoV-2 in wastewater were observed during the Spring relative to the Fall semester. Dorms with higher numbers of COVID-19 cases also had higher concentrations of SARS-CoV-2 in their wastewater. A significant inverse relationship was observed between vaccine rates and student COVID-19 cases. As vaccinations rates increased within the dormitories, the number of student cases decreased. Students became more receptive to the vaccine in the Fall semester in comparison to the Spring. This change in attitudes may have helped the University's vaccination rates in the Fall semester thus affecting student COVID-19 rates. Here, we saw students a significant difference in virus perception between Spring 2021 and Fall 2021 semesters. Specifically, a lower number of students having a negative perception of the virus. Additionally, students reported having less restrictive behavior (e.g., visitors, mask wearing) in Fall 2021 compared to Spring 2021. Overall, this study showed that universities may successfully use surveillance techniques such as wastewater-based epidemiology to help determine when swarm testing of students should be initiated. It also provided evidence that vaccination campaigns may have helped to reduce the incidence rate of COVID-19 on campus. Gaining an understanding of how students feel and behave regarding the threat of disease outbreaks, the implementation of various preventative measures, and the effects that changes in educational delivery platforms may have on learning and social interactions are also important for developing successful programs to mitigate the spread of diseases.

Title

Evaluation of the use of Wastewater Based Epidemiology as a Surveillance Tool and the Potential effects of Vaccines and Students Beliefs and Practices in Mitigating the Spread of COVID-19 Among Students at East Carolina University

A Dissertation

Presented to the Faculty of the Department of Public Health

East Carolina University

In Partial Fulfillment of the Requirements for the Degree

Doctor of Public Health

By Avian White

December 2022

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Dedication

This doctoral dissertation is dedicated to my daughter Madison White. I am so blessed and thankful that God made me your mom-Madison. Madison, you are awesome, and I hope you know this. I also dedicate this to my family that believed I could do this, even before I thought I could. This is also dedicated to all the people out there that think; I can't do this, I'm not smart enough, I am a bit different, and have had setbacks. You guys can do it!

Acknowledgements

There are a number of people I would like to thank and without them this project could not have been accomplished. I would like to thank Dr. Charles Humphrey and Dr. Guy Iverson for inviting me to join this project. I don't know if they realized along with the enormity of piloting this novel surveillance project, they would also become a chair and member of a dissertation committee. This was a huge project that I was excited to join the team. Speaking of teams, I have to thank Dr. Lanika Wright and Dr. John. Fallon. Their expertise and help were amazing. I am also thankful, for their serving as committee members and guidance. I enjoyed working with Dr. Fallon's lab immensely, not only were they crucial to this project, but they gave much needed tips to students working in our lab. Dr. Wright's team was so accommodating when I had questions or needed information. There is no way we could have gotten this done without Facility Services. An enormous thanks goes out to those gentlemen. I was impressed at how they always brought us samples with a smile on their faces. I would also like to acknowledge student living and all they did with parsing through the information we handed off and making sure follow-up testing was conducted. Additionally, I would like to thank ECU admin and Health Education and Promotion for allowing us to commandeer much needed space. I would also like to thank the students that worked on this project. We could not have done it without them. There was such a huge team supporting this project and I know I have forgotten so many. Thank you!

Most important I have to thank my daughter Madison. She really was truly understanding when we couldn't play Legos or race in Mario Kart. She is such a jewel! I have been blessed to have such a strong support group as I have worked to complete my goals on this project.

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Chapter I: Introduction and Purpose of the Study

Emerging infectious diseases have the potential to cause significant harm and are routinely broken down into two categories: newly emerging and reemerging (Nii-Trebi, 2017). Worldwide, newly emerging and re-emerging infectious diseases and pathogens have led to increases in the number and frequency of disease outbreaks. It has been reported that between 1940 and 2004, over 335 infectious diseases have emerged (Jones et al., 2008). Many pathogens have a remarkable ability to adapt and change thus ensuring their survivability. For example, seasonal outbreaks of some influenza strains have been identified as genetic descendants from the influenza virus responsible for the 1918 pandemic (Morens and Fauci, 2020). Additionally, these adaptations may lead to increased contact with previously unaffected populations. Several of the newly identified infectious pathogens affecting human populations in recent decades were zoonotic in nature (Wang and Anderson, 2019; Nii-Trebi, 2017).

Host-switching or spillover of pathogens may naturally occur over time. However environmental factors such as natural disasters, deforestation, and expansion or migration of human populations into previously undeveloped landscapes may lead to increased contact with zoonotic pathogens (Nii- Trebi, 2017; Neiderud, 2015). Human behavior with respect to animal contact may also be a factor in disease transmission. Domestication of animals, used as food sources, including demand for wild animal meat products are practices contributing to augmented interactions with zoonotic pathogens (Bird and Mazet, 2018). Additionally, globalization is an important aspect of transnational economic integration. Thus, the necessity and ease of widespread travel is imperative to its success. Nevertheless, an unintended consequence has been increased pathogen flow contributing to the emergence and reemergence of infectious disease (Labonté et al.,2011).

Emerging infectious diseases are not a new phenomenon. It has been estimated worldwide that 25% of 60 million deaths occurring yearly are the result of infectious diseases (Fauci et al., 2005; Nii-Trebi, 2017). Recent studies indicate the past century alone has experienced multinational and potentially global pandemics because of newly emerging and re-emerging infectious disease, with many of these diseases being respiratory in nature (McCloskey et al., 2014; Hays, 2005; Jones et al., 2008). These pandemics, coupled with an account of notable outbreaks that have occurred throughout human history, such as the bubonic plague during the 1300's and measles in the Americas during the 16^{th} -19^{th} centuries, may signify the intensity of various emerging infectious diseases (McClosky et al., 2014). Recent outbreaks (e.g., Ebola, SARS, H1N1), have led to the realization of a need for early detection systems in preparation for public health emergencies. Indeed, in summarizing the 2009 H1N1 Influenza Pandemic, the World Health Organization (WHO) issued a review on International Health Regulations of 2005. Included in this report, the committee highlighted timely detection, identification, characterization, and monitoring via the Global Influenza Surveillance Network and Response System (GISRS) (WHO, 2011). The importance of surveillance systems in providing valuable information to aid public health officials in navigating and developing mitigation protocols during a pandemic was outlined. Additionally, the WHO GISRS noted that vaccine development, manufacturing and distribution is a measure of its success (Hay and McCauley, 2018). Hence, vaccines may be a crucial part of managing public health outbreaks.

Coronavirus Disease- 2019 or (COVID-19), was declared a global public health emergency by WHO in January 2020 (Wang et al., 2020). The disease was initially reported in China to the

WHO Country office on 31 December 2019 (Morawski and Cao, 2020). Research has shown the virus was able to spread throughout the entire country of China within 30 days (Hua and Shaw, 2020). China reported closing off Wuhan by 23 January 2020, however the virus was already detected in several regions within China along with neighboring countries such as South Korea and the Philippines by 9 February 2020 (Mavragani, 2020; Neilson and Woodward, 2020). Early during the outbreak, Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) showed itself to be effective at spreading, infecting 1000 people in 48 days. In contrast, SARS needed approximately 4 months and Middle East Respiratory Virus Syndrome related coronavirus (MERS-CoV) needed two and a half years to reach this number (Boulos and Geraghty, 2020). Differences in infection rates between SARS and SARS-CoV-2 may be more profound as speculation has risen that China underreported its viral infections (Liu and O'Brien, 2020). By 21 February 2020, Italy reported its first death attributed to COVID-19 and on 11 March 2020, the WHO declared SARS-CoV-2 a pandemic (WHO, 2020).

The ability of emerging infectious diseases such as SARS-CoV-2 to effectively spread and infect people is indeed a public health issue that may have tremendous impacts on morbidity and mortality. Thus, the ability to establish effective public health policy is essential to curb further spread of these diseases. Programs such as public health surveillance is essential in the fight against emerging infectious diseases. Data received from surveillance programs can guide the decision-making process for not only public health officials, but also elected officials, policy makers and administrators.

Viruses may mutate and change over time or between seasons. Surveillance data may be imperative in determining antigenic changes in viruses. Hence, the GISRS aims to monitor the spread of influenza variants. Analysis and knowledge of these changes are important in vaccine development which may depend on a specific viral strain. The resultant creation and distribution of these vaccines may impact surveillance type and disease control strategies during a pandemic response (Zhang et al., 2017). Surveillance programs that include monitoring for vaccinated individuals may help public health officials determine persons potentially at risk for a specific disease.

Surveillance systems may often be paired with surveys to better understand populations being served. For example, research has shown that bio-behavioral surveys may have influenced HIV surveillance of key populations, becoming the backbone of that surveillance program (Weir et al., 2018). Information obtained from surveys may be used to obtain characteristics of populations to help determine sampling and research strategies useful in constructing intervention plans (Ponto, 2015). In addition, surveys may be powerful tools that can be used to guide the construction of measurement indicators. Thus, use of a survey may enhance constructs of a surveillance system. Results from surveys may help lead to recruit of additional and their expertise needed to evaluate and assess needs, resulting in a robust interdisciplinary program.

The ability to collect and analyze data in real-time (or near real-time) from surveys and surveillance systems is crucial to help shape intervention and management programs used to curb the spread of disease. Understanding the importance and usage of surveillance in public health programs may impact morbidity and mortality locally and on a global scale especially during early outbreak periods when vaccines are not readily available. Elucidating the importance of using surveillance programs as part of an overall effective intervention strategy may have profound impacts on community as well as global health.

The objectives of this study are to:

1. Evaluate the use of Wastewater Based Epidemiology as a surveillance tool during the COVID-19 pandemic on a college campus (East Carolina University) and its accuracy in predicting SARS-CoV-2 outbreaks in dormitories

    a. Compare SARS-CoV-2 concentrations in wastewater from dorms with high cases of confirmed COVID-19 cases to those with low cases of COVID-19 infection

        i. It was hypothesized that dormitories with higher confirmed student cases of COVID-19 will have higher concentrations of SARS-CoV-2 in their wastewater.

    b. Was wastewater sampling effective in identifying new cases of COVID-19 persons when concentrations surpassed identified margins?

        i. It was hypothesized that sharp increases in SARS-CoV-2 concentrations in wastewater will correspond to new COVID-19 cases.

2. Summarize the history and efficacy of vaccines while observing vaccine rollout on a college campus (East Carolina University)

    a. Did the university see a statistically significant difference in the average viral copy count between Spring and Fall semesters as vaccines became more readily available to student populations?

        i. Because vaccines for COVID-19 were offered to more persons prior to the start of the Fall semester, it was hypothesized that the viral copy count for the Spring semester will be statistically higher than the virus copy count for the Fall semester.

b. Is there is a significant correlation between vaccine compliance and incidence of student cases?

i. COVID-19 vaccines were rolled out to reduce the likelihood of contracting the disease. Students were encouraged to have been vaccinated prior to coming to campus. Thus, it was hypothesized that as vaccine compliance increased, the incidence of student cases would decrease.

3. Evaluate student practices and beliefs concerning the COVID-19 pandemic by evaluating student survey responses at East Carolina University

a. Was there a statistically significant difference in student attitudes and beliefs concerning COVID-19 between Spring and Fall 2021?

i. It was hypothesized that attitudes and beliefs concerning COVID-19 will differ between the Spring and Fall semesters. Specifically, smaller numbers of students will be concerned about the virus during the Fall semester when vaccines were readily available.

b. As student vaccinations occurred during Fall 2021, was there significant differences in student behaviors (e.g., handwashing, meeting in groups of 5+) between Spring and Fall semesters?

i. It was hypothesized that as more students became vaccinated, there would be a statistical difference in student behaviors between the Fall and Spring semesters. It was anticipated that students would become more relaxed with their behaviors in the Fall semester.

The first paper discusses a way to use environmental surveillance as an instrument in monitoring the spread of COVID-19 and as a potential tool to identify and reduce the magnitude of outbreaks. In this paper, the efficacy of wastewater-based epidemiology on a college campus and the usefulness of information the surveillance system may generate was established. This information ties into the second paper that is focused on vaccination rollout on a college campus. The second paper explores differences in viral concentrations in wastewater and COVID-19 cases in students between semesters when vaccines were readily available for students and when there was not vaccine availability. Thus, leading to the third paper summarizing the differences in student behaviors and beliefs between the semesters in response to the rollout of vaccinations. These papers are interrelated as they will focus on factors attributing to semester differences in SARS-CoV-2 cases on a college campus.

Competencies Addressed

This dissertation satisfies the requirements of the Doctor of Public Health Requirement by addressing the following competencies.

Foundational Competencies

- Design a qualitative, quantitative, mixed methods, policy analysis or evaluation project to address a public health issue
- Explain the use and limitations of surveillance systems and national surveys in assessing, monitoring and evaluating policies and programs and to address a population's health
- Integrate knowledge, approaches, methods, values and potential contributions from multiple professions and systems in addressing public health problems

Environmental and Occupational Health Competencies

- Apply the components and functions of conventional and advanced wastewater systems and stormwater treatment technologies and agriculture best management practices
- Interpret results of data analysis for public health research and policy

Chapter II: Background

Surveillance And Wastewater-Based Epidemiology

The continuous systematic collection of data coupled with its analysis and interpretation describes the basic tenants of what is considered public health surveillance (Centers for Disease Control and Prevention [CDC], 2018). Equally important is the timely dissemination of this information to necessary officials, enabling them to make appropriate decisions in response to a problem (Groseclose and Buckeridge et al., 2017). Thus, public health surveillance systems are theoretically constructed to provide data to assist in interventions (e.g., inhibit spread of disease) (Nsubuga et al., 2006). In addition to helping stop the spread of emerging infectious diseases, surveillance systems may be used to monitor social determinants of health (e.g., socioeconomic factors, diet, behaviors) and track mental health issues, infectious and chronic disease outcomes along with environmental health (Groseclose and Buckeridge et al., 2017). Historically, surveillance was used to monitor diseased persons or those expected of disease exposure. However, during the 21st World Health Assembly in 1968, the concept of public health surveillance was officially adopted with the aforementioned traits: collection, analysis, and dissemination of data, as an essential function of public health practice (Delich and Carter, 1994).

Surveillance may be broken down into 2 categories: event-based surveillance (EBS) and indicator-based surveillance (IBS) (Balajee et al., 2021). While entities may and should use both in the process of stemming outbreaks, EBS often refers to the use of reports, rumors, stories or other word of health events. This information is often considered unstandardized or subjective. In contrast IBS often involves reports of specific diseases, such as laboratory confirmed cases of a disease (CDC, 2019; Balajee et al., 2021). Some data sources and strategies of IBS include (but are not limited to) healthcare facilities, laboratories, animal health surveillance, and sentinel health surveillance. In addition, IBS often includes some type of regular data collection and weekly alert threshold monitoring (Early Warning Alert and Response System [EWARS], 2019). Thus, IBS may be effective in monitoring weekly bacterial or viral levels of specified diseases.

There may be multiple techniques used to monitor bacterial and viral levels within a community. Typically, human virus replication does not occur within the environment and their introduction may be through human bodily fluids (Rooney et al., 2021). These bodily fluids may include material such as blood, saliva, and/or fecal matter. Bacteria and viruses found in these fluids may cause serious harm. There are approximately 15 million infections from enteroviruses along with thousands of hospitalizations each year (Faleye et al., 2021). First used as an indicator tool of community drug use, testing of untreated wastewater has progressed in its usage to measuring infectious pathogens (Devault and Karolak, 2020; Zuccato et al., 2005; Kankaanpää et al., 2016; Yang et al., 2015).

Wastewater can be procured from multiple locations within a community including pumping stations, wastewater treatment plants, and manhole portals in local neighborhoods (Erickson et al., 2021). This availability of sample procurement may enhance the ability to use wastewater as a form of surveillance. Wastewater-based epidemiology was founded on the belief that fecal and urinary biomarkers may be used to give real-time information on population health (Sims and Kasprzyk-Hordern, 2020). Thus, biomarkers that are stable in wastewater and rapidly obtained and pooled from sewage treatment systems may provide valuable information on bacterial and/or viral presence in a population (Zuccato et al., 2016). Biomarkers may include DNA and/or RNA residues from pathogenic fungi, bacteria, and viruses (Sims and Kasprzyk-

Hordern, 2020). Many viruses that are transmitted by the fecal-oral route are hardy in wastewater and may be detected during its surveillance.

The Global Polio Eradication Initiative, an international public health project, consisted of environmental surveillance, e.g., monitoring sewage systems, for polio biomarkers (Hovi et al., 2011). Prior to this, sewage had been monitored for polio in Helsinki, Finland following an outbreak. Here, sewage analysis helped evaluate the efficacy of the current polio vaccination campaign (Pőyry et al., 1988). Another study in Havana also sought to determine whether wastewater sampling may be used to detect polio. Researchers concluded that wastewater sampling may be a sensitive supplement to the current surveillance system (Lago et al., 2003).

Studies such as these have laid the groundwork for surveillance of other viral pathogens in sewage. Techniques derived from those used for the polio eradication program have been used to determine efficacy of surveilling sewage for Hepatitis A and Norovirus as an early warning system (Rezaeinejad et al., 2014; Hellmér et al., 2014). Researchers in Sweden collected and sampled wastewater from a treatment plant that served the Gothenburg region. Results indicated wastewater surveillance could be instrumental as an early warning outbreak detection system. In norovirus (genogroup GII) and astrovirus, virus may be excreted before symptoms appear, 1 to 2 days and 4 to 5 days, respectively (Hellmér et al., 2014).

In 2003, over 32 countries experienced an outbreak of SARS-CoV, a disease primarily spread through respiratory droplets (Xu et al., 2004; Wang et al., 2005). A study in Beijing, China, elucidating the potential for additional modes of transmission of SARS-CoV, resulted in researchers being able to detect the virus from sewage of hospitals with SARS-CoV infected patients (Wang et al., 2005). The ability to detect SARS-CoV in wastewater has led researchers to reasonably conclude that wastewater may be used to detect viral SARS-CoV-2 resulting from the current SARS Covid -19 outbreak.

Before the onset of symptoms, SARS-CoV-2 has as incubation period of 5.2 days (Reyes et al., 2021). It has been documented persons may shed the virus prior to the onset of symptoms, with studies showing asymptomatic persons may also shed the virus (He et al., 2020; Lewis et al., 2021). One study estimated that peak viral shedding may occur before the onset of symptoms (He at al., 2020). Additionally, research from SARS-CoV-1 showed a reduction in household transmission when patients isolated prior to peak shedding (Lewis et al., 2021; Wilder-Smith et al., 2020). This suggests that the availability of real-time data may stem COVID infections. Reliance solely on laboratory confirmed cases after the onset of symptoms may not be enough to slow the spread COVID infections. Additionally, studies have shown that wastewater-based epidemiology can identify asymptomatic carriers. In situations such as living centers or dormitories, this may contribute to viral spread as persons may not be aware they are sick due to not having any symptoms.

Wastewater- based epidemiology may be an effective tool in capturing potential SARS-CoV-2 infections prior to symptoms. The virus has shown stability in room temperature wastewater for an average of 2.1 days (low titers) (Bivins et al., 2020). This may allow untreated sewage to serve as part of an early detection warning system. This is extremely important as isolation is a powerful tool in halting human-to-transmission. Locations testing positive for the virus may pinpoint where additional testing (e.g., PCR testing, swarm testing) should occur. Additionally, partnering this step with contact tracing may help reduce the spread of the virus before reported symptoms occur in infected persons. This is important in places such as college dormitories where pre-symptomatic students may spread the virus to other dormitories, leading to campus-wide outbreaks. Thus, wastewater-based epidemiology may be instrumental in stemming outbreaks and allowing campuses to stay open and fully functional.

Vaccine History in Disease Outbreaks

The idea of disease surveillance has been hailed as a significant tool in stemming disease outbreaks. However, it is important to note that surveillance alone may not be enough. A notable example was the spread of smallpox in the late 1700's. Smallpox, a centuries old disease caused by 2 variants of the Variola virus: Variola major and Variola minor, is an extremely contagious disease that may be spread via droplets and contact with infected pustules or scabs (Centers for Disease Control and Prevention [CDC], 2021; Meyer et al., 2020). Persons affected with smallpox often suffered scars and some suffered blindness and disfiguration, with mortality rates averaging 30% (Krylova and Earn, 2020; CDC, 2021). The number and rates of infections of smallpox often differed depending on the size of the city or town. Larger cities (e.g., Paris, London) often experienced year-long endemics, whereas smaller towns seemingly experienced outbreaks but only during periodic intervals. Thus, not only did this suggest smallpox needed continuous new susceptible hosts for the virus, but also that survivors seemed to have immunity against future infections (Eyler, 2003; Thèves et al., 2014). Hence, the use of smallpox survivors in medieval times to nurse those who were afflicted (Reidel, 2005).

Throughout centuries, people have sought ways to combat the spread of smallpox. Places such as Africa, China, and India often exposed uninfected persons to infected smallpox material. This process, considered inoculation, has also been referred to as variolation (Best et al., 2004; Behbehani, 1983). The high rate of fatality and disfigurement often experienced as a result of smallpox infections helped usher in the practice of variolation in Western Europe and the New World. In Western Europe, this was aided by the championing of Lady Mary Wortley Montagu, whom in the New World Reverend Cotton Mather pushed for variolation upon learning of it from an enslaved African (Best et al., 2004; Behbehani, 1983; Reidel, 2005).

In addition to variolation using material from infected persons, material from cowpox pustules was used by others, such as Benjamin Jesty (Geddes, 2006). Building on these efforts, Edward Jenner worked to develop a vaccina vaccine, leading to what has been considered the first vaccination protocols (Geddes, 2006; Reidel, 2005; Meyer et al., 2020). As Jenner's vaccine was shown to be successful, its use spread. However, the continuance of smallpox epidemics over the years led to a goal by the WHO to eradicate smallpox. The worldwide campaign began in 1967 and by 1980 the disease was considered officially eradicated (Krylova and Earn, 2020).

The efficacy of the smallpox vaccine fueled study and hope that vaccines could be created for other diseases. Louis Pasteur, a prominent microbiologist and chemist sought to create vaccines to combat infectious diseases occurring in animals and humans (Pasteur et al., 2002). One such concern was the rabies virus, resulting from bites of infected "rabid" animals. In humans, rabies has a 99% mortality rate (Pieracci et al., 2019). Most human exposure to rabies is through pet dogs. In 1885, the first effective vaccine to treat humans against rabies was developed by Pasteur, constituting the second created human vaccine (Hicks et al., 2012; Hoenig et al., 2018). Use of this vaccine in humans had a profound effect on mortality from rabies. When the vaccine is given promptly, rabies is considered a vaccine-preventable disease (Zhu and Guo, 2016).

Vaccine development has continued in response to outbreaks of global and endemic diseases, particularly of those considered childhood diseases. Diphtheria is caused by the bacterial pathogen *Corynebacterium* genus and is considered an acute respiratory infection. Mainly affecting children under 15 years, it was once considered a chief cause for morbidity and mortality among children (Sharma et al., 2019). Pertussis, whooping cough, is extremely contagious and spread through respiratory droplets. The disease is especially dangerous to infants, who were typically most susceptible to infection. Thus, this age group had a higher risk of mortality and morbidity from pertussis infection (Nguyen and Simon, 2018; Skoff et al., 2017). This has contributed to pertussis becoming a nationally notifiable disease and was listed in the National Notifiable Disease Surveillance System (Skoff et al., 2015). Tetanus, caused by *Clostridium tetani*, is a potentially fatal disease that is introduced into the body through breakage of skin, poor wound care, and/or neonate improper cord care. Most reported tetanus cases are infants (Rhinesmith and Fu, 2018; Finklestein et al., 2017).

The introduction of vaccines helped mitigate and stem the spread of many diseases. In the 1940's, the U.S. reported 266,000 pertussis cases. After introduction of the pertussis vaccine, there was a decline in cases (> 99 %) with reported cases reaching nadir during the 1980's (Skoff et al., 2015; Nguyen and Simon, 2018; Nieves and Heininger, 2021). Likewise, introduction of a diphtheria vaccine has led to a substantial decline in the global incidence of the disease (Sharma et al., 2019). Instrumental in the decline of morbidity and mortality from these illnesses was the development of a trivalent vaccine, Diphtheria, Tetanus and Pertussis (DTaP) in 1948 and the administration of this vaccine to children and infants (Britannica, 2017). Indeed, with the induction of its national childhood DTaP vaccination program, the Netherlands experienced an 82.4% decline of diphtheria in the first 13 years (Sharma et al., 2019). Thus, both pertussis and diphtheria are now considered vaccine-preventable diseases.

Eradication of polio viruses is largely based on the use of vaccines. This was influenced by the WHO recommendation to immunize children to polio during the 1970's (Hovi et al., 2011).

Successful vaccination campaigns resulted in a dramatic decrease of polio, with the number of countries considered polio-endemic dropping from 125 in 1988 to 20 by the year 2000 (Bahl et al., 2018). In the United States, wild-type polio virus has not been reported since 1979, and worldwide there have been no wild-type polio virus 2 cases since 1999 (Ehrenfield et al., 2009; Hovi et al., 2011). While overall infections are down, some countries are still grappling with infections such as polio-wildtype 3 (e.g., Nigeria), (Ahmad et al., 2020). Countries such as Pakistan and Afghanistan contribute to 85% of world polio cases. In these areas, vaccination campaigns have been hindered due to issues such as mistrust, violence against polio workers and insecurity. Lack of a successful vaccination program in these areas may be attributed to these obstacles. It has been observed in Pakistan, polio vaccination rates are as low as 5% during high insecurity, with incidence of cases reporting higher than 73% (Ahmad et al., 2020). Thus, it may be inferred that successful vaccination campaigns may be instrumental in mitigating spread of disease.

Successful vaccination campaigns may depend on knowledge of public perception around issues such as disease severity, safety of vaccine, and ease of becoming vaccinated among others. Thus, it is important for public health officials to engage in the use of additional tools to obtain this knowledge.

Survey Use in Public Health

Surveys are a useful tool in gathering population information. Generally, surveys are issued to a representative sample of a particular population and its results may be generalized to the entire population (CDC, 2012). This collection of information may be of particular importance during times of disease outbreaks. As infectious diseases can rapidly expand across populations, the ability to collect efficacious data in a short amount of time may have a profound effect on public health policy development (Geldsetzer, 2020).

The use of surveys for information on disease and health-related behaviors may provide invaluable information. Importantly, surveys acquiring information such as private behaviors, mental health, and attitudes from persons may result in more reliable and valid data (Institute of Medicine (US) Committee on a National Surveillance System for Cardiovascular and Select Chronic Diseases, 2011). The ease in which some surveys can be delivered may provide a cost-effective means of gathering additional necessary data that may be difficult to obtain from large populations (Safdar et al., 2016). Thus, surveys have been useful in healthcare epidemiology.

During the height of the AIDS epidemic, public health experts scrambled for a way to complement surveillance and help with prevention. The spread of AIDS has typically been linked and associated with patterns of behavior and communities at risk (National Research Council (US) Panel on Monitoring the Social Impact of the AIDS Epidemic, 1993). One of the most important ways public health experts were able to garner information concerning behaviors that contribute to the spread HIV was through the use of surveys (National Research Council (US) Panel on the Evaluation of AIDS interventions, 1991). One tool utilized by health agencies is the behavioral surveillance survey, that has been used to document knowledge, attitudes, and risk behaviors for HIV/AIDS. When surveys such as these are used by trained persons, they may be helpful in observing actions and circumstances of special populations (Spiegel, 2006).

Responses from surveys may help public health agencies determine populations most at risk, (as used during the height of the HIV/AIDS epidemic). This may help when determining and administering prevention programs. Prevention programs often should be culturally, developmentally and socioeconomically based (Prothrow-Stith, 1995). Thus, effective prevention program may differ based on the focus population.

Population focused surveys may indeed help researchers and public health officials garner additional information that may contribute to health behaviors affecting disease spread. Recently, surveys have been used on specific populations during the current COVID-19 outbreak. One such study in Guangdong, Province in China sought to determine the mental effects and awareness in college students and its association with future health behaviors. Here, researchers found older students had greater levels of awareness and higher-level changes in future behaviors (Chang et al., 2020). Knowledge of these future behaviors may be imperative in constructing prevention programs. Surveys focused on student populations have shown an increased prevalence of psychological health problems and a negative association with COVID-19 awareness levels (Zhou et al., 2020). Increased levels of disease awareness may have an impact on behaviors that may contribute to spread of disease and affect public health. One survey looking at disease COVID-19 awareness implied those with increased awareness were more likely to adopt strategies such as mask-wearing, social distancing and handwashing (Teslya et al., 2020). This suggests that information gleaned from these surveys may be used to develop specific cost-effective prevention strategies for targeted populations based on their needs

Chapter III Wastewater Based Epidemiology as a surveillance tool during the current COVID-19 pandemic on a college campus (East Carolina University) and its accuracy in predicting SARS-CoV-2 outbreaks in dormitories

Note: This chapter is formatted as a complete manuscript and will be submitted to a peer reviewed journal in the future. Hence, there may be some repetition in Chapter 2 (Background-Literature Review) and Introduction for Chapter 3

Abstract

The COVID-19 outbreak led governmental officials to close many businesses and schools, including colleges and universities. Guidance for mitigating viral spread included practices such as wearing masks, hand hygiene, and social distancing- including avoidance of large groups. On-campus activities have been shown to play an important role in student learning and provide needed services to students. Thus, the ability to re-open and safely monitor COVID-19 on college campuses safely was of increased importance. The use wastewater monitoring as part of a surveillance program to control COVID-19 outbreaks at East Carolina University was evaluated. During the Spring and Fall 2021 semesters, wastewater samples (N= 830) were collected every Monday, Wednesday, and Friday from the sewer pipes exiting the dormitories on campus. Samples were analyzed for SARS-CoV-2 and viral quantification was determined using qRT-PCR. During Spring, there was a significant difference in SARS-CoV-2 virus copies in wastewater when comparing dorms with the highest number student cases of COVID-19 and those with the lowest number of student cases, (p= 0.002). Additionally, during the Fall 2021 semester it was observed that when weekly virus concentrations exceeded 20 copies per ml, there were new confirmed COVID-19 cases 85% of the time during the following week. This study showed wastewater-based epidemiology may be paired with additional surveillance tools such as

contact tracing and routine testing to reduce the spread of viruses and potential outbreaks on a university campus.

Introduction

The continuous systematic collection of data coupled with its analysis and interpretation describes the basic tenants of what is considered public health surveillance (Centers for Disease Control and Prevention [CDC], 2018). Equally important is the timely dissemination of this information to necessary officials, enabling them to make appropriate decisions in response to a problem (Groseclose and Buckeridge et al., 2017). Thus, public health surveillance systems are theoretically constructed to provide data to assist in interventions (e.g., inhibit spread of disease) (Nsubuga et al., 2006). Surveillance may be broken down into 2 categories: event-based surveillance (EBS) and indicator-based surveillance (IBS) (Balajee et al., 2021). IBS systems often includes some type of regular data collection and weekly alert threshold monitoring, while EBS do not (Early Warning Alert and response System [EWARS], 2019). Hence, IBS may be effective in monitoring weekly bacterial or viral levels of specified diseases.

Bacterial and viral pathogens may be found in many types of bodily fluids and materials including blood, saliva, and/or fecal matter. Thus, there may be multiple techniques used to monitor bacterial and viral levels within a community. These monitoring techniques may be dependent upon survivability of the bacterial or viral pathogen in the environment or a specific medium. First used as an indicator tool of community drug use, testing of untreated wastewater has progressed to measuring infectious pathogens (Devault and Karolak, 2020; Zuccato et al., 2005; Kankaanpää et al., 2016; Yang et al., 2015). Fueling the utility of wastewater as indicators may be the ability to procure it from multiple locations including pumping stations, wastewater treatment plants, and manhole portals in local neighborhoods (Erickson et al., 2021). This availability of sample procurement may enhance the ability to use wastewater as a form of surveillance. Wastewater-based epidemiology (WBE) is based on the rationale that fecal and urinary biomarkers may be used to give real-time information on population health (Sims and Kasprzyk-Hordern, 2020). Therefore, biomarkers that are stable in wastewater and rapidly obtained and pooled from sewage treatment systems may provide valuable information on bacterial and/or viral presence in a population (Zuccato et al., 2016).

In 2003, over 32 countries experienced an outbreak of severe acute respiratory syndrome coronavirus (SARS-CoV), a disease primarily spread through respiratory droplets (Xu et al., 2004; Wang et al., 2005). Subsequent research led to the discovery of detectable SARS-CoV in sewage of infected hospital patients (Wang et al., 2005). The ability to detect SARS-CoV in wastewater has led researchers to reasonably conclude that wastewater may be used to detect to viral SARS-CoV-2 resulting from the current SARS COVID -19 outbreak.

Before the onset of symptoms, SARS-CoV-2 has as incubation period of 5.2 days (Reyes et al., 2021). It has been documented persons may shed the virus prior to the onset of symptoms, with studies showing asymptomatic persons may also shed the virus (He et al., 2020; Lewis et al., 2021). One study estimates that peak viral shedding may occur before the onset of symptoms (He at al., 2020). Additionally, research from SARS-CoV showed a reduction in household transmission when patients isolated prior to peak shedding (Lewis et al., 2021; Wilder-Smith et al., 2020). This suggests that the availability of real-time data may stem COVID-19 infections. Reliance solely on laboratory confirmed cases after the onset of symptoms may not be enough to slow the spread COVID-19 infections. In situations such as living centers or dormitories, this may contribute to viral spread as persons may not be aware they are sick due to not having any symptoms. Wastewater-based epidemiology may be an effective tool in capturing potential SARS-

CoV-2 infections prior to symptoms. The virus has shown stability in room temperature wastewater for an average of 2.1 days (low titers) (Bivins et al., 2020). This may allow untreated sewage to serve as part of an early detection warning system. This is important in places such as college dormitories where pre-symptomatic students may spread the virus to visiting students that reside in other dormitories, leading to campus-wide outbreaks. Thus, wastewater-based epidemiology may be instrumental in stemming outbreaks and allowing campuses to stay open and fully functional.

The University of Arizona used wastewater-based epidemiology as part of a re-entry strategy for students returning to campus. Researchers there monitored wastewater in a student dormitory, where upon detection of SARS-CoV-2 resulted in clinical testing of students living in the dorm. Officials found WBE important in containing COVID-19 (Betancourt et al., 2021). Similarly, an interdisciplinary team at Norwich University, in Northfield, Vermont, set out to determine if WBE could be used to assist its school in COVID-19 surveillance and detection (Crowley, 2020). More universities have begun to incorporate the use of WBE as a part of their COVID-19 mitigation strategies. Schools like UNC Charlotte have sought to use the results obtained from their wastewater testing as part of their approach to stemming cases and found it to have been successful at early detection (Gibas et al, 2021).

For this research, wastewater-based epidemiology was used to detect SARS-CoV-2 in wastewater obtained from dormitories on a college campus, East Carolina University, in Greenville, NC, USA. Raw wastewater samples were collected triweekly during the Spring and Fall semesters of 2021. The aim of this research was to evaluate the use of wastewater-based epidemiology as a surveillance tool during the COVID-19 pandemic by comparing SARS-CoV-2 concentration in wastewater to the number of confirmed cases of COVID-19 in dormitories.

Specifically, it was hypothesized that dorms with higher numbers of confirmed student COVID-19 cases would have statistically higher concentrations of SARS-CoV-2 in their wastewater. It was also hypothesized that sampling and analyses for SARS-CoV-2 in dorm wastewater would be effective in identifying new cases of COVID-19 in dormitories, thus potentially helping to prevent possible spread and future outbreaks of the disease.

Methods

Sample Procurement

Wastewater from dormitories on ECU's campus was collected and analyzed during the 2021 Spring (9 dormitories) and Fall semesters (16 dormitories), respectively. Wastewater samples were collected Monday, Wednesday, and Friday excluding holidays and university approved days off (n= 830). Wastewater samples from each dormitory on campus were collected using Hach AS950 portable samplers with vacuum tubes extending down a manhole and into the main sewer pipe exiting each dormitory (Figure 3.1). Each Hach AS950 used a peristaltic pump to pull wastewater through the tubing from the sewer pipe into a 7.6-L capacity sample bottle. Sample bottles were encased in ice within the sampler housing to ensure stability of samples at 4°C. For this study, the pumps were programmed to collect 21 mL of raw wastewater every 15 minutes, equating to 84 mL per hour, which allowed for collection of a daily composite wastewater sample. On sample collection days, composite samples were retrieved from autosamplers and stored on ice until they were delivered to the Water Research Laboratory at East Carolina University.

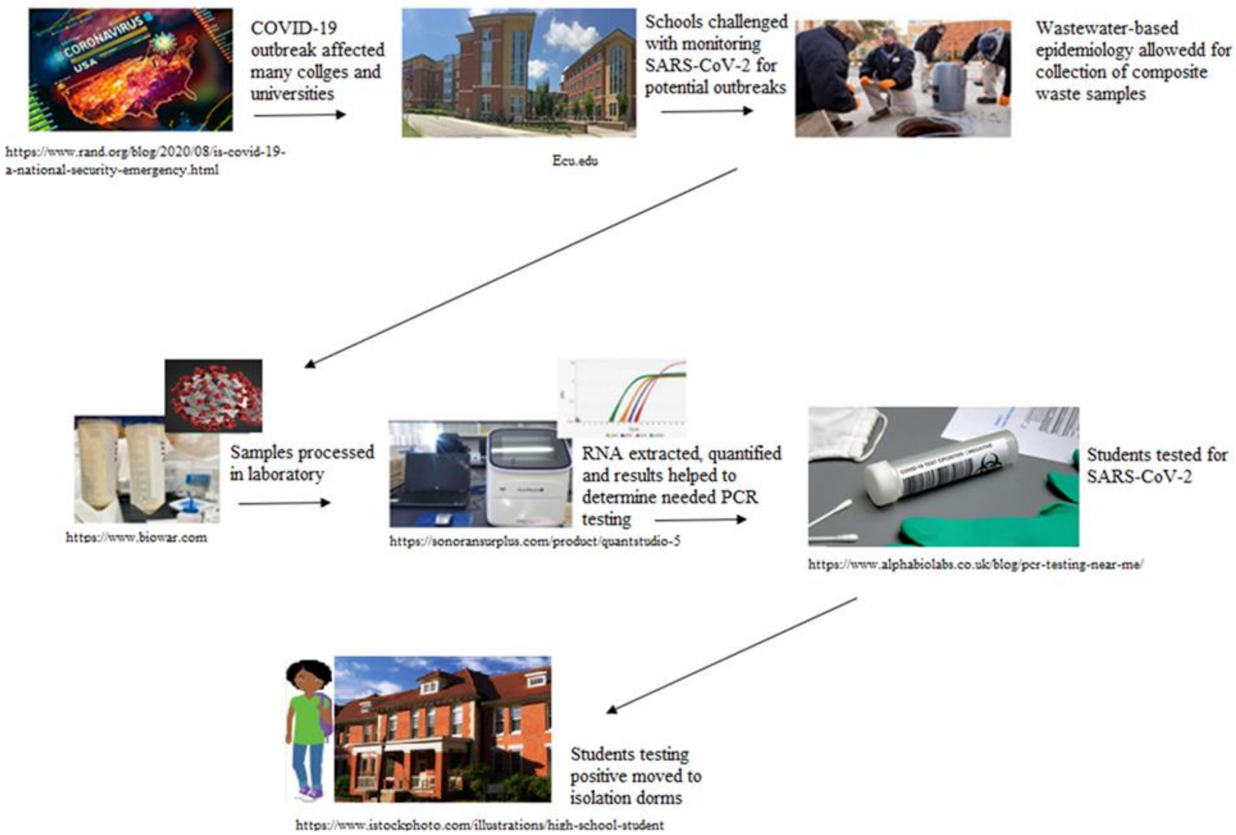


Figure 3.1. Flow Diagram of Wastewater -Based Epidemiology on Campus of East Carolina University

Sample Processing

Approximately 95 mL of composite sample was aliquoted into 2 labeled, 50 mL conical tubes corresponding with the respective dormitory. Samples were heat pasteurized via placement into a 75°C water bath for 45 minutes (Pecson et al., 2021; Kitajima et al., 2020; Ahmed et al., 2020). Next, samples were removed from water baths and placed into -80°C freezer to cool samples to between 2° - 8°C. Temperatures were verified using a Traceable Precision Thermometer (Fischer Scientific Cat# 150790712). Cooled samples were centrifuged at 4100 RPM for 30 minutes at 4°C, to remove large particles. The supernatant was decanted into new 50 mL ultra-centrifugation conical tubes containing a mixture of 3.5 ± 0.1 g Polyethylene Glycol 8000 (PEG) and 0.788 ± 0.01 g NaCl and mixed until the PEG/NaCl mixture was dissolved. The resultant solution was centrifuged 12,000 x g at 4° C, for 30 minutes, ensuring the formation of the viral pellet. The supernatant was carefully decanted from the conical tube so as not to disturb the viral pellet. The pellet was resuspended using 1 mL of TRIzol and transferred to the second sample tube containing a viral pellet (IDEXX, Westbrook, Maine). The resultant 1 mL solution was transferred into a labeled 2 mL microcentrifuge tube and placed on ice. Samples were transferred to a Pathology laboratory at Brody School of Medicine, East Carolina University with RT-qPCR.

Quantifying SARS-CoV-2 Concentration using RT-qPCR

RNA was extracted from PEG8000/NaCl precipitated pellet by combining resultant 1 mL solution in TRIzol with Lying Matrix B beads (MP Biomedicals) in a 2mL microcentrifuge tube and lysed using the FastPrep-24 5G (MP biomedicals) at 6m/s for 30 seconds (1 cycle). The lysate was centrifuged at 12,000 x g for 1 minute and transferred to a new 2 mL microcentrifuge tube and combined with an equal volume of ethanol (95%-100%). The resultant mixture was transferred to a Zymo-Spin IC Column (Direct-Zol RNA microprep, Zymo Research) and centrifuged at 12,000 x g for 30 seconds, repeated until entire mixture flowed through column. The column was washed with 400 µL RNA Pre-Wash Buffer. Next, 700 µL RNA Wash Buffer was added to the column and centrifuged for 1 minute and then transferred to a new 1.5 mL microcentrifuge tube. RNA was eluted by adding 20 µL of nuclease-free water into the column and centrifuging for 1 minute.

Viral RNA was quantified using LUNA SARS-CoV-2 RT-qPCR multiplex Assay (New England Biolabs) in a 96-well MicroAmp Reaction Plate with the QuantStudio 5 thermocycler

(Thermo Fisher, Carlsbad, CA.). Primer/probe mix (N1/N2/RP) (1 µL), Luna One-step RT-qPCR 4x Mix with UDG (2.5 µL), and nuclease-free water (2.5 µL) were placed into 96-well plate and combined with extracted RNA (4 µL). The plate was sealed and centrifuged at 1,000 g for 30 seconds to push reactions to the bottom of wells. The RT-qPCR detection was programmed for one cycle of (25°C 30 sec, 55°C 10 min, and 95°C 1 min) and 45 cycles of (95°C 10 sec and 60°C 30 sec with plate read), using fluorescence HEX for N1, FAM for N2, and Cy5 for RP targets. A standard curve was generated using diluted synthetic SARS-CoV-2 (Twist Bioscience) at 0, 10, 100, 1000, and 10000 copies. Prior to 15 February 2021, quantification of viral copies obtained from wastewater was not achieved, and thus only presence/absence data were available prior to this date.

Student COVID numbers and Vaccine information

The numbers of student COVID-19 cases used in this study were obtained from student housing databases and were only from students who lived in dorms on campus. The numbers of student COVID-19 cases for each dorm during each semester were tallied. Total student housing numbers established at the beginning of the semester were used with number of positive cases to determine incidence rates per semester. Student vaccine data were obtained from ECU COVID-19 vaccine dashboard on the ECU website. The ECU dashboard was a visual representation published on the university's website used to convey COVID-19 information. The dashboard was used as a tool to help monitor COVID-19 trends across campus.

Statistical Analysis

Student COVID-19 cases were analyzed for each dormitory on a semester basis to determine the dorms that had the highest number of COVID-19 cases and dorms that had the lowest number of COVID-19 cases. The mean SARS-CoV-2 concentration (virus copies per mL) in wastewater for each dormitory was calculated during the Spring (Feb – May 2021) and Fall (Aug – Nov 2021) semesters. Mean concentrations of SARS-CoV-2 in wastewater from dormitories with relatively high student COVID-19 cases were compared to the concentrations of those with relatively low number of student cases to determine if the differences were statistically significant ($p < 0.05$). The normality and linearity of data were evaluated to determine which statistical tests were most appropriate. A chi-square test of independence was performed to determine if there was a statistically significant difference between mean viral copies per mL of sample between dorms with "low" and "high" numbers of confirmed COVID-19 student cases. For nonparametric data, Kruskal-Wallis tests were used to determine significance between data consisting of more than 2 categorical grouping variables, while Mann-Whitney testing were used to analyze significance between 2 samples. Statistical analyses were performed using SPSS (SPSS Institute, Chicago, Ill). SPSS analysis also included a post-hoc pairwise Mann-Whitney with Bonferrroni adjustments. Weekly averages for SARS-CoV-2 in wastewater were determined during each semester and any increases in the week-to-week viral concentrations were noted. If a new positive COVID-19 case in a dorm followed an increase in the weekly mean concentration of SARS-CoV-2 in wastewater from that dorm, then the wastewater tests and analyses were considered an accurate predictor of new cases. Student COVID-19 cases documented the week following a high viral concentration were tabulated and used to calculate the percent of time new cases were identified following high virus counts.

Results

Comparison of COVID Cases across dormitories

Overall, there was a total of 367 ECU confirmed cases of COVID-19 within the dormitories during the Spring and Fall semesters of 2021 (Figure 3.2). The highest number of cases and highest incidence rates were observed during March (Spring) and September (Fall) (Table 3.1, Table 3.2). During the Spring semester, the Greene, Scott and Jones dorms contained the highest number of COVID cases (combined total cases, n= 33). The highest mean number of cases for those dorms was M = 11. Subsequently, White, Clement, and Ballard West dorms had the lowest number of COVID-19 cases (n = 9) and the lowest average number of cases per dorm (M = 3). For the Fall semester, sampling results indicated that Clement, Legacy and Fletcher dorms had the highest number of COVID cases (n = 113) and the three dorms averaged 37.7 cases each. Garrett, Fleming and Jarvis had the lowest number of cases (n = 21) and averaged 7 cases per dorm.

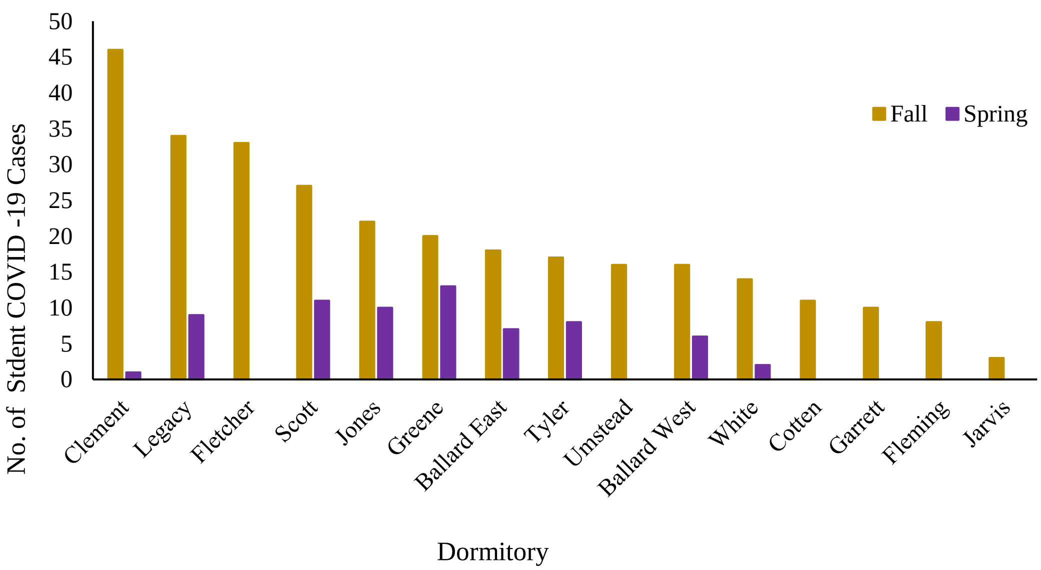


Figure 3.2. Total Number of Student COVID-19 Cases Per Dorm During the Spring and Fall 2021 Semester

Table 3.1. COVID Incidence Rates for Sampled Dormitories Between 15 February 2021 and 1 May 2021

Dormitory	February Covid %	March Covid %	April Covid%	Semester Covid %
Greene	4%	3%	0%	7%
Scott	1%	3%	0%	4%
Jones	1%	4%	1%	5%
Legacy	1%	3%	2%	5%
Tyler	0%	3%	0%	4%
Ballard East	1%	3%	1%	4%
Ballard West	0%	3%	1%	3%
White	0%	1%	0%	1%
Clement	0%	0%	0%	1%

Table 3.2. COVID Incidence Rates for sampled Dormitories Between 30 August 2021 and 19 November 2021

Dormitory	September Covid %	October Covid %	November Covid%	Semester Covid %
Clement	12%	0%	0%	12%
Legacy	7%	0%	0%	8%
Fletcher	8%	0%	0%	8%
Scott	4%	0%	0%	5%
Jones	4%	1%	0%	6%
Greene	5%	0%	0%	5%
Ballard East	4%	1%	1%	5%
Tyler	4%	0%	0%	4%
Umstead	9%	0%	0%	9%
Ballard West	4%	0%	0%	4%
White	4%	0%	0%	4%
Cotten	5%	0%	0%	5%
Garrett	3%	0%	0%	4%
Fleming	5%	0%	0%	5%
Jarvis	3%	0%	0%	3%

Thus, there were large differences in the number of COVID-19 cases between dorms, with some having 3 or more times as many as others. However, not all dorms housed the same number of students. Additionally, there were differences in maximum student housing occupancy for the semesters. For example, during the Spring 2021 semester student housing was limited to one person residency per dorm room, which was approximately half capacity. The following semester (Fall 2021) those restrictions were lifted, and rooms could support normal occupancy, thus allowing multiple students sharing a room. It may be possible that the number of students in the dorms affected the number of COVID cases captured. Results showed that while the model was significant, ($p = 0.006$), the model may only explain 10.2% of the variance. Overall, the number of students in dorms did significantly predict the number of COVID-19 cases detected ($ß_1 = -0.026$, $p = 0.006$), with a final predictive model = -1.24 + (0.023*Number of Students in Dorm).

SARS-CoV-2 Concentration in Wastewater

Concentrations of SARS-CoV-2 in wastewater obtained from sewer pipes connected to dormitories at East Carolina University were quantified. Overall, changes in virus gene copies throughout both semesters were observed. Large increases in SARS-CoV-2 concentrations in wastewater during the early Spring semester were noticed. The City of Greenville was also conducting wastewater-based epidemiology during the same time frame. While the magnitude of wastewater flow and viral concentrations were different between the City of Greenville and ECU, both reported large increases in SARS-CoV-2 concentrations in wastewater after the start of the Spring and Fall semesters during February and September, respectively (Figure 3.33A, Figure 3.33B). The September increases corresponded with a fully re-opened ECU campus and related activities (sports games, Labor Day festivities, etc.,) (Figure 3.3A, Figure 3.3B) (North Carolina Department of Health and Human Services [NCDHHS], 2022). Near the start of the Spring semester in February 2021, concentrations of SARS-CoV-2 in wastewater increased between 20-39% for the City of Greenville while ECU experienced an increase of 11.2%. Similarly, near the start of the Fall semester of 2021, ECU experienced a 96.3% increase in SARS-CoV-2 concentrations in dorm wastewater while the City of Greenville experienced a 70-89% increase.

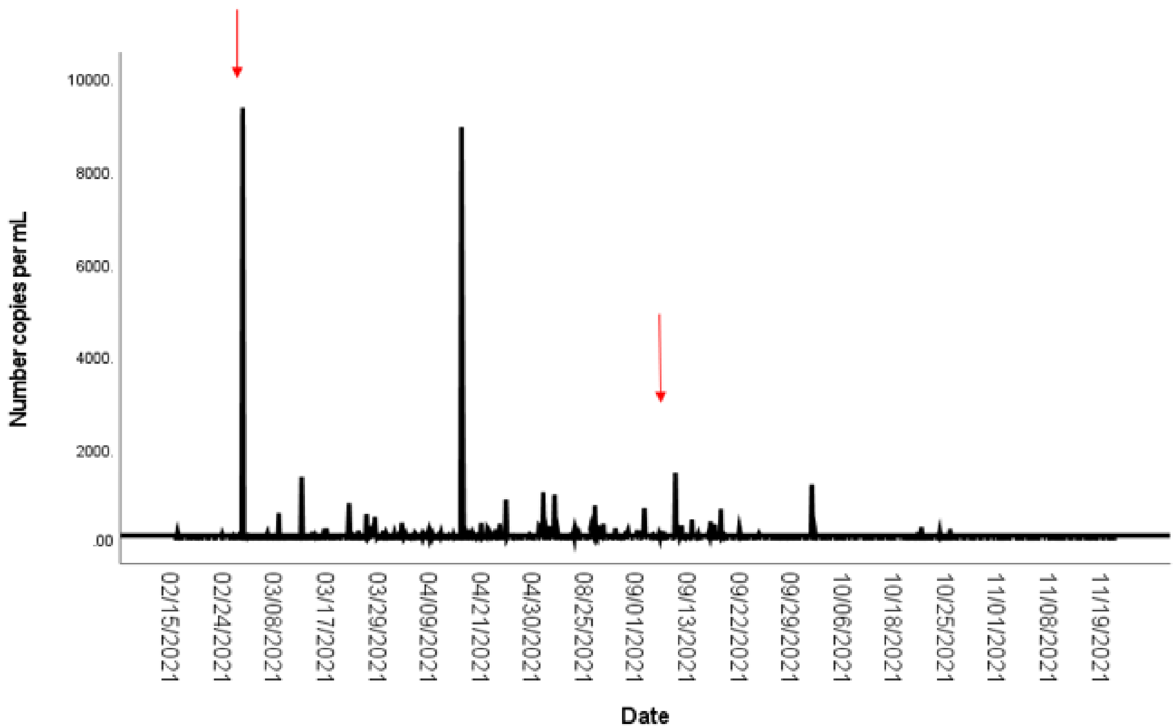


Figure 3.3A. SARS-CoV-2 in Dormitory Wastewater Samples Collected Throughout the Spring 2021 and Fall 2021 Semesters. Red arrows denote times where the City of Greenville also saw noticeable increases in COVID-19 virus in wastewater.

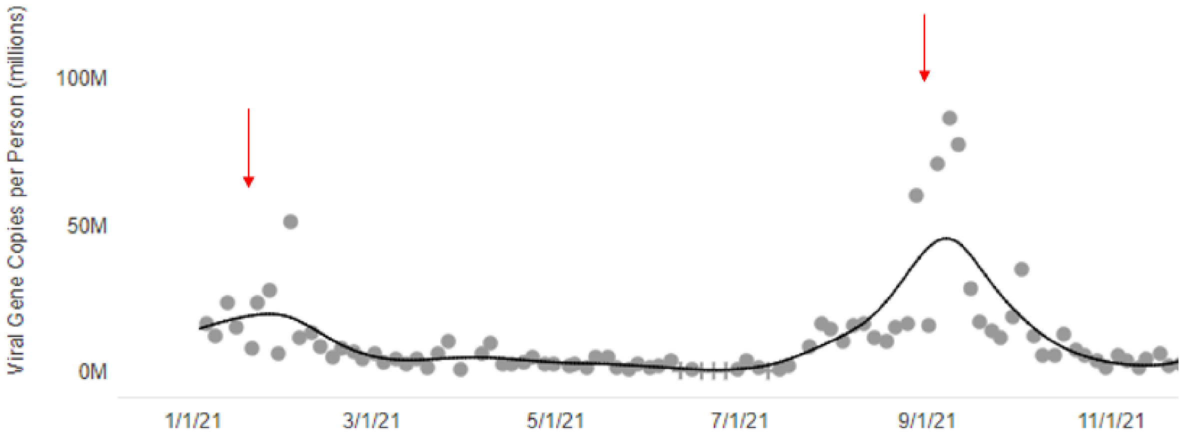


Figure 3.3B. SARS-CoV-2 in Wastewater Samples for the City of Greenville During the 2021 Year. Figure obtained from the NCDHHS wastewater sampling dashboard (NCDHHS, 2022). Red arrows denote times where the City of Greenville also saw noticeable increases in COVID-19 virus in wastewater.

Comparison of SARS-CoV-2 Concentrations in Wastewater from Dormitories with Higher and Lower Student Cases of COVID-19

Viral concentrations in wastewater from the dorms with the 2 highest and 2 lowest confirmed student cases of COVID-19 during both the Spring 2021 and Fall 2021 semesters were compared. During the Spring 2021 semester, student COVID-19 testing showed the highest number of confirmed cases were in the dormitories of Scott (n = 8) and Jones (n = 9). In contrast White (n = 2) and Clement (n = 1) had the lowest number of positive COVID-19 cases. During the Spring semester the mean number of SARS-CoV-2 viral copies per mL for dormitories with the highest number of student cases was 111.1, while the mean number of viral copies per mL for dorms with the lowest number was 7.3. This difference was statistically significant (U= 10.0, *p*= 0.002). The relationship between the number of virus copies in wastewater during the spring semester and the number of student cases was evaluated using Pearson's correlation. The results showed a statistically significant positive correlation between the two, (r = 0.642, N= 20, *p*=

0.002). This indicates that when the number of virus copies increased there was a corresponding increase in in the number of student cases during the Spring.

During the Fall 2021 semester, the dorms with the highest number of students with COVID-19 were Clement (45) and Legacy (31). Conversely, the dorms with the lowest numbers of COVID-19 cases were Fleming (8) and Jarvis (3). The mean number of SARS-CoV-2 viral copies for the dormitories with the highest number of COVID-19 cases was 49.3, while the dorms with the lowest number of COVID-19 cases had a mean of 3.6. This difference was statistically significant (U= 34; *p*= 0.023). A Pearson correlation performed on the Fall semester data also showed a significant positive relationship between virus copies and cases, (r = 0.522, N= 34, p= 0.013).

Wastewater Sampling and Determination of New Cases

Overall, of the 830 samples processed and analyzed, 594 (71%) tested positive for the virus. Prior to 15 February 2021, quantification of viral copies obtained from wastewater was not achieved, and thus only presence/absence data were available. However, in the week leading up to February 15, 2021, positive samples for 77% of dorms were reported. Student COVID-19 cases were confirmed following this sampling period with 55% of dorms reporting cases and some dorms having multiple cases. Typically, ECU celebrates a spring break around the 1st week of March (corresponding here 01 March – 07 March). During 2021, the University did not hold a traditional spring break, but there was a decrease in the number of student COVID-19 cases during that week. It may be possible though that some students in keeping with past traditions left campus (as classes were virtual) and returned later. Additionally, in lieu of a full “spring break” week for students, the university sponsored a “Spring Festival” on 10 March. A 7-fold rise in cases after the festival and extending through the end of March 2021 was observed (Figure 3.4).

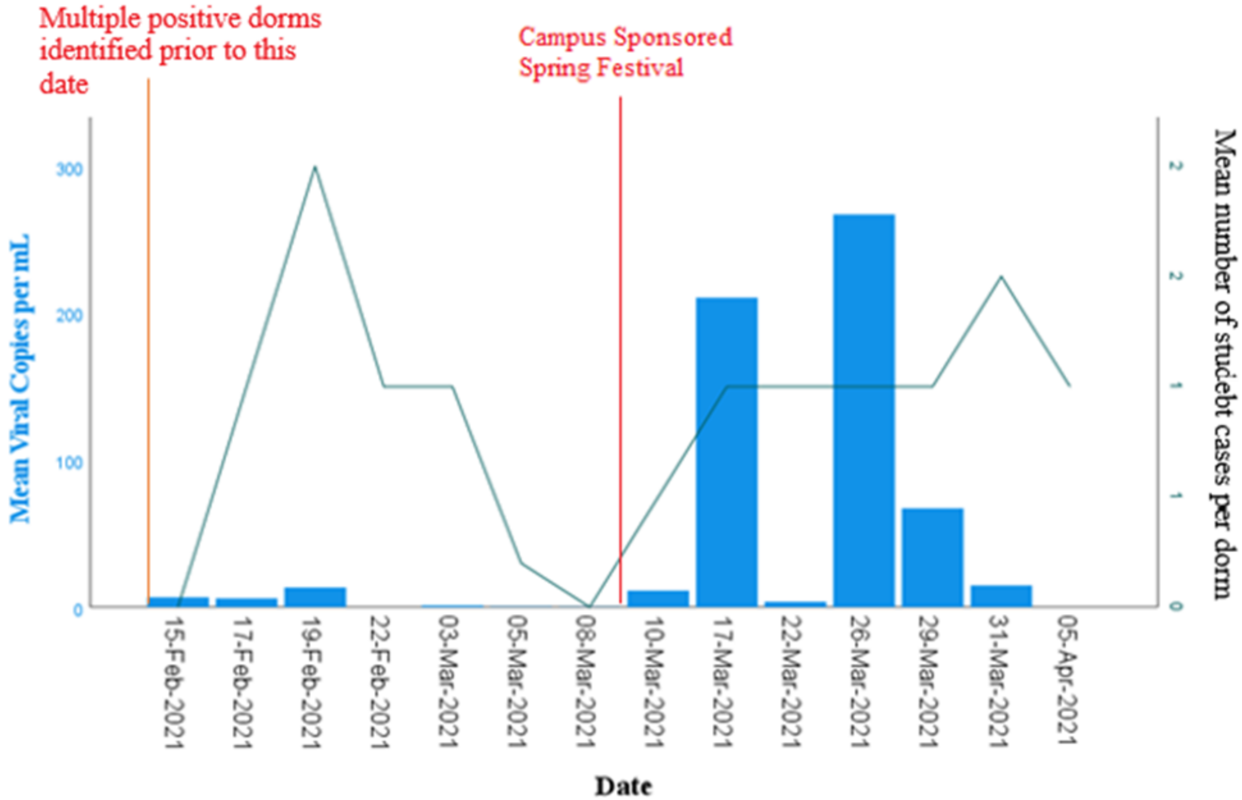


Figure 3.4. Time-lapse of Mean SARS-CoV-2 Virus Copy per mL Extracted from Wastewater and Students COVID-19 Cases in Dormitories During Spring Semester. Bars represent mean virus copy per mL and lines represent student cases.

An increase in virus concentrations in wastewater at the beginning of the Fall semester corresponded with an increase in the number of student cases (Figure 3.5). More specifically, at the beginning of semester, testing showed a rise in viral copies of SARS-CoV-2 in wastewater starting on 23 August 2021 (208.2 copies per mL) to 03 September 2021 (1070 copies per mL) which coincided with a 97.5% increase in the number of students testing positive for COVID-19. The number of positive students peaked on 04 September 2021. Students that tested positive for COVID-19 were removed from their respective dorms and placed into isolation dorms. During that time in isolation dorms, concentrations of viral copies in wastewater from the home dorms of the students declined 67.2%. Virus copies may have also fallen during this time due to students traveling for the Labor Day holiday on 06 September 2021. However, when students began returning to their original dorms from isolation (~10 days, around 13 to 17 September 2021), a 74.1% rise in virus concentration in wastewater sampled from their original dorms was observed, possibly because those students were still shedding the virus. This may explain the persistence of relatively high concentrations of SARS-CoV-2 in wastewater even as the number of student cases declined.

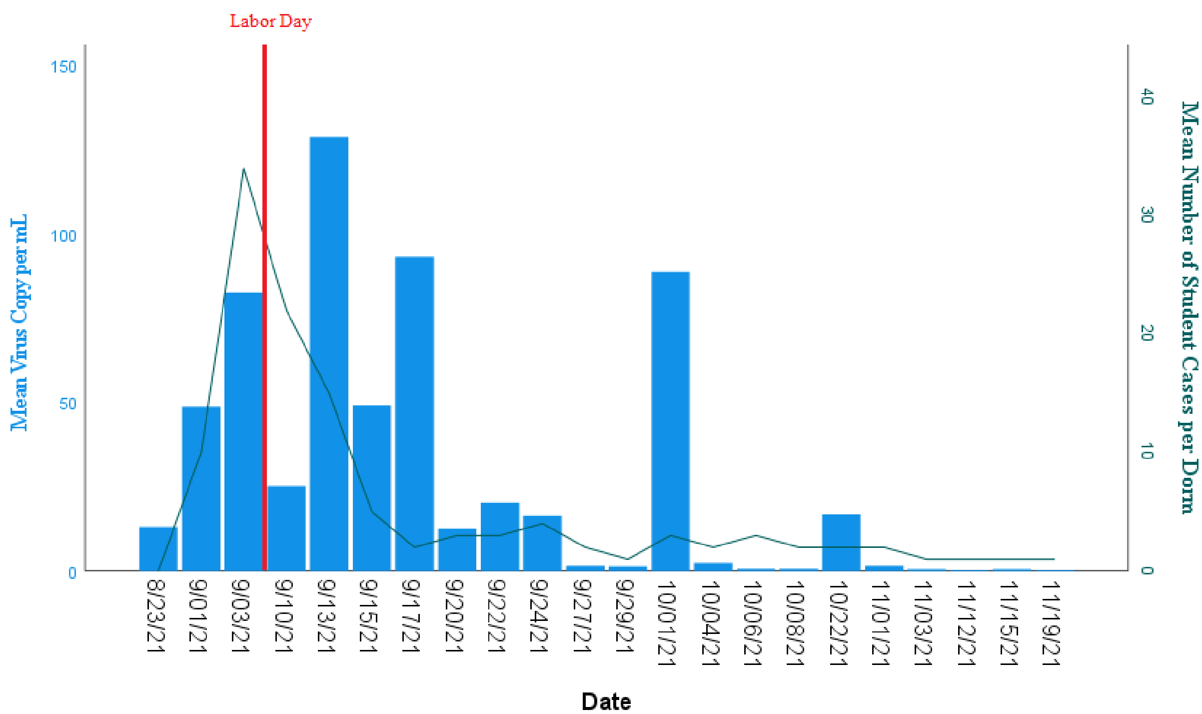


Figure 3.5. Time-lapse of Mean SARS-CoV-2 Virus Copy per mL Extracted from Wastewater and Students COVID-19 Cases in Dormitories During Fall Semester. Bars represent mean virus copy per mL and lines represent student cases.

Studies have shown persons may shed the virus many days prior to symptom onset (typically persons seek testing after experiencing symptoms) (He et al., 2020; Lewis et al., 2021).

For this reason, new COVID cases (n= 1) in students that occurred within a week following a high viral count in wastewater were recorded and the frequency of positive cases calculated. Overall, about 60% of the time at least 1 new case of COVID-19 was observed following a SARS- CoV-2 concentration of 9.2 copies per mL in wastewater sampled from a dorm. There was great variability between the Spring and Fall semesters regarding the results though. During the Spring semester, when wastewater samples from dorms yielded at least 9.2 SARS-CoV-2 viral copies per ml there was at least 1 new COVID-19 case in dorms within the following week during 47% of the times tested. New cases of students with COVID-19 were observed the subsequent week following a testing that yielded 9.2 copies of the virus 73.8% of time during the Fall semester. Additionally, as some students recognized they may have had an increased chance of exposure, they may have voluntarily removed themselves from dormitories which may have also impacted the results from that time period, with new cases not showing as students left before being tested. When the data are reviewed based on percentage increases in SARS-CoV-2 concentrations in wastewater and identification of new cases, less variability is observed between semesters. More specifically, during the Spring semester, when the concentration of SARS-CoV-2 in wastewater increased by 24.4% in a dormitory, a new case of COVID-19 was observed 68.8% of the time the week following the increase. During the Fall semester, a new case of COVID-19 was observed 64.3% of time the week following a 17.6% increase in SARS-CoV-2 concentration in wastewater.

Saliva Surveillance

Students, faculty, and staff participated in saliva surveillance particularly if they had been exposed to someone who had COVID-19. During the Spring semester, it was required that all student athletes and 25% of students who lived on-campus participate in saliva testing. As the university fully opened in Fall 2021, students enrolled in face-to-face classes, residing on campus and participating in NCAA athletics were required to be a part of the routine surveillance. At the beginning of the Fall semester at least 50% of on campus students were required to be tested weekly. However, as the number of cases increased, it was determined beginning 01 September 2021, that surveillance testing frequency would also increase with unvaccinated students residing in residence halls. Unvaccinated students living in dorms had to undergo weekly testing, with some testing being PCR testing. Saliva surveillance of students living in residence halls during 01 September 2021 through 30 September 2021 were analyzed. During this time, the University processed 2820 samples with 16 samples (0.56%) testing positive. During the first 2 weeks the trend in number of positive saliva tests and the mean concentrations of SARS-CoV-2 in wastewater was similar. An initial drop in both the mean virus concentrations in wastewater and the number of positive saliva tests over the first week (03 September to 11 September 2021) were followed by at least 2-fold increases in virus concentrations in wastewater and positive saliva tests the next week (Figure 3.6). However, the trends for mean virus concentrations in wastewater and number of positive saliva tests diverged the last week of September 2021. A Spearman's rho correlation determined an overall weak association between SARS-CoV-2 obtained from wastewater and positive saliva samples (r= 0.200, p= 0.800). The overall weak association between virus concentrations in wastewater and the number of positive saliva samples may be because the sample populations were different. All students that had face to face classes including those that lived off campus were included in the saliva testing, while the wastewater analyses were only applicable for students that lived on campus. Thus, the sample sizes and populations were different.

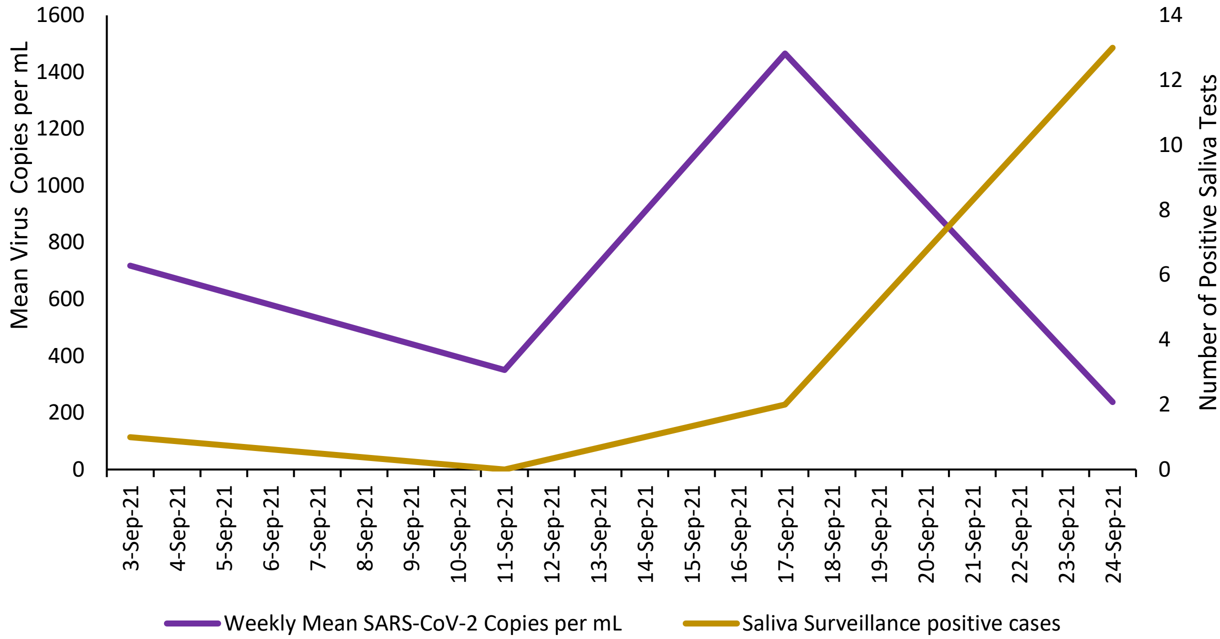


Figure 3.6. Positive Saliva Surveillance Samples compared to mean SARS-CoV-2 copies per mL obtained from wastewater.

Discussion

The COVID-19 pandemic was unprecedented in that it led governmental officials to shut down and/or pivot routine services. This included educational institutions and many private businesses. Colleges and universities were tasked with developing and/or incorporating new ways to monitor SARS-CoV-2 on their campuses to keep students, faculty, and staff safe as services and operations were gradually restored. Wastewater-based epidemiology was a tool used by ECU to help prevent the spread of COVID-19. Wastewater solids tend to be negatively charged and SARS-CoV-2 is a positive-sense single stranded virus (Ye at al., 2016, Jackson et al., 2022). Thus, SARS-CoV-2 may sorb to wastewater solids and the wastewater may be used as an indicator of the virus. This study aimed to determine if wastewater-based epidemiology was effective as an environmental public health surveillance system to help control COVID-19 outbreaks on college campuses.

An objective of this study was to determine if wastewater monitoring could be used to reduce the likelihood of outbreaks by triggering student testing and isolation when SARS-CoV-2 concentration in wastewater spiked and subsequent testing for related dorms showed positive cases. The CDC has stated that COVID-19 outbreaks may be foreshadowed by results of wastewater tested 7 days earlier (Crowley, 2022). For the current study, it was noted that at specific times during each semester when a rise in virus concentrations in wastewater was observed an increase in the number of COVID-19 cases in on-campus students typically (60% of times) followed 5-7 days later. This same trend was noted when observing percentage increases in virus concentration in wastewater, where overall new COVID cases were found ~ 71.2% of times. Thus, WBE may help reduce the likelihood of future outbreaks as this potential 7-day period may provide meaningful time for public health officials in contacting/identifying potential cases and placing those cases in isolation. This would be of tremendous aid in helping to mitigate the spread of disease, as this would possibly help to reduce the number of potential contacts for the infected persons.

However, it is important to note that changes in guidelines and protocols may affect how data are used to predict cases. For example, during the Fall semester, students were allowed to have visitors that did not live in the dormitories. This was not allowed during the Spring semester. It is possible that visitors with COVID-19 contributed to viral concentrations in wastewater to the tested dorms. This may cause a large enough rise in viral concentration to trigger mass PCR/swab testing without yielding new cases from that specific dorm and thus affect the accuracy of WBE in predicting future cases. Researchers and decision makers need to also be aware of those returning from quarantine and isolation. As guidelines and timelines change, more people could be introduced back into the dorms potentially shedding the virus. Studies have shown that the medium detectable timeframe for the virus in stools was 17 (11-32) days (Jones et al., 2020, Huang et al., 2020) but some patients may shed up to 59 days (Huang et al., 2020). Students at ECU were allowed to leave quarantine and return to their dorms after 10 days. Therefore, those returning students may have continued shedding detectable SARS-CoV-2 in wastewater, increasing the virus concentrations, and triggering “false alarms” regarding the need for saliva testing.

Persons may also shed the virus at different rates. Studies have shown persons affected with coronaviruses typically have lower rates of viral shedding in the initial days, with peak shedding 12-14 days after disease onset (Cheng et al., 2004). However, viral shedding is known to occur prior to the onset of symptoms for SARS-CoV-2 (Jones et al., 2020; Wei et al., 2020). These issues may impact an important component of using wastewater surveillance as a predictor tool. Public health officials have to be able to set viral thresholds that may trigger additional testing. Skewing of this data may affect the ability of public health professionals to use one standard isolation protocol. Thresholds for triggering actions such as swarm testing may need to be set for individual entities and may need to be fluent and allow for change during different time periods of an outbreak.

An additional challenge may be testing compliance. The timing and ability to test suspected persons is important in mitigating spread of the virus. Students often have differing schedules, and this may impede swarm testing. Some may also feel testing is not important or they have an aversion to how the test is performed. We also saw high politicizing of COVID-19 virus and vaccinations, making them both polarizing issues, which may made added to unease of virus discussion among healthcare professionals. For these reasons, it is imperative that colleges and universities develop plans to help increase the percent of students who are compliant with testing protocols.

Despite these challenges, wastewater surveillance may be an effective tool as part of a comprehensive surveillance system for use by colleges, universities, and other institutions. Persons who are asymptomatic or have mild symptoms may not realize they are carriers and/or are spreading the virus. Asymptomatic patients may forego contact tracing, which may lead to underestimates of the case numbers and may exacerbate the viral spread. Thus, detection using WBE may be helpful in identifying these cases. Wastewater-based surveillance may also be useful to determine fluctuations in outbreaks once they become endemic in an area. As viruses mutate, the virulence and transmissibility may be affected (Shao et al., 2017). Upticks in cases may alert officials to changes in the virus.

Additionally, use of wastewater viral data may help inform officials of the efficacy of existing mitigation strategies and protocols and whether current strategies need to be adjusted. It may also be used to implement focused surveys or questionnaires to determine compliance with existing strategies and whether compliance is an issue. Using wastewater-based epidemiology as an early warning system may allow public health officials to evaluate the spread or potential future spread of a disease.

Limitations

While this study aimed to analyze wastewater-based epidemiology in public health surveillance, several limitations were encountered. While research has shown that SARS-Cov-2 may be extracted from wastewater, data are lacking on the concentration of the virus that is typically shed in feces (i.e., illness duration and differences in persons). Thus, it was possible for us to quantify SARS-CoV-2 concentrations in wastewater over time, however we were not able to estimate or determine the exact number of virus copies that would correspond to an infected individual. Researchers have also noted as time passed during the semester, it was difficult to determine SARS-CoV-2 virus copies shed from persons returning from quarantine and new cases in the same dorm. Additionally, issues such as clogged autosamplers resulting from inappropriate student waste disposal may have affected the ability to collect full-volume samples. Student compliance with regards to saliva testing also inhibited timely testing at times during the semester, affecting case identification. We also were not able to ascertain flow data which may be used to determine differences in concentrations during varying period.

Chapter IV: The Use and Efficacy of the COVID-19 Vaccine on a College Campus to Aid in Mitigating Spread of the Virus in Dormitories

**Note: This chapter is formatted as a complete manuscript and will be submitted to a peer reviewed journal in the future. Hence, there may be some repetition in Chapter 2 (Background-Literature Review) and Introduction for Chapter 3*

Abstract

Since their creation, vaccines have been used to help mitigate disease outbreaks. For example, successful campaigns have been instrumental lessening morbidity and mortality of diseases such as polio and smallpox. These past successes have led to vaccinations becoming essential components of an efficacious healthcare system. The spread of COVID-19 led to the creation of multiple vaccines to help mitigate effects of the virus. The perceived efficacy of COVID-19 vaccinations led many businesses and schools to require, recommend, or incentivize vaccination. This was the case at many universities as they sought to re-open. Vaccination of university students was an important part of their public health strategy. An objective of this research was to determine if SARS-CoV-2 virus copies in wastewater and student COVID-19 cases were affected by student vaccination rates. A significant ($p < 0.001$; $R^2 = 0.857$) inverse relationship between vaccination rates and percentage of student cases was observed among students living in dormitories. Concentrations of SARS- CoV-2 in wastewater were significantly ($p = 0.016$) higher during the Spring 2021 semester when vaccines were not accessible to most students when compared to Fall 2021 semester. These results suggest vaccines were effective as part of a mitigation strategy in helping to slow the spread of COVID-19 on a college campus.

Introduction

Disease surveillance has been hailed as a significant tool in stemming outbreaks, however, other actions are often needed to protect public health. A notable example may be the spread of smallpox in the late 1700s. Some people were intentionally exposed to smallpox infected materials in places such as Africa, China, and India. This process, considered inoculation, and also referred to as variolation, was championed in Western Europe by many, such as Lady Mary Wortley Montagu (Best et al., 2004; Behbehani, 1983). Additionally, those in the New World such as Reverend Cotton Mather pushed for variolation upon learning of it from an enslaved African (Best et al., 2004; Behbehani, 1983; Reidel, 2005). Building on variolation work, Edward Jenner developed a vaccina vaccine, leading to what has been considered the first vaccination protocols (Geddes, 2006; Reidel, 2005; Meyer et al., 2020).

The efficacy of the smallpox vaccine fueled study and hope that vaccines could be created for other diseases. Louis Pasteur, a prominent microbiologist and chemist, sought to create vaccines to combat infectious diseases occurring in animals and humans (Pasteur et al., 2002). Thus, vaccine development continued in response to outbreaks of global and endemic diseases, particularly those affecting children such as diphtheria and pertussis. The development and roll out of a trivalent vaccine, Diphtheria, Tetanus and Pertussis (DTaP) in 1948 was instrumental in the decline of infant and child morbidity and mortality from these illnesses (Britannica, 2017). Induction of a national childhood DTaP vaccination program in the Netherlands led to an 82.4% decline in diphtheria in its first 13 years (Sharma et al., 2019).

Other successful vaccination campaigns include the one for polio credited with the dramatic decrease of the disease in many countries. More specifically the number of countries considered polio-endemic dropped from 125 in 1988 to 20 by the year 2000 (Bahl et al., 2018). Countries such as Pakistan and Afghanistan contribute to 85% of world polio cases. In these areas, vaccination campaigns have been hindered due to issues such as mistrust, violence against polio workers and insecurity. It has been observed in Pakistan, that polio vaccination rates are as low as

5% during high insecurity (e.g., political instability, fear of bodily harm), with incidence of cases reporting higher than 73% (Ahmad et al., 2020). Thus, it can be inferred that successful vaccination campaigns may be instrumental in mitigating spread of disease.

Many states and school systems, from elementary to university-level, have some type of vaccination requirement. Prior to starting kindergarten, many children are required to have measles, mumps, and rubella (MMR), DTaP and varicella vaccines (Kuehn, 2019). These requirements are key to high vaccination rates in young children, as some states will not allow children into schools without proof of vaccination (CDC, 2007). Vaccine requirements are also required for secondary education. Some states, such as North Carolina, require vaccines that have more than one dose (e.g., DTaP: 3 doses, Hepatitis B: 3 doses) (National Conference of State Legislatures, 2021), prior to being admitted to secondary education institutions. These vaccinations are used to keep college students safe, particularly among those living in close quarters such as dormitories and student housing.

The COVID-19 pandemic led many schools and universities to shut down and pivot to online or virtual learning to ensure safety of students, faculty, and staff. While this pivot may have been sufficient in some didactic learning situations, it proved difficult in others including laboratory-based learning (Franchi, 2020; Schultes et al., 2021). Thus, it is possible that a lack of experiential learning may have been a factored into the ability to develop curricula for certain learning styles. A recent study of student perceptions of online teaching during COVID-19 of medical students in the UK showed that generally, students did not find online learning enjoyable or engaging. Additionally, 82.1% felt online teaching did not allow them to learn practical clinical skills (Dost et al., 2020).

In addition to difficulty adjusting to new learning platforms, students also faced other socioeconomic externalities. A study of Midwestern university students found higher rates of food insecurity among students who lived on their own (Davitt et al., 2021). In another study of students attending City University of New York, 37% of those surveyed reported they sometimes worry about running out of food. The same study also showed students being either very worried or somewhat worried about housing (49.8%) (Jones et al., 2021). Stress resulting from dormitory closure, food insecurity, and increased unemployment impacted college students in many ways including their mental health. A 2020 study on adolescents in China indicated a prevalence of psychological health problems (Zhou et al., 2020). Thus, many universities recognized the necessity of returning to a semblance of normalcy and the potential positive effects that returning to campus may have on affected students.

As colleges and universities moved to reopen, many employed prevention and mitigation strategies such as periodic testing, questionnaires, contact tracing, accelerated semesters that ended early, and wastewater-based epidemiological surveillance (Pollock et al., 2021; Benneyan et al., 2021; Pelt et al., 2021). The development of a COVID-19 vaccine aided in this endeavor, becoming a part of the COVID-19 mitigation strategy. Initially, vaccine rollout was set in phases with recommendations from the CDC, in which many states adopted and set up their own phase or group rollouts (Dooling et al., 2021). North Carolina adopted a model with vaccination rollout taking place over 4 phases, with some phases having multiple groups (e.g., Phase 2- Groups 1-4) (North Carolina Department of Health and Human Services [NCDHHS], 2020). In North Carolina, the first phase, which began in December 2020 and carried into January 2021, allowed healthcare workers and long-term care staff and residents to gain access to the vaccine. In January 2021, this phase expanded to include persons aged 75 or older and healthcare and frontline workers. In

February 2021, Phase 2, with multiple groups, opened to adults at high risk for exposure, including essential workers who have not been vaccinated. College students residing in dormitories or apartments became available for vaccinations on 31 March 2021 (Covington, 2021). As vaccinations became available to all persons (at least 16 years old) over the summer of 2021, many schools either required vaccinations or strongly encouraged vaccination prior to Fall 2021 semester. Some universities and states used incentives (i.e., gift cards, money) to help increase vaccination rates.

Vaccines were rolled out across the campus of East Carolina University at different rates, typically based on which group a person was assigned to, following NC DHHS recommendations. Typically, there was a 3- to 5-day turnaround time between scheduling and receiving the first vaccine dose. Additionally, depending on the vaccine type, persons may have needed either 1 or 2 doses. For example, persons receiving Pfizer-BioNTech vaccine would need 2 doses between 3-8 weeks apart. Those receiving the Moderna vaccine would also need 2 doses between 4-8 weeks apart, while those receiving Johnson and Johnson vaccine would only need 1 dose (CDC, 2022). Vaccinations for dormitory residing college students did not open until 31 March and with the lag times between scheduling and receiving a vaccine, most students would not have been considered fully vaccinated until at least the week of 01 May 2021. During this time-period, students would have been finishing up exams and moving out of dormitories. Thus, for this study, Spring 2021 semester was considered a semester when students were not fully vaccinated, while Fall 2021 was considered the vaccinated semester.

The research goal was to assess how vaccination affected concentrations of SARS-CoV-2 and cases of COVID-19. The specific objectives were to determine: 1) if vaccinations on campus affected the number of COVID-19 cases among college students; 2) the relationship between case incidence and vaccine compliance; and 3) if vaccinations affected the concentration of SARS-CoV-2 in wastewater collected from the dorms. It was hypothesized that as more students became vaccinated for COVID-19 there would be a decrease in the number of COVID-19 cases and a decrease in concentration of SARS-CoV-2 in wastewater. Furthermore, it was hypothesized that an inverse relationship exists between vaccination rate and SARS-CoV-2 concentrations and cases of COVID-19.

Methods

SARS-CoV- 2 Procurement

Wastewater samples were collected Monday, Wednesday, and Friday on a weekly basis excluding holidays and university approved days off from 9 and 16 dormitories during the Spring and Fall 2021 semesters, respectively. The specific sampling and laboratory protocols were described in a previous chapter but will be briefly summarized. Composite samples of wastewater were collected using HACH autosamplers from sewer pipes exiting the dormitories on ECU's campus. Samples were kept on ice for preservation while in the autosamplers and during transport to labs. In the lab the samples were heat pasteurized, processed, and concentrated to obtain a viral pellet. The resultant viral pellet underwent RNA extraction to obtain SARS-CoV-2. Virus concentrations were quantified during the Spring and Fall semesters of 2021 using LUNA SARS-CoV-2 RT-qPCR multiplex assay. A standard curve was generated using diluted synthetic SARS-CoV-2 (Twist Bioscience) at 0, 10, 100, 1000, and 10000 copies was used to help with virus quantification.

Vaccine Analysis

Vaccination data were obtained from ECU dashboard and exported into SPSS (SPSS Institute, Chicago, Ill) for analysis. Students were considered fully vaccinated two weeks after receiving either their second dose of a 2-dose vaccine or completing 1-dose regimen. The ECU dashboard was a visual representation published on the university's website used to convey COVID-19 statistics and information. The dashboard was used as a tool to help view COVID-19 trends across campus. Data derived from the wastewater analysis section were also used in the vaccine analysis. Differences within the semesters were analyzed for statistical significance ($p < 0.05$). The means for SARS-CoV-2 virus copies per mL of wastewater in each dorm were calculated for Spring and Fall semesters and compared using a chi-square test of independence to determine if the differences were statistically significant ($p < 0.05$). The SARS-CoV-2 concentrations in wastewater data were compared to vaccination rates on campus using SPSS and a Pearson Correlation analyses to determine if there was a statistically significant inverse relationship.

Results

Differences in SARS-CoV-2 Between Semesters

A total of 830 samples were processed and analyzed for SARS-CoV-2, of which 594 samples (71.6%) tested positive for the virus. Overall, a large variation (SD = 594) in virus copies per mL was observed among positive samples. Significant ($p = 0.016$) differences in mean SARS-CoV-2 concentrations in wastewater between Spring (129.7 copies mL) and Fall (83.7 copies mL) semesters (Figure 4.1, Figure 4.2) was observed. The three dormitories with the highest mean number of SARS-CoV-2 copies observed within a semester were from Fletcher (322.4), Ballard West (318.7), and Greene (154.2), all occurring in the Spring (Figure 4.1). Also, of the 9 dorms that were occupied during both Spring and Fall semesters, 6 (66.7%) had higher mean concentrations during the Spring.

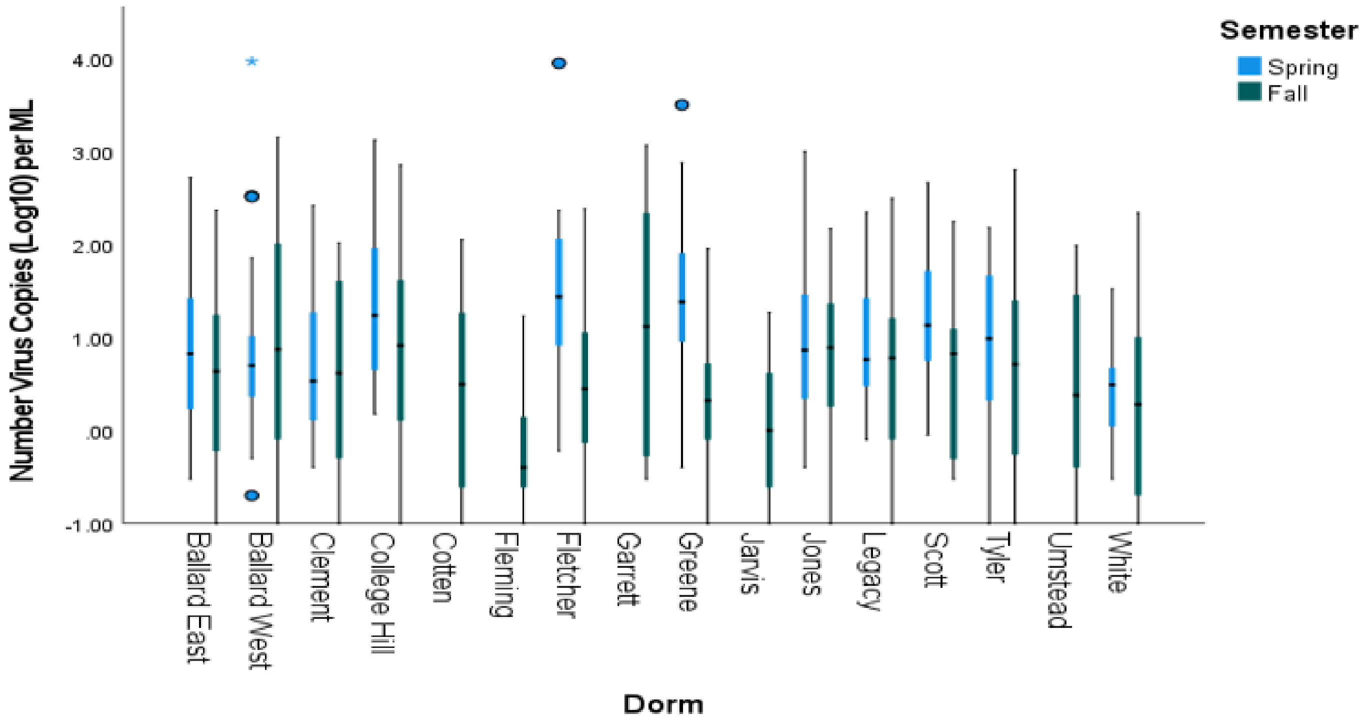


Figure 4.1. Mean SARS-CoV-2 copies per mL Detected in Wastewater by Dormitory During Spring and Fall Semesters. During Spring 2021, not all dormitories were open for student living. Data was $\log_{10}$ transformed.

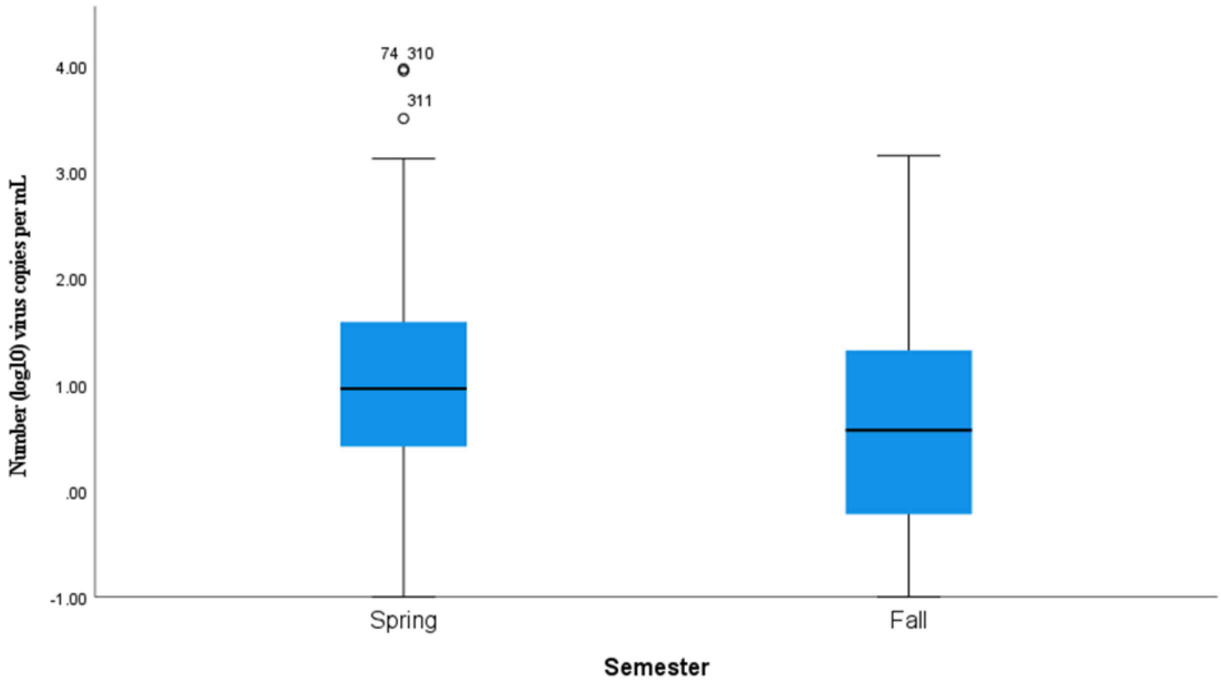


Figure 4.2. Number of SARS-CoV-2 Copies per ml for 2021 Spring and Fall Semester. Dormitories with zero copies were represented by -1.00 on the figure.

Relationship Between Vaccine Compliance and Student Cases and Virus Copy Count

At the beginning of the Fall 2021 semester students were asked to vaccinate prior to arrival on campus. Additionally, vaccine clinics continued throughout the Fall semester and students were encouraged to get vaccinated. As the percentage of students vaccinated increased, the number of student cases declined (Figure 4.3). A standard linear regression was performed to determine if the percentage of students vaccinated was associated with the weekly number of new COVID-19 cases. A significant inverse relationship between vaccination rates and number of students with COVID-19 was observed ($ß$ = -0.169, p = < 0.001; R^2 = 0.857). So, as the vaccination rate increased, the number of students with COVID-19 decreased. A weak R^2 = 0.373, but significant inverse relationship (ß = -3.976, $p = 0.021$) was also observed between the concentration of SARS-CoV-2 in wastewater and the percentage of students vaccinated (Figure 4.4).

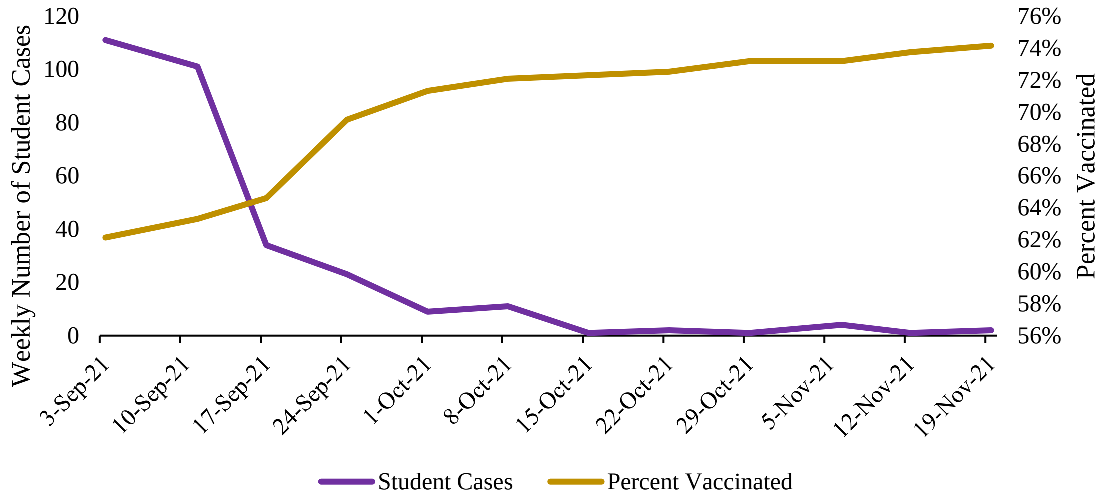


Figure 4.3. COVID-19 Cases among students living dormitories compared to percent of students vaccinated between 03 September 2021 and 19 November 2021.

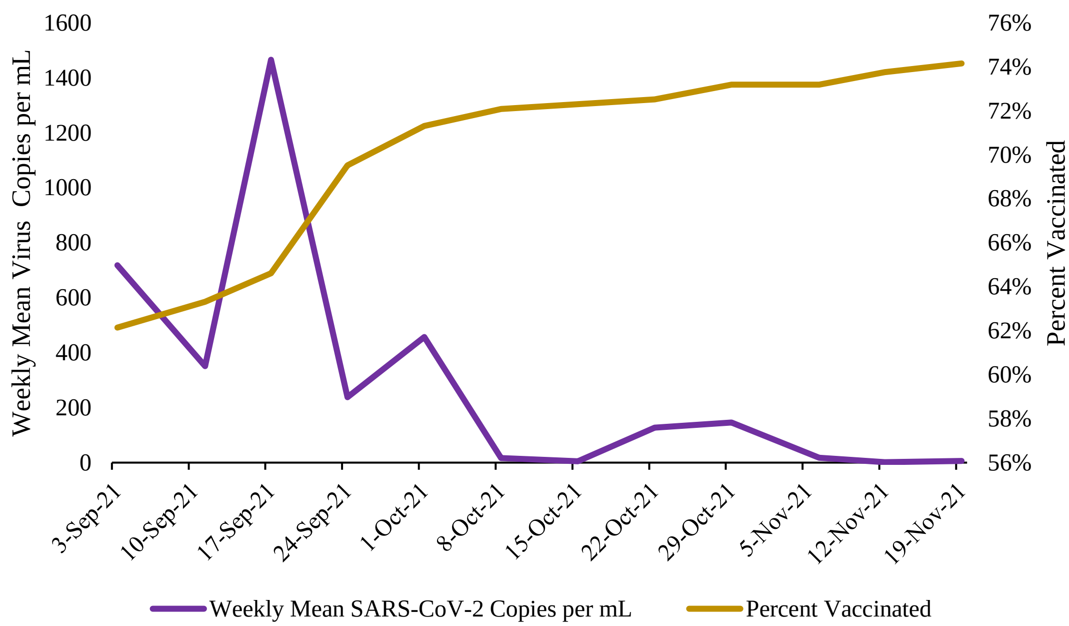


Figure 4.4. COVID-19 Weekly mean SARS virus copies obtained from students living dormitories compared to percent of students vaccinated between 03 September 2021 and 19 November 2021.

Discussion

The COVID-19 pandemic forced many colleges and universities to adjust educational delivery platforms to provide student learning. This pivot, while helpful in maintaining some continuity, led to many students feeling online fatigue. Indeed, some studies have shown a relationship between Zoom exhaustion and fatigue on life satisfaction (which may impact learning) (Deniz et al., 2022; Sobral et al., 2022). Thus, as universities sought to re-open to address some of these issues, they searched for ways to keep students safe on campus. In some instances, this included multiple types of surveillance to help proactively find cases and isolate students to help mitigate the spread of disease. The advent of vaccines for COVID-19 provided universities with an additional way to help stem viral spread.

One objective of this study was to determine if the COVID-19 case rate on a college campus differed between a semester when vaccines were available to all students (Fall 2021) and when they were not available (Spring 2021). Students attending the University during the Spring 2021 semester typically were unvaccinated as vaccines did not fully begin to roll out for all individuals over the age of 18 until the end of March. University students were heavily encouraged to be vaccinated prior to arrival on campus before the Fall semester. During the pandemic in 2021, the school used wastewater-based epidemiology as a surveillance tool for potentially identifying COVID-19 cases. Significant differences in SARS-CoV-2 concentrations in wastewater from dormitories on ECU’s campus were observed between Spring and Fall semesters, with the Spring semester having higher concentrations. A significant inverse relationship between vaccination rate and number of cases was observed. As the number of students receiving the vaccine increased the number of COVID-19 cases on campus decreased. This may be comparable to a similar situation seen with the introduction of the mumps vaccine. Prior to vaccine introduction (1963), the United

States reported approximately 500,000 cases each year. However, post vaccine introduction cases declined to as few as 3,750 cases (1984-1988) each year (McLean et al., 2013). Both results indicate the usefulness of vaccines in reducing illness.

These data suggest that vaccinations were a key factor in stemming the spread of COVID-19 on campus. Vaccination programs are often used to help populations reach herd immunity, in which a largely vaccinated portion of a population may protect smaller immunocompromised, non-vaccinated or immunologically naïve persons within the population (Frederiksen et al., 2020). The percentage of vaccinated students living in dormitories rose from 62% at the beginning of the September 2021 to 71% by 01 October 2021. During this same time frame, the University experienced a noticeable drop in cases (91.8% change). The threshold percentage (of the population) for vaccine-induced herd immunity varies by pathogen, with studies indicating the level for SARS-CoV-2 at approximately 67% (Frederiksen et al., 2020). This may indicate that the University experienced some herd immunity within residents living in university housing.

Another factor that may have influenced the COVID-19 rates on campus were students with hybrid immunity. Persons who after recovering from viral infection, subsequently obtained a vaccination have been shown to have better protection from the virus than those just receiving an mRNA vaccine (Goldberg et at., 2021). A study conducted in Qatar found those with hybrid immunity were at lower risk of breakthrough infection (Abu-Raddad et al., 2021). The University had multiple students obtaining vaccination after becoming ill with COVID-19. The heightened immune awareness of these persons may have prevented re-infections that may have occurred later in the semester, thus contributing to lower numbers of COVID-19 cases. It is possible to conclude that an effective vaccination program may be advantageous in mitigating the spread of COVID-19 on university campuses. Students living in dormitories are often in close quarters and congregate in buildings housing hundreds of students. This may increase the probability to spread the virus not only among those living in their respective buildings, but also elsewhere on campus as these students most often have face-to face classes. Thus, it may be necessary or highly encouraged among universities to implement vaccinations campaigns on their campuses as part of their COVID-19 mitigation strategy. This may not only aid in reducing transmission among those living in school sponsored housing, but other publicly occupied buildings on campus that endure a large amount of foot traffic.

Chapter V: COVID-19 Beliefs, Behaviors, and Perceptions Among Students on a College Campus During the Pandemic

**Note: This chapter is formatted as a complete manuscript and will be submitted to a peer reviewed journal in the future. Hence, there may be some repetition in Chapter 2 (Background-Literature Review) and Introduction for Chapter 3*

Abstract

Elucidating how people think and behave during a disease outbreak may provide valuable insight and help direct programs or surveillance to combat the spread of disease. Surveys may allow public health officials to predict the actions of large sects of the population. Officials may also use this information to determine target populations or those who are most at risk. Additionally, as people endure outbreaks, their feelings may change during the event and that may affect the mitigation strategies they use. As universities welcomed students back to their campuses following COVID-19 shutdowns, it became important to know how students were feeling and what their behaviors were regarding the disease. A goal of this study was to determine how students at East Carolina University felt about COVID-19, which behaviors they exhibited during the pandemic, and if their feelings and behaviors differed between the Spring and Fall 2021 semesters. Results showed most students felt "somewhat concerned" about the COVID-19 pandemic during both semesters. Significant differences in student concern regarding COVID-19 between Spring and Fall semesters, were not observed $p = 0.598$. However, more students indicated during the Spring semester in comparison to the Fall that they believed the vaccine was not safe and they would not take it ($p < 0.001$). This information may be important to officials as cases may fluctuate over time and attitude or behavior and awareness may help explain these fluctuations.

Introduction

Surveys can be a useful tool in gathering population information if they are properly developed, administered, and analyzed. Surveys with questions that solicit information such as private behaviors, mental health, and attitudes from persons may result in more reliable and valid data (Institute of Medicine (US) Committee on a National Surveillance System for Cardiovascular and Select Chronic Diseases, 2011). Generally, surveys should be administered to a representative sample of a the population of interest, thus allowing for generalization of results to the entire population (CDC, 2012). This collection of information may be of particular importance during times of disease outbreaks. Because infectious diseases have the capacity to rapidly expand across populations, the ability to collect efficacious data quickly may have a profound effect on public health policy development (Geldsetzer, 2020). The ease in which some surveys can be delivered may provide a cost-effective means of gathering necessary data (Safdar et al., 2016). Additionally, responses from surveys may help public health agencies determine populations most at risk, as used during the height of the HIV/AIDS epidemic. This may help when determining and rolling out prevention and disease mitigation programs. Thus, surveys have been useful in healthcare epidemiology.

Recently, surveys have been used to gather information from specific populations during the COVID-19 outbreak. One such study in Guangdong, Province in China sought to determine the mental effects and awareness in college students regarding the disease and their association with future health behaviors. Researchers found older students had greater levels of awareness and higher-level changes in future behaviors (Chang et al., 2020). Other surveys have shown an increased prevalence of psychological health problems and a negative association with COVID-19 awareness levels in students (Zhou et al., 2020). Increased levels of disease awareness may have an impact on behaviors that could contribute to the spread of disease and affect public health.

Researchers conducted a survey on COVID-19 awareness and concluded that those with increased awareness were more likely to adopt strategies such as mask-wearing, social distancing, and handwashing (Teslya et al., 2020). This suggests that information gleaned from these surveys may be used to develop specific cost-effective prevention strategies for targeted populations based on their needs.

Students on the campus of ECU were surveyed to determine their beliefs, attitudes, and practices during the COVID-19 outbreak. It was hypothesized that there would be significant differences with student attitudes and beliefs concerning COVID-19 between the Spring and Fall semesters, with students becoming less concerned as vaccines become available and pandemic fatigue grew. Additionally, a goal was to determine whether behavioral changes occurred between semesters with students becoming more relaxed with their manners (i.e., handwashing, congregating in large groups, etc.) after the rollout of vaccines.

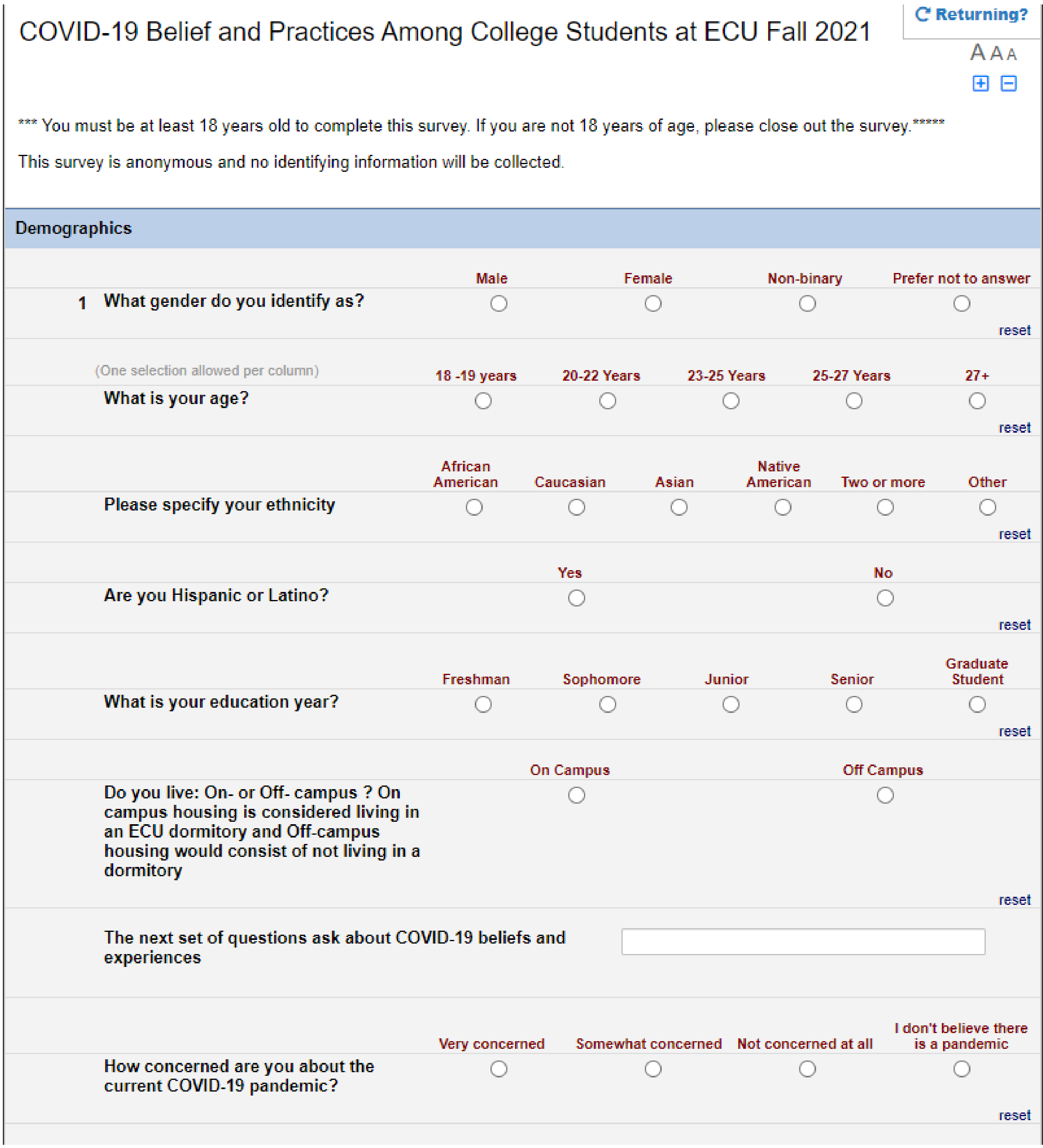
Methods

Participants

Surveys were distributed to students who were currently enrolled in Environmental Health Science classes during the Spring and Fall semesters of 2021. Environmental Health Science 2110 is considered a general science requirement, thus students from multiple majors (e.g., psychology, pre-health, elementary education, etc.) enroll in this class. Students had to be at least 18 years of age and actively enrolled to participate in the survey. Student participants in these classes ranged from freshmen to seniors. Additionally, master’s students enrolled in Environmental Health Science 6210, a graduate writing series class, were also invited to take the survey. Data were collected from students using an online anonymous survey created in and distributed through Research Electronic Data Capture (RED Cap) survey system hosted at ECU.

Survey

The survey included demographic questions regarding gender, race and ethnicity in addition to information concerning housing status (e.g., on- or off- campus), and education levels. To determine student beliefs and behaviors, participants were asked questions about virus perceptions, hand washing and mask wearing. Additionally, students answered questions about their social and learning experiences during the semester. Students in the Fall semester were given an additional question concerning the impact of university transitions from different class types (e.g., online to face-to-face) (Figure 5.1A-C).



COVID-19 Belief and Practices Among College Students at ECU Fall 2021

Returning?

AAA

*** You must be at least 18 years old to complete this survey. If you are not 18 years of age, please close out the survey.*****

This survey is anonymous and no identifying information will be collected.

Demographics

	Male	Female	Non-binary	Prefer not to answer
1 What gender do you identify as?	○	○	○	○

reset

(One selection allowed per column)

	18 -19 years	20-22 Years	23-25 Years	25-27 Years	27+
What is your age?	○	○	○	○	○

reset

	African American	Caucasian	Asian	Native American	Two or more	Other
Please specify your ethnicity	○	○	○	○	○	○

reset

	Yes	No
Are you Hispanic or Latino?	○	○

reset

	Freshman	Sophomore	Junior	Senior	Graduate Student
What is your education year?	○	○	○	○	○

reset

	On Campus	Off Campus
Do you live: On- or Off- campus ? On campus housing is considered living in an ECU dormitory and Off-campus housing would consist of not living in a dormitory	○	○

reset

The next set of questions ask about COVID-19 beliefs and experiences

	Very concerned	Somewhat concerned	Not concerned at all	I don't believe there is a pandemic
How concerned are you about the current COVID-19 pandemic?	○	○	○	○

reset

Figure 5.1A. Shows some of the questions included on the survey on COVID-19 Beliefs and Practices disseminated to students during Spring and Fall Semester 2021

How would you characterize the transmissibility of COVID-19?	○	○	○	○

reset

	Yes	No
Have you ever been diagnosed with COVID-19?	○	○

reset

	Yes	No
Do you know anyone who has been diagnosed with COVID-19?	○	○

reset

	Yes	No
Do you know anyone who has died as a result of COVID-19?	○	○

reset

	Yes	No	I was not going to live on-campus regardless of COVID-19
Did COVID-19 concerns and/or regulations affect your ability to stay on campus?	○	○	○

reset

(One selection allowed per column)	Yes	No	Not applicable
Do you feel safe staying on campus during the pandemic?	○	○	○

reset

	Yes, very safe in taking it	A little safe, but would still take it	Not safe, but would still take it	Not safe and would not take it
Do you feel safe taking the COVID-19 vaccine?	○	○	○	○

reset

Are you currently vaccinated? This survey is anonymous and your vaccination status will not be reported to anyone. This is strictly for informational purposes only.

○ Yes
○ No
○ Prefer not to answer

reset

	Yes	No	Unsure
Would you consider yourself an "anti-vaxxer" (someone who is opposed to vaccination)?	○	○	○

reset

Figure 5.1B. Shows some of the questions included on the survey on COVID-19 Beliefs and Practices disseminated to students during Spring and Fall Semester 2021

	Always	Most of the time	Sometimes	Never	
Do you wear a mask when you have visitors?	○	○	○	○	reset
	Always	Most of the time	Sometimes	Never	
When you have visitors, do you follow recommendations to distance 6- feet apart?	○	○	○	○	reset
	Yes		No		
Do you allow visitors to use the restroom when they are in your residence?	○		○		reset
	Daily	Only after I have visitors	Twice a week	Weekly	Bi-weekly
How often do you clean high touch areas (e.g. door knobs, light switches, faucets, etc.)	○	○	○	○	○
					reset
	Daily	Weekly	Bi-Weekly	Monthly	I don't congregate in groups of 5 or more persons
Aside from work or class, how often are you in groups of 5 persons or more? This may include study groups, parties, small get-togethers.	○	○	○	○	○
					reset
	Yes		No		
Do you work at a job where you have to face customers (e.g. restaurant, retail, childcare)?	○		○		reset
	Yes		No		
Have the potential exposure risks you have at your job increased the safety precautions (i.e. washing hands, changing out masks) you take before returning to your place of residence?	○		○		

Figure 5.1C. Shows some of the questions included on the survey on COVID-19 Beliefs and Practices disseminated to students during Spring and Fall Semester 2021

Statistical Analysis

Cross tabulations were performed to compare responses by different groups. Questions were developed using a Likert scale and were analyzed to determine significant differences ($p < 0.05$) between Spring and Fall semesters. For nonparametric data, a Kruskal-Wallis test were used to determine significance between data consisting of more than 2 samples, while Mann-Whitney testing were used to analyze significance between 2 samples. Statistical analyses were performed using SPSS (SPSS Institute, Chicago, Ill). SPSS analysis also included a post-hoc pairwise Mann-Whitney with Bonferroni adjustments.

Results

Surveys (n = 408) were disseminated to students enrolled in environmental health classes during the Spring 2021 semester, with 102 responses received (25.2% response rate). During the Fall, 243 surveys were administered with 99 responses received (40.7% response rate). Demographic data from ECU admissions (Spring 2021 data not available) showed the sample population for the surveys exhibited similar racial percentages as the greater ECU student population, with the exception of respondents with Hispanic heritage. Tables 5.1A and 5.1B show the demographic breakdown of participants completing the survey. More specifically, differences in the racial percentage of surveyed students in comparison to the general population for the two largest groups (African American and Caucasian) were less than 5% each. However, there was a 17% increase in the percentage of female students that participated in the survey relative to percentage of females at ECU, while the percentage of males surveyed (22%) was lower than the percentage of ECU's general population that identifies as male (41%) gender. Table 5.2A and 5.2B show ECU Fall 2021 demographic/gender breakdown compared with survey demographic average of the two semesters

Table 5.1A. Demographic Data from Student Spring 2021 COVID Attitude, Beliefs, and Practices Survey

Gender		n	%
	Male	22	21.6
	Female	79	77.5
	Prefer not to answer	1	1
Race			
	African-American	15	14.7
	Caucasian	66	64.7
	Asian	8	7.8
	2 or More	6	5.9
	Other	7	6.9
Ethnicity			
	Hispanic or Latino	6	5.9
	Not Hispanic of Latino	96	94.1

Table 5.1B. Demographic Data from Student Fall 2021 COVID Attitude, Beliefs, and Practices Survey

Gender		n	%
	Male	23	23.2
	Female	74	74.7
	Non-Binary	2	2
Race			
	African-American	17	17.2
	Caucasian	68	68.7
	Asian	3	3
	Native American	1	1
	2 or More	1	1
	Other	9	9.1
Ethnicity			
	Hispanic or Latino	15	15.2
	Not Hispanic of Latino	84	84.8

Table 5.2A. Demographic breakdown of ECU student population for Fall 2021 compared to survey demographics

Race	ECU %	Survey %
African-American or Black	16.7	16
Caucasian	63.8	66.7
Hispanic	8	10.5
Asian	2.8	5.5
Other	8.7	8.5

Table 5.2B. Gender breakdown of ECU student population for Fall 2021 compared to survey demographics

Gender	ECU %	Survey %
Male	41	22.4
Female	59	76.1

Student Attitudes and Beliefs Concerning COVID-19

Overall, it was shown that many students were somewhat concerned (46.5%) about the pandemic and believed it to be very transmissible (59.2%) (Table 5.3, Table 5.4). Further analysis showed there was no significant difference in those feeling somewhat concerned between the Spring and Fall semesters, X^2 (3, N= 200) = 1.877, p = 0.598. The number of those who felt the virus was "very transmissible" declined from Spring (5.9%) to Fall (5.1%) semesters, however the differences were not statistically significant X^2 (2, N= 201) = 0.921, p= 0.631. Interestingly, 5.5% of the population felt the virus was very transmissible but were not concerned at all about the pandemic. It is possible these persons felt that while transmissible, the virus did not cause significant sickness and thus were not concerned.

Table 5.3. Student Concern about the COVID-19 Pandemic During Spring and Fall 2021 Semester

Semester	Very concerned	Somewhat concerned	Not concerned at all	I don't believe there is a pandemic	Total
Spring	36	47	18	1	102
Fall	30	46	22	0	98
Total	66	93	40	1	200

Table 5.4. Student Concern about COVID-19 Virus Transmissibility During Spring and Fall 2021 Semester

Semester	Very transmissible	Slightly transmissible	Not very transmissible	Total
Spring	63	36	3	102
Fall	56	38	5	99
Total	119	74	8	201

While most classes during the Spring semester 2021 were online, dorms were open at limited capacity and students had the option to live in dormitories. Of the students who planned to live on campus, most (67.8%) felt safe with the housing arrangements. When analyzed by semester, 61.5% of persons felt safe on campus during the Spring semester with the number rising to 72.7% for the Fall semester. This perception of safety may have affected a student's decision to stay on campus, in addition to capacity limitations. When students who lived off campus were queried, 31.6% said the COVID-19 pandemic affected their campus stay during the Spring semester, while 47.8% of those during the Fall semester said the pandemic affected their stay. It is also possible that online classes and the ability to go to school from home may have contributed to the Spring semester having a lower percentage of students on campus being affected by COVID-19.

Overall, there was some concern about COVID-19 vaccine with only 45.8% responding they felt “very safe taking it” and 69.7% felt the vaccine was at least a little safe and would take it (Table 5.5). During the Spring semester, prior to full roll out of the vaccines, 30% of the student population felt the vaccine was “not safe and would not take it”, while only 7.1% of students felt this way during the Fall semester. There was an almost 23% increase in the percentage of students surveyed that perceived the vaccine as being safe from Spring to Fall. Chi-square analysis showed significant differences between the semesters X^2 (3, N= 201) = 18.418, $p < 0.001$. For those who did not feel safe taking the vaccine, the predominant reason was “untrusting of medical professionals”. Others noted “fear of long-term side effects in a vaccine that had a very short study time” and “too politicized” as reasons for not wanting the vaccine.

Table 5.5. Overall Vaccine Safety Perception by Race

Race	Yes, very safe taking it	A little safe, but would still take it	Not safe, but would still take it	Not safe, and would not take it	Total
African American	14 (15.2)	8 (16.7)	5 (21.7)	5 (13.2)	32 (15.9)
Caucasian	60 (65.2)	33 (68.8)	16 (69.6)	25 (65.8)	134 (66.7)
Asian	7 (7.6)	2 (4.2)	1 (4.3)	1 (2.6)	11 (5.5)
Native American	0	1 (2.1)	0	0	1 (0.5)
2 or More	3 (3.3)	2 (4.2)	0	2 (5.3)	7 (3.5)
Other	8 (8.7)	2 (4.2)	1 (4.3)	5 (13.2)	16 (8.0)
Total	92	48	23	38	

When reviewing vaccine perception data those feeling very safe taking the vaccine did not differ much based-on gender. However, slightly more males, 24% responded as “not safe and would not take it” compared to 17% of females, a 7% difference. Overall, the percentage of students who would take the vaccine was 81.1%, regardless of the varying feelings of safety (Table 5.6).

Table 5.6. Vaccine Safety perception by Gender

	Yes, very safe in taking it	A little safe, but would still take it	Not safe, but would still take it	Not safe, and would not take it	
Gender					Total
Male	22 (23.9)	4 (8.3)	8 (34.8)	11 (28.9)	45 (22.4)
Female	69 (75)	43 (89.6)	15 (65.2)	26 (68.4)	153 (76.1)
Non-binary	1 (1.1)	1 (2.1)	0	0	2 (1)
Prefer not to answer				1 (2.6)	1 (0.05)
Total	92	48	23	38	201

Student Behaviors During Spring and Fall 2021 Semesters

To help mitigate the spread of COVID-19 among persons, the CDC gave advice on preventative behaviors such as hand washing, visiting, and mask wearing. Observations of student responses in this survey showed frequency in daily handwashing behavior was almost evenly split between 4-6 times (24.9%), 7-8 times (21.8%), and 9+ times (22.7%). Additionally, the pandemic may have affected how students visited others or allowed visitors. Overall, 39.0% of students reported having visitors at least 1-2 times during the week, 28.5% of respondents reported not having any visitors. To help reduce the likelihood of spreading the virus, off campus students were discouraged from visiting dorms and students were cautioned against congregating in large groups whether on or off campus during the Spring semester. A chi-square test of independence was performed to determine if dorm visitor occurrence differed by semester. Significant differences were observed between the semesters (p= 0.005). Notably, an increase in visitor frequency during the Fall semester and less students reported not having visitors during the Fall was noted (Table 5.7).

Table 5.7. Frequency of Visitors

		Semester		
		Spring	Fall	Total
Visitation Frequency	1-2 Times	43	35	78
	3-4 Times	17	19	36
	5-6 Times	1	11	12
	Daily	5	12	17
	I don't have visitors	35	22	57
	Total	101	99	200

Although mask wearing was strongly encouraged, only 5.7% reported always wearing a mask when having visitors and 39.9% reported never wearing a mask. A higher percentage of students reported wearing masks during the Spring relative to Fall semesters, and the differences were statistically significant (p = 0.042). When analyzing mask wearing between genders, we found no statistical difference (p = 0.161). It's possible that COVID perceptions may have influenced mask wearing when campus students were entertaining visitors. Visitation may have also been influenced by the type of visitor (e.g., family, close friend), however we were not able to gather that information from this survey. Chi-square testing showed a significantly significant (p = 0.001) association between transmissibility perception and mask wearing. Notably, almost all persons who perceived the virus as not very transmissible, reported never wearing a mask (87.5%) (Table 5.8).

Table 5.8. Reported Mask Wearing Among Students When Having Visitors Compared to their Perceptions on Virus Transmissibility.

	Transmissibility Characterization			
	Very transmissible	Slightly transmissible	Not very transmissible	
Mask Wearing				Total
Always	11	2	0	13
Most of the time	27	7	0	34
Sometimes	46	25	1	72
Never	34	38	7	79
Total	118	72	8	198

Large gatherings were often discouraged during the COVID-19 outbreak. Survey responses showed 33.5% of students gathered in groups of 5+ on a weekly basis. There was an increase of persons reporting daily and weekly gatherings of 5+ in the Fall semester relative to the Spring and the differences were statistically significant ($p < 0.001$). no significant differences were observed between genders ($p = 0.220$). When comparing responses to perception of virus transmission, the majority of those that felt the virus was not very transmissible reported gatherings of 5+ at least weekly. The majority of those who reported not congregating in groups in 5+ also responded as viewing the virus as very transmissible (70.7%) (Table 9).

Table 9. Reported Frequency of Group Gatherings Among Students Compared to their Perceptions on Virus Transmissibility

	Transmissibility Characterization			
Visitation Frequency	Very Transmissible	Slightly Transmissible	Not Very Transmissible	Total
Daily	16	17	1	34
Weekly	36	25	2	63
Bi-weekly	20	13	0	33
Monthly	17	8	0	25
I don't congregate in groups of 5+	29	11	1	41
Total	118	74	8	200

Student Perceptions of ECU and COVID During Fall and Spring 2021 Semesters

The full return to campus may have been intimidating for some students. The University often worked to make sure COVID-19 information was disseminated and that students were able to access the information. Students were asked questions on whether they felt ECU gave them proper instructions to follow during the COVID-19 pandemic. The majority of students (87%) felt they received proper guidance and chi-square analysis showed the responses were between semesters were not significant (p = 0.157). One of the ways in which students were able to determine if it was okay to come to campus or class was by using a COVID Daily Screening Tool. Students were asked to use this checklist prior to coming to campus. Over half the students surveyed (52.5%) reported never using the daily screening tool, while only 11% reported always using it. There were no significant differences in tool usage when comparing Fall and Spring semesters (p = 0.601). The COVID daily screening tool was sent out via text message and email. Students were polled to find their preferred medium, with most students preferring texts (46.5%) followed by email (37.5%).

Universities were also tasked with making sure student learning was not greatly affected by shutdowns or transitions to remote learning during times of outbreak. Interestingly, 67% of ECU students felt their overall learning experience during COVID-19 was either greatly reduced or somewhat reduced (Figure 5.2). While most classes during the Spring semester were online, Fall saw the pivot to more traditional face-to-face learning for most classes. Results showed that the differences between Fall and Spring semesters with regards to perceptions of learning experience were not significant (p = 0.780). Another objective was to determine whether students had difficulty transitioning from online learning to face-to-face during Fall semester. All students reported some difficulties in the transition, with 62.5% reporting the transition was extremely difficult. This falls in line with other studies that saw difficulties in transitioning to online platforms. One such study cited students as having increased stress and anxiety, difficulties concentrating along with technological and instructional challenges in the transition to online learning (Lemay et al., 2021). These challenges may indeed have impacted students here, particularly technological as East Carolina University has a large population from rural areas.

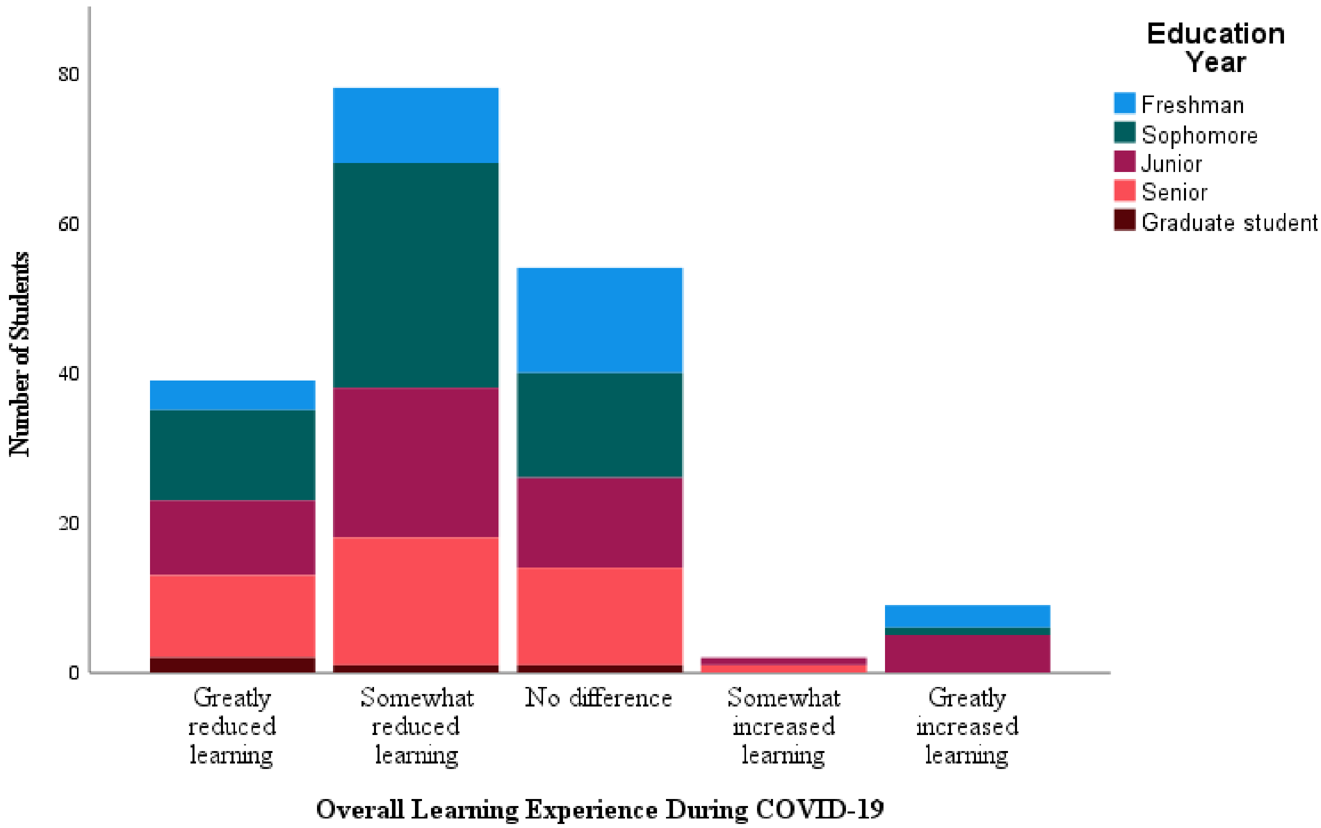


Figure 5.2. Overall learning experience during COVID-19 pandemic by education year.

Learning is a crucial part of student experience on college campuses, however social interactions and experience also play a role in student collegiate life. Overall, student responses showed most (80.8%) felt COVID-19 either greatly or somewhat affected their social activity. Students indicated that their overall social experience was better during the Fall relative to Spring semesters and the differences were statistically significant ($p = 0.005$), with 27.3% of Fall students compared to 50.6% of Spring semester students reporting “greatly reduced social activity”. Hence, students felt better socially (i.e., visiting, going out, being around people, etc.,) during the Fall semester (Table 5.10).

Table 10. Perception of the Effects of COVID-19 on the Spring 2021 and Fall 2021 Semesters

		Semester		
Social Activity		Spring	Fall	Total
	Greatly Reduced	42	27	69
	Somewhat reduced	26	49	78
	No Difference	12	23	35
	Total	83	99	182

Discussion

Viral outbreaks often have effects on daily activities. Thus, routine activities may be influenced by perceptions and beliefs. The perceptions and beliefs among ECU students concerning the COVID-19 outbreak and whether their feelings differed between the Spring and Fall 2021 semesters were evaluated. Most students were concerned about the COVID-19 pandemic, while also feeling it to be very transmissible. The pandemic did not have a large overall effect on student's perception of safety on campus as most students felt safe throughout both semesters. Overall, most students felt the vaccine had some level of safety and would take it. However, 30% of respondents during the Spring semester reported they felt the vaccine was "not safe and would not take it". This may have been due to the origination of the vaccine during the Spring and the confusion over vaccine information (e.g., number of doses, potential side effects, etc.,). Additionally, students may have been concerned with the quickness in which the vaccine was developed, accepted, and dispersed to the general population. A 2020 study by Lucia et al., highlighted a survey showing vaccine hesitancy among medical students (Lucia et al., 2020). Another recent study on vaccine hesitancy highlighted vaccine acceptance rates of 77.6% for COVID-19 vaccine among general population along with an acceptance rate of 69% for the influenza vaccine among the general population (Troiana and Nardi, 2021). Interestingly, respondents noted some of the same reasons for hesitancy as students in our study such as safety, vaccine produced to quickly, and lack of trust.

Another objective was to determine if student behaviors differed between semesters as the pandemic continued. Behavioral guidance was issued to help stem virus spread which included mask wearing and discouraging large gatherings. Differences in mask wearing were observed between Spring and Fall semesters with more persons reporting never wearing a mask during the Fall semester when having visitors or when out visiting. Significant differences between semesters were observed as more students reported gathering in groups of 5+ persons during the Fall. This may have been attributed to multiple factors. By the Fall semester, vaccines were readily available and at the beginning of the semester many students, faculty, and staff had obtained vaccinations. Thus, students may have felt a sense of "herd immunity" and safer being in large groups. Additionally, many persons began to feel COVID burnout or fatigue as the pandemic continued on. Many people tired of restrictions and the feeling of helplessness (Anthony 2021). It has been observed many persons, particularly those in healthcare experienced fatigue and burnout (Blake et al., 2020). This may have been experienced among students also and impacted behaviors and resulted in reduced caution among students.

The COVID-19 pandemic caused many schools and businesses to shut down and limit occupancy and activity in their buildings. Many campuses switched to online learning to help stem the spread of the virus while still allowing students to take needed classes. While this solution allowed students to continue their educational goals, it was important for universities to determine whether these changes had any effects on their student populations. Changes in educational delivery mechanisms attributed to COVID-19 may have affected students learning. Results from this survey showed 67% of students felt their learning was either somewhat or greatly reduced due to COVID-19. A survey conducted among 800 Polish medical students, showed while many felt online learning was enjoyable, they felt e-learning or online learning was statistically (p <0.001) less effective than traditional learning (Baczek et al., 2021). This appeared to be similar to students surveyed here, feeling they experienced a reduction in learning while using the online platform.

As universities sought to help students with these changes and perceived impacts on learning, there was an emphasis on reopening and resuming normal (face-to-face) classes. Part of this road to "normalcy" was an emphasis on students receiving vaccinations. Significant differences between semesters on the perceived safety of vaccines was observed. Students during the Fall semester had more positive perceptions and were more willing to take the vaccine. This may have been attributed to the fact that by the Fall semester, vaccination rollouts had been going on for numerous months and students were able to observe vaccine effects. Another reason that the perception of the vaccine may have changed could be that students were ready to return to campus. This change in perception may have aided in the University's 74% achieved vaccination rate among on-campus students. As vaccines were heavily suggested, students may have felt they were safer. Universities, such as ECU, implemented tools such as COVID daily screening tools to help students determine the safety of coming to campus and/or to class. While these tools were disseminated via the preferred platforms of use by students: texts (46.5%) and emails (37.5%), over half of students surveyed reported never using the tool. Usage of the tool was low during each semester. It's possible that students did not use the tool because they felt they had been given proper guidance on protocols to take to help stem the virus. Students s reported they felt ECU had given them proper guidance during the pandemic. Thus, it's possible students felt that if they followed this guidance there was no reason to use the daily screening tool and that the tool was functioning as a redundancy.

Surveys may be instrumental in helping colleges and universities learn of student perceptions to issues. Knowing how students perceive the severity of a pandemic may play a role in helping to ensure continuity of education for students. This knowledge may also be useful when determining what delivery methods will be most effective. If universities are using instruments such as voluntary daily screening tools to help monitor potential COVID-19 cases, it's possible cases may be missed by lack of participation. If universities are aware of student perceptions, they may be able to develop guidance based on these perceptions perhaps influencing students' acceptance on protocol.

Chapter VI: Conclusion, Management Implications, and Competencies Addressed

Pandemics have occurred throughout human history. However, the way pandemics have been monitored and managed has improved over the years in response to emerging methodological and technological innovations. Recently, the world experienced the COVID-19 pandemic born from the spread of SARS-CoV-2. Many businesses were forced to shut down or drastically alter their modes of operation. Schools and universities were not spared from this phenomenon as many were forced to pivot for a period to online learning. As universities sought a return to traditional classrooms, they needed a way to monitor the spread of the virus. Wastewater surveillance was evaluated to identify locations for student testing in an effort to reduce outbreaks. Increases in COVID-19 cases occurred approximately 60% - 70% of the time within 5 – 7 days following an increase in SARS-CoV-2 concentration in wastewater. This indicates wastewater-based epidemiology may be effective at pinpointing dormitories where additional student testing (i.e., PCR) may be needed. The ability to identify dormitories with increased concentrations of SARS-CoV-2 in wastewater may help universities save funding on supplies and testing by focusing swarm testing on specific dormitories. Also, it is known that viral shedding may occur prior to symptoms, thus detecting noticeable rises in wastewater may serve as an early warning system of a potential impending outbreak. In settings where persons are often in close quarters, the ability to alert people of the virus in their area may prompt at-risk persons to get tested and those that test positive can be removed from the environment slowing the spread of disease.

While surveillance tools are necessary in monitoring disease spread, other tools are important in stemming outbreaks. The use of COVID-19 vaccines may have helped the university avoid widespread outbreaks. A significant inverse relationship between increasing vaccination rates and COVID-19 cases was observed on ECU’s campus, suggesting the vaccine was successful in helping reduce the spread of the disease on campus. An inverse relationship was also noticed when comparing vaccination rates to SARS-CoV-2 concentrations in wastewater. Knowledge of areas and locations that have high vaccination rates, may allow officials to focus specific surveillance efforts. If an area has a vaccination rate (potentially considered high enough to aid in herd immunity), public health officials may decide these areas need minimal surveillance and resources may be directed to areas with lower vaccination rates and thus more susceptible to disease transmission. Additionally, these resources and funds could be put towards other mitigation strategies such as pamphlets, notifications, or disseminating information on how to stay safe.

Identifying areas with relatively high concentrations of SARS-CoV-2 in wastewater may also allow officials to inquire about the attitudes and actions demonstrated by people living in those areas that are contributing to the prevalence of the disease. Students were surveyed to determine their attitudes and beliefs concerning COVID-19. There were significant differences in some beliefs and behaviors between Spring and Fall semesters. Specifically, during the Spring relative to the Fall semester, a significantly larger percentage of students did not feel safe taking the vaccine. This may have contributed to the University having a relatively high vaccination rate in the Fall, possibility leading to lower SAR-CoV-2 obtained in wastewater and fewer student cases. The use of surveys may help institutions better understand the reasons that vaccination rates are lower in certain areas. This knowledge may allow public health officials the opportunity to disseminate information that may help with issues such as vaccine hesitancy. Additionally, behaviors were evaluated in the survey which may also have an impact on disease spread. More students during the Spring in comparison to the Fall were wary of congregating in large groups. By Fall, students were more relaxed and fewer responded that they avoided being in large groups.

Management Implications

This study highlights the usefulness of wastewater-based surveillance, vaccines, and surveys during a recent pandemic on a university campus. Utilization of these tools may be aid universities in mitigating outbreaks and controlling the transmission of disease. As diseases continue to spread and reemerge it is important for public health officials to formulate informed, data-based approaches that may be used in disease mitigation.

Here, we showed a significant positive correlation between virus copies in wastewater and the number of student cases (R^2= 0.642, p = 0.002). Knowledge of data such as this may allow universities and school systems to make adjustments to scheduling, initiate additional testing, and plan for potential outbreaks. Additionally, other universities have shown usefulness of WBE in their fight to mitigate the virus. Wastewater surveillance the University of Arizona couple with clinical testing resulted showed accurate diagnosis for new cases (82.0% positive predicative value, 88.9% negative predicative value) (Betancourt et al., 2021). Studies such as this show sensitivity of WBE as an epidemiological tool. Wastewater analysis at University of North Carolina Charlotte credited WBE in identifying asymptomatic persons residing in dormitories (Gibas et al., 2021). The tool has been used to identify cases early, with is paramount to stemming public health outbreaks. Indeed, WBE at University of California San Diego resulted in early diagnosis of 85% of all COVID-19 cases (Smruthi et al., 2021).

Many trends in cases and virus concentrations seen on campus were also seen in the greater community. During the same time frame as ECU's wastewater sampling, the City of Greenville was also sampling its wastewater for COVID-19. Officials at East Carolina University saw similar wastewater trends in sampling conducted by the city of Greenville. While the magnitude of wastewater flow and viral concentrations were different between the City of Greenville and ECU, both reported large increases in SARS-CoV-2 concentrations in wastewater after the start of the Spring and Fall semesters during February and September (Figure 1.3A, Figure 1.3B). Additionally, there were similarities during specific time points that typically saw large gatherings such as Labor Day. Thus, alluding to its usefulness outside of a school setting and its ability to be used as an alert to what may be going on in the larger community.

Additionally, survey results indicate the need for public health officials to know how and what their communities think and feel about certain issues. This may have a profound effect on compliance with mitigation strategies such as vaccines. Knowledge here may allow public health officials to properly target populations with the correct information and understand concerns that may hinder healthcare. As seen with HIV surveys, information gathered from a representative sample of the population may inform public health officials of concerning behaviors that may exacerbated outbreaks and thus allow a more targeted approach. It may also guide community-based outreach by having officials work with those who live in the community and have trust to help disseminate information and keep people safe.

Competencies Addressed

Design a qualitative, quantitative, mixed methods, policy analysis or evaluation project to address a public health issue

This competency was addressed using wastewater as a surveillance system for the current COVID-19 outbreak. Wastewater was procured, analyzed and presence of viral copies was used as a measure of prevalence of SARS-CoV-2 on the campus of East Carolina University. These data provide important information that allow the University to identify dormitories with elevated viral copies in wastewater. Dormitories with elevated viral copies can be indicative of the formation of clusters or transmission of disease. By identifying dormitories with elevated copies, university officials can mobilize public health interventions (i.e., swarm testing, quarantine and isolation, contact tracing) to safeguard community health. These interventions are designed to reduce or prevent spread of COVID-19, thereby mitigating incidence of new cases. Results from this study are salient to the ongoing COVID-19 pandemic but can also be applicable to future efforts in surveilling pathogenic microbes, especially those that have potential to result in epidemics or pandemics.

Explain the use and limitations of surveillance systems and national surveys in assessing, monitoring and evaluating policies and programs and to address a population's health

Results obtained from dormitory surveillance will be compared to campus COVID-19 rates and evaluated for effectiveness. Past research has shown wastewater-based surveillance to be an effective tool for epidemiological programs for microbes (Rezaeinejad et al., 2014; Hellmér et al., 2014). The efficacy of East Carolina University's wastewater-based epidemiology program will be evaluated and compared to other university programs and those developed to surveil other pathogenic microbes. Information obtained from literature reviews and/or public dashboards will be used to address surveillance and survey limitations in addressing a public health outbreak. This information will be compared with the ECU program and public health recommendations for future epidemiological programs will be developed.

Integrate knowledge, approaches, methods, values and potential contributions from multiple professions and systems in addressing public health problems

ECU's wastewater-based epidemiological program for SARS-CoV-2 consisted of an interdisciplinary team, which included project contributions from Student Health Services, the Department of Health Education and Promotion, the Department of Pathology, Facilities Services, the Dean of Students, Campus Living, Environmental Health & Safety, and Research Economic Development and Engagement. This dissertation committee consists of representatives from the Department of Health Education & Promotion, Student Health Services, and the Department of Pathology. The composition of this committee was developed to integrate expertise from multiple educational backgrounds to collect, analyze, and evaluate public health data on SARS-CoV-2 to mitigate spread of COVID-19 at East Carolina University.

Environmental and Occupational Health Competencies

Apply the components and functions of conventional and advanced wastewater systems and stormwater treatment technologies and agriculture best management practices

Understanding the functionality of municipal wastewater treatment was necessary in executing this project. The sewer network on campus was assessed to identify locations where researchers could isolate wastewater from only one dormitory could be collected. Wastewater from student dormitory using autosamplers and collected as a daily composite sample to analyze for the presence of SARS-CoV-19 among the on-campus student population. It was vital to locate sewer access points that would allow researchers to intercept wastewater from only one dormitory. Without this information, university officials would not be able to identify dormitories with elevated SARS-CoV-2 copies, which would complicate public health interventions and threaten success of the epidemiological program.

Interpret results of data analysis for public health research and policy.

This dissertation involves data analysis and interpretation of microbiological and social data. Concentrations of SARS-CoV-2 was quantified for all dorms where students resided in for the Spring 2021 and Fall 2021 semesters. Rapid processing and interpretation of these results was paramount to guide public health interventions on ECU's campus. Furthermore, additional processing and interpretation is necessary to evaluate and determine the practicality of wastewater-based surveillance on college and university campuses to monitor disease outbreaks. Results may help determine sampling frequencies and when or where laboratory-based testing should occur. Furthermore, a survey tool was developed and distributed to students in Spring 2021 and Fall 2021 to assess their beliefs and practices during a public health crisis. These data provide insight into the efficacy of other public health recommendations (e.g., masking, hand-washing practices, social distancing, etc.), which can be used to guide public health and safety messages focused on reaching university students.

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Appendix A

IRB Approval Letter

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board
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600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** ·
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Notification of Exempt Certification

From: Social/Behavioral IRB
To: Avian White
CC:
Date: 2/15/2021
Re: UMCIRB 21-000186
Review of student beliefs and behavioral practices during the COVID-19 pandemic at East Carolina University

I am pleased to inform you that your research submission has been certified as exempt on 2/12/2021. This study is eligible for Exempt Certification under category # 2c.

It is your responsibility to ensure that this research is conducted in the manner reported in your application and/or protocol, as well as being consistent with the ethical principles of the Belmont Report and your profession.

This research study does not require any additional interaction with the UMCIRB unless there are proposed changes to this study. Any change, prior to implementing that change, must be submitted to the UMCIRB for review and approval. The UMCIRB will determine if the change impacts the eligibility of the research for exempt status. If more substantive review is required, you will be notified within five business days.

Document	Description
Consent For for Expedited Survey(0.01)	Consent Forms
COVID-19 Belief and Practices among College Students at ECU(0.02)	Surveys and Questionnaires
Review of student beliefs and behavioral practices during the COVID-19 pandemic at East Carolina University (0.01)	Study Protocol or Grant Application
Survey Script for class(0.02)	Recruitment Documents/Scripts

For research studies where a waiver or alteration of HIPAA Authorization has been approved, the IRB states that each of the waiver criteria in 45 CFR 164.512(i)(1)(i)(A) and (2)(i) through (v) have been met. Additionally, the elements of PHI to be collected as described in items 1 and 2 of the Application for Waiver of Authorization have been determined to be the minimal necessary for the specified research.

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

IRB00000705 East Carolina U IRB #1 (Biomedical) IORG0000418
IRB00003781 East Carolina U IRB #2 (Behavioral/SS) IORG0000418

Appendix B

Figures

**The first number in the figure caption denotes the respective chapter, followed by the figure number within the chapter* —

Chapter III

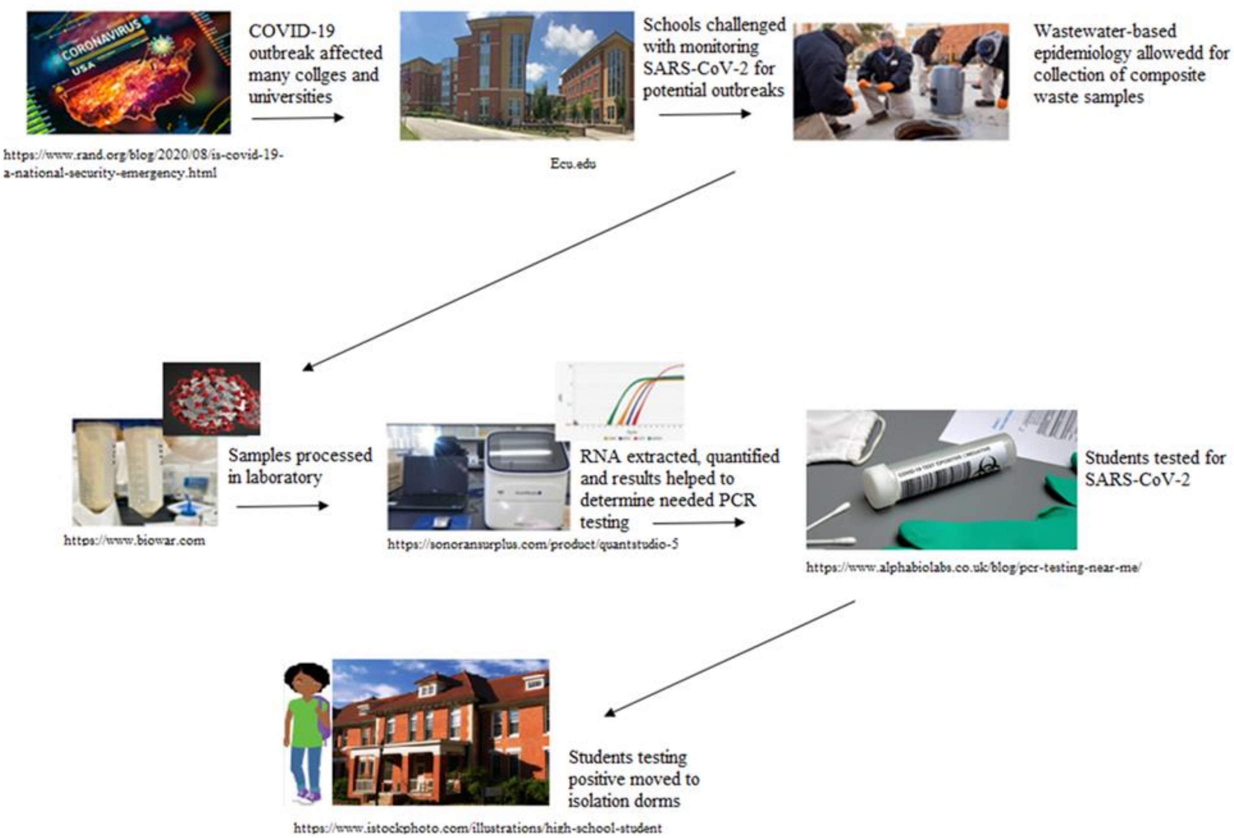


Figure 3.1 Flow Diagram of Wastewater -Bases Epidemiology on Campus of East Carolina University

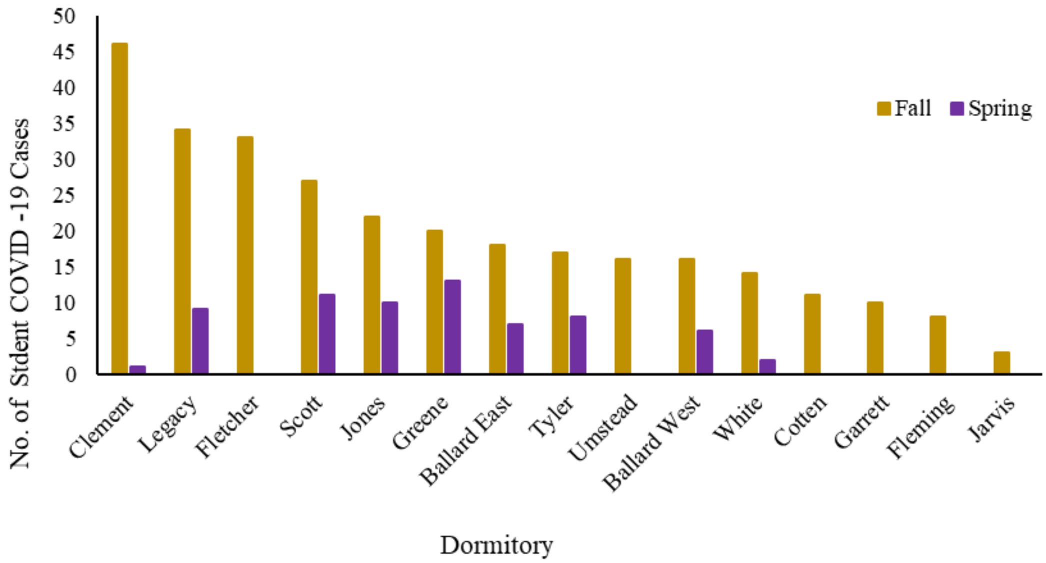


Figure 3.2. Total Number of Student COVID-19 Cases Per Dorm During the Spring and Fall 2021 Semester2

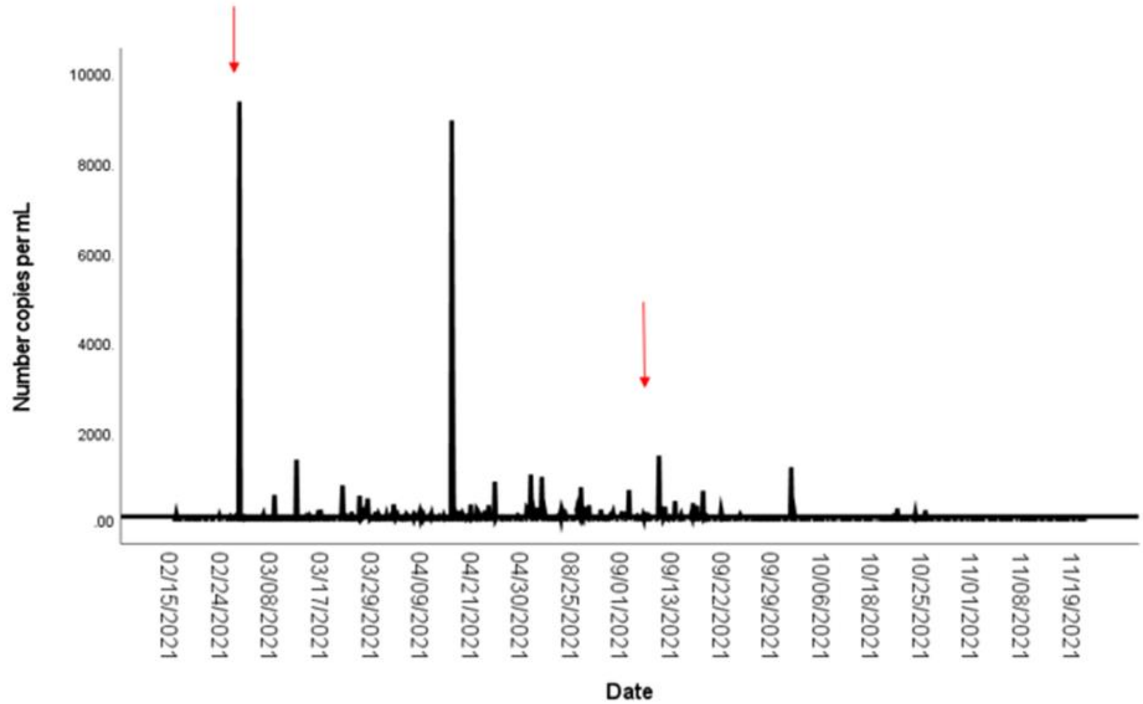


Figure 3.3A. SARS-CoV-2 in Dormitory Wastewater Samples Collected Throughout the Spring 2021 and Fall 2021 Semesters. Red arrows denote times where the City of Greenville also saw noticeable increases in COVID-19 virus in wastewater.

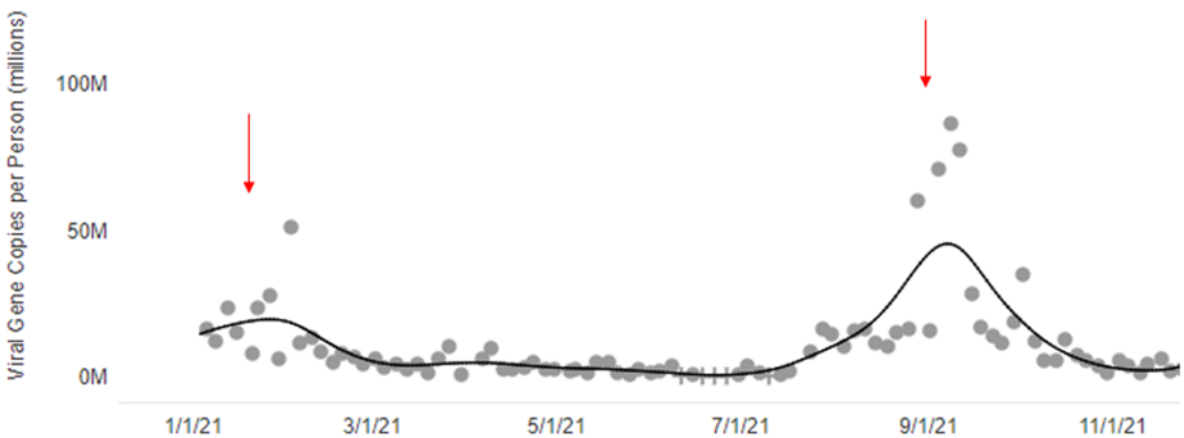


Figure 3.3B. SARS-CoV-2 in Wastewater Samples for the City of Greenville During the 2021 Year. Figure obtained from the NCDHHS wastewater sampling dashboard (NCDHHS, 2022). Red arrows denote times where the City of Greenville also saw noticeable increases in COVID-19 virus in wastewater

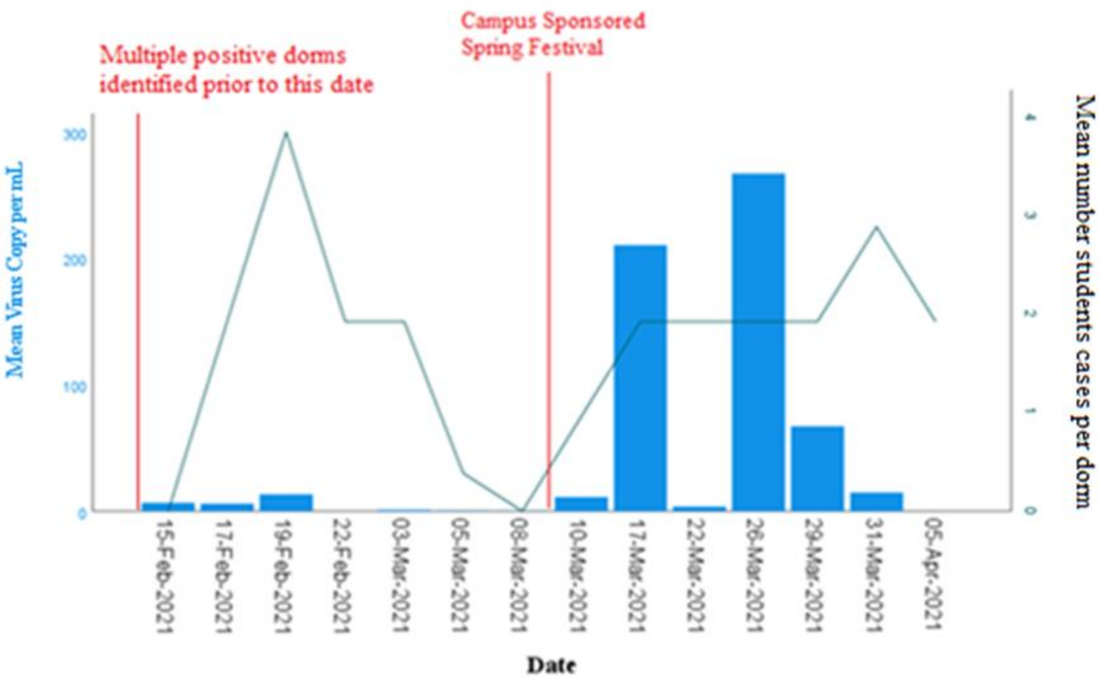


Figure 3.4. Time-lapse of Mean SARS-CoV-2 Virus Copy per mL Extracted from Wastewater and Students COVID-19 Cases in Dormitories During Spring Semester. Bars represent mean virus copy per mL and lines represent student cases.

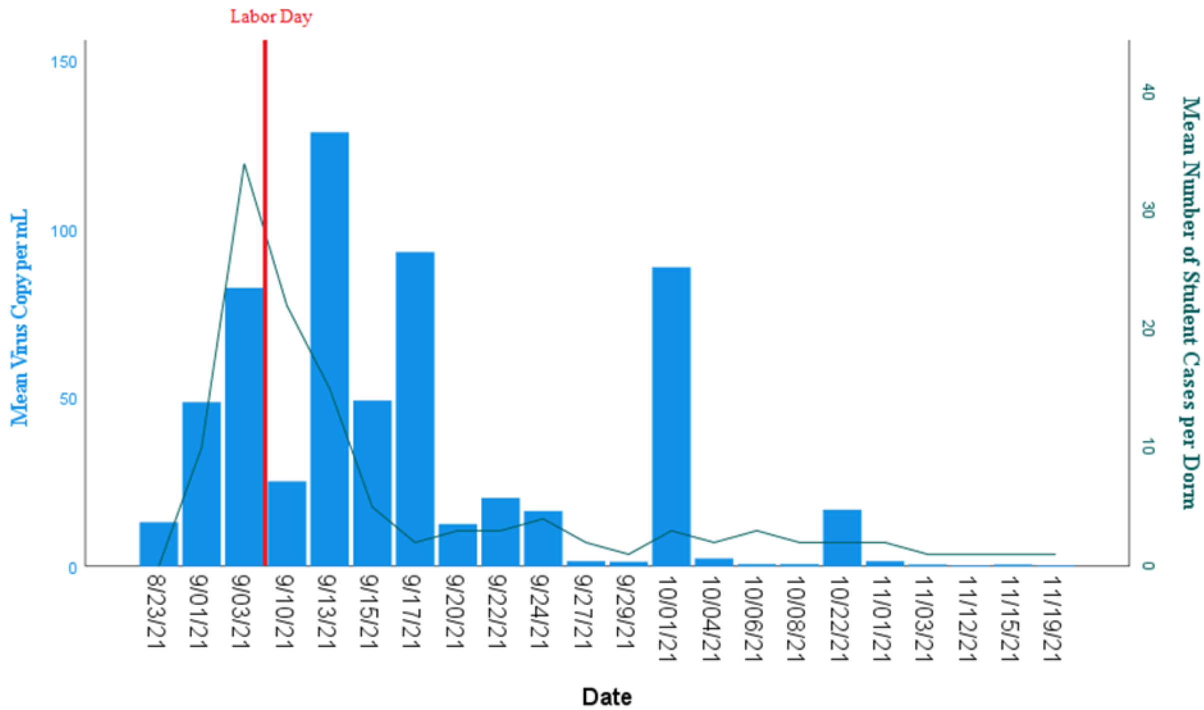


Figure 3.5. Time-lapse of Mean SARS-CoV-2 Virus Copy per mL Extracted from Wastewater and Students COVID-19 Cases in Dormitories During Fall Semester. Bars represent mean virus copy per mL and lines represent student cases

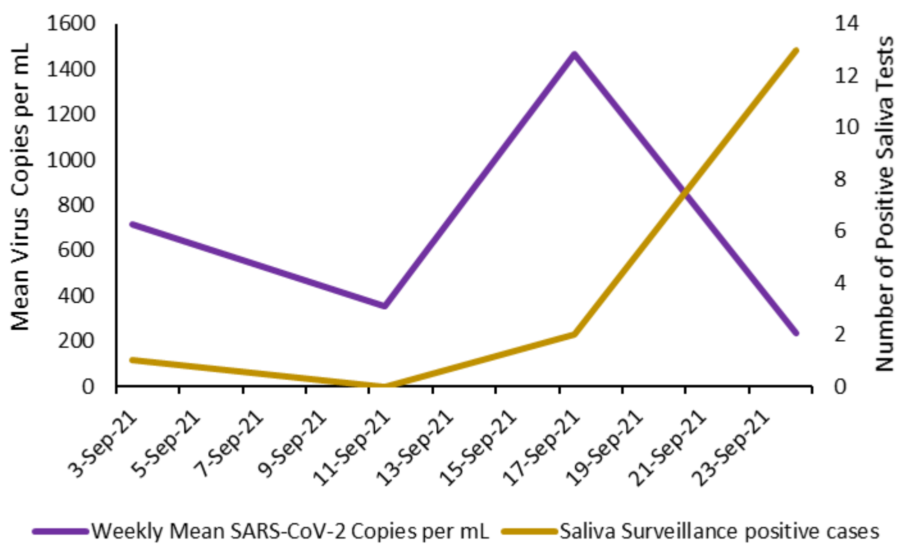


Figure 3.6. Positive Saliva Surveillance Samples compared to mean SARS-CoV-2 copies per mL obtained from wastewater.

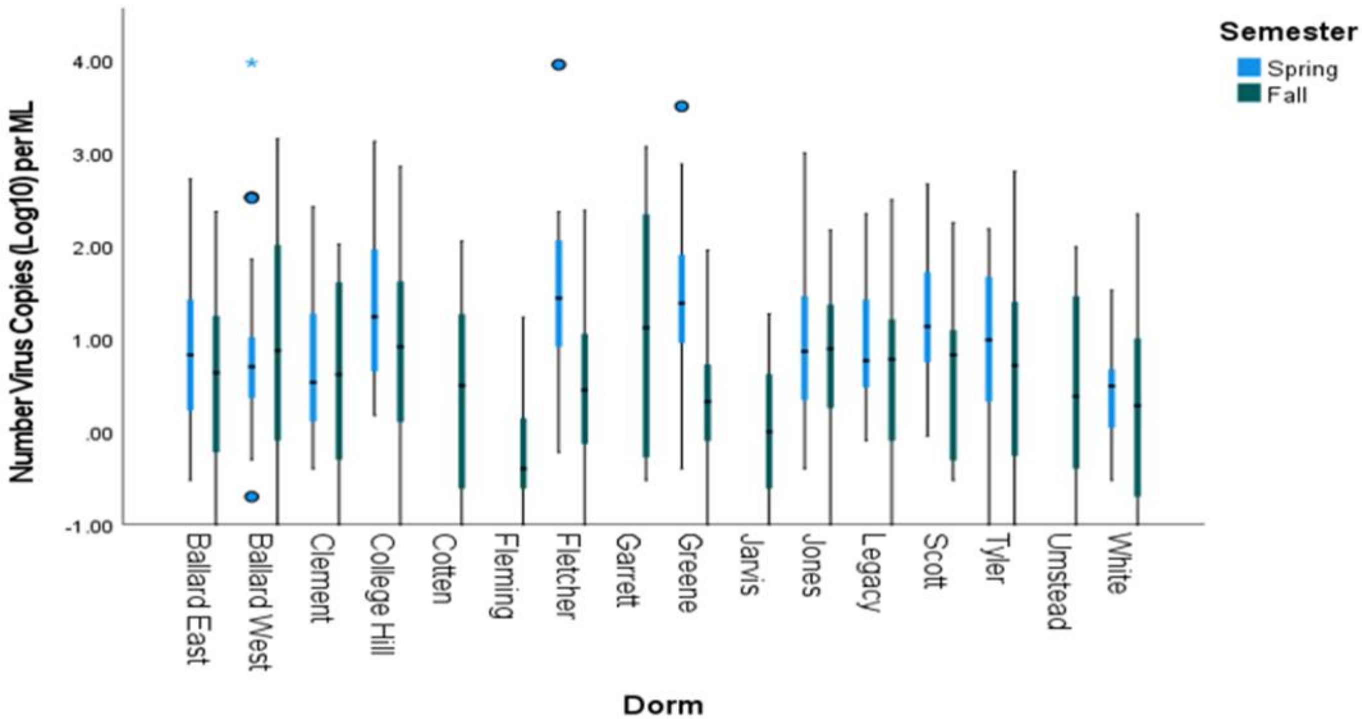


Figure 4.1. Mean SARS-CoV-2 copies per mL Detected in Wastewater by Dormitory During Spring and Fall Semesters. During Spring 2021, not all dormitories were open for student living. Data was log10 transformed4

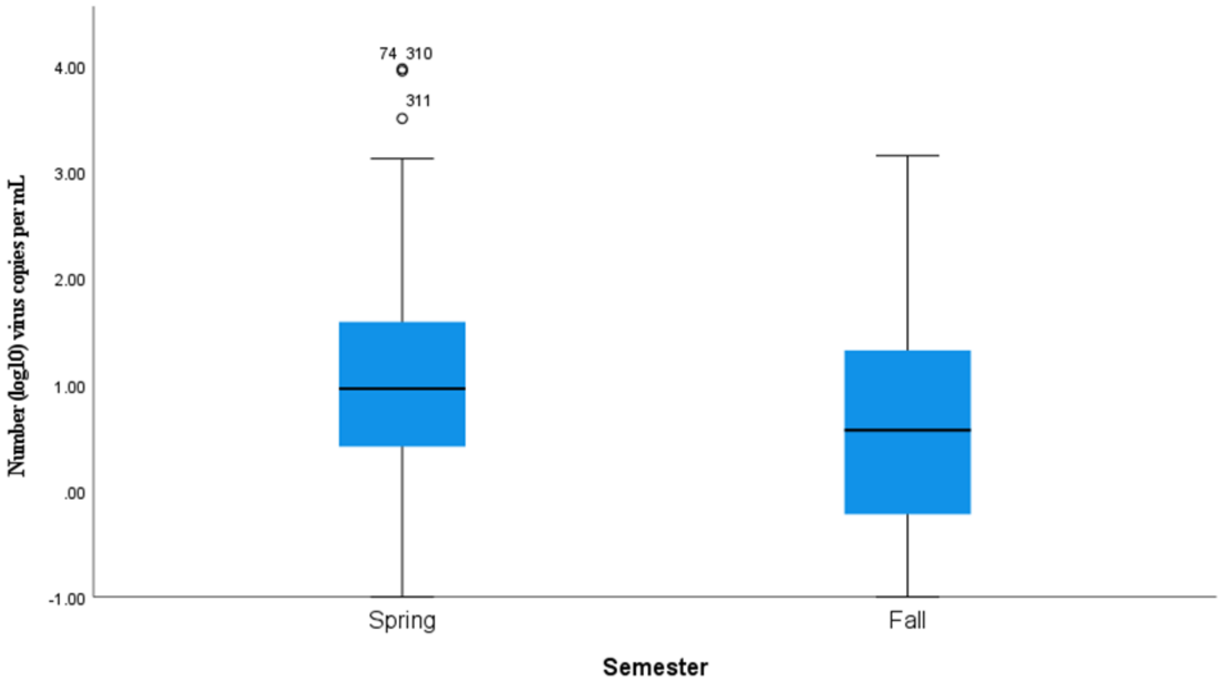


Figure 4.2. Number of SARS-CoV-2 Copies per ml for 2021 Spring and Fall Semester

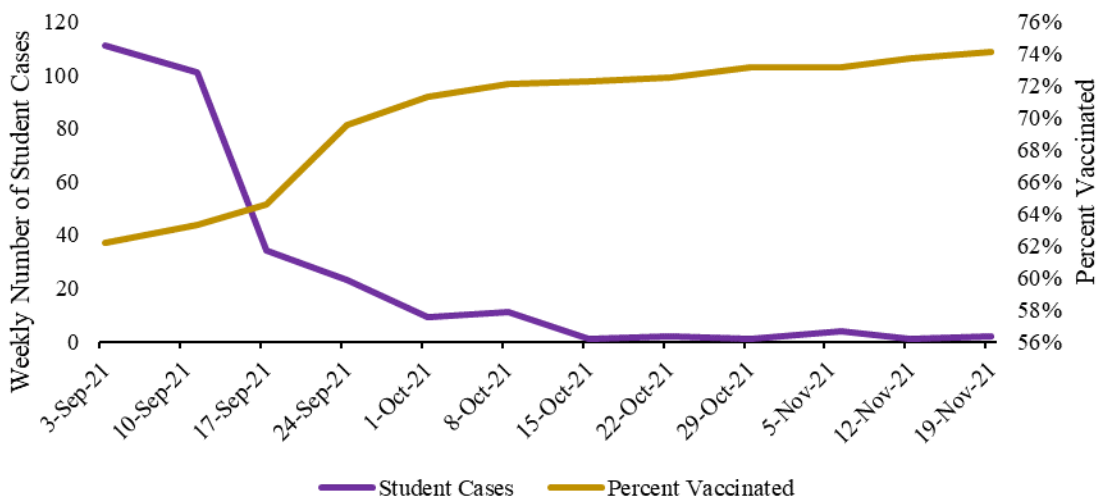


Figure 4.3. COVID-19 Cases among students living dormitories compared to percent of students vaccinated between 03 September 2021 and 19 November 2021.

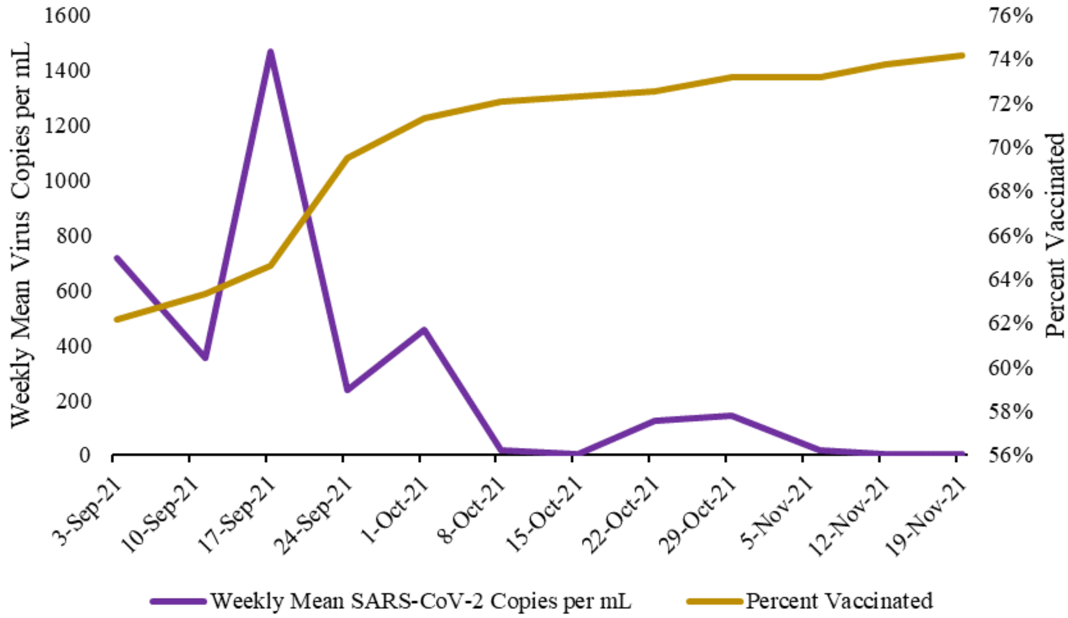
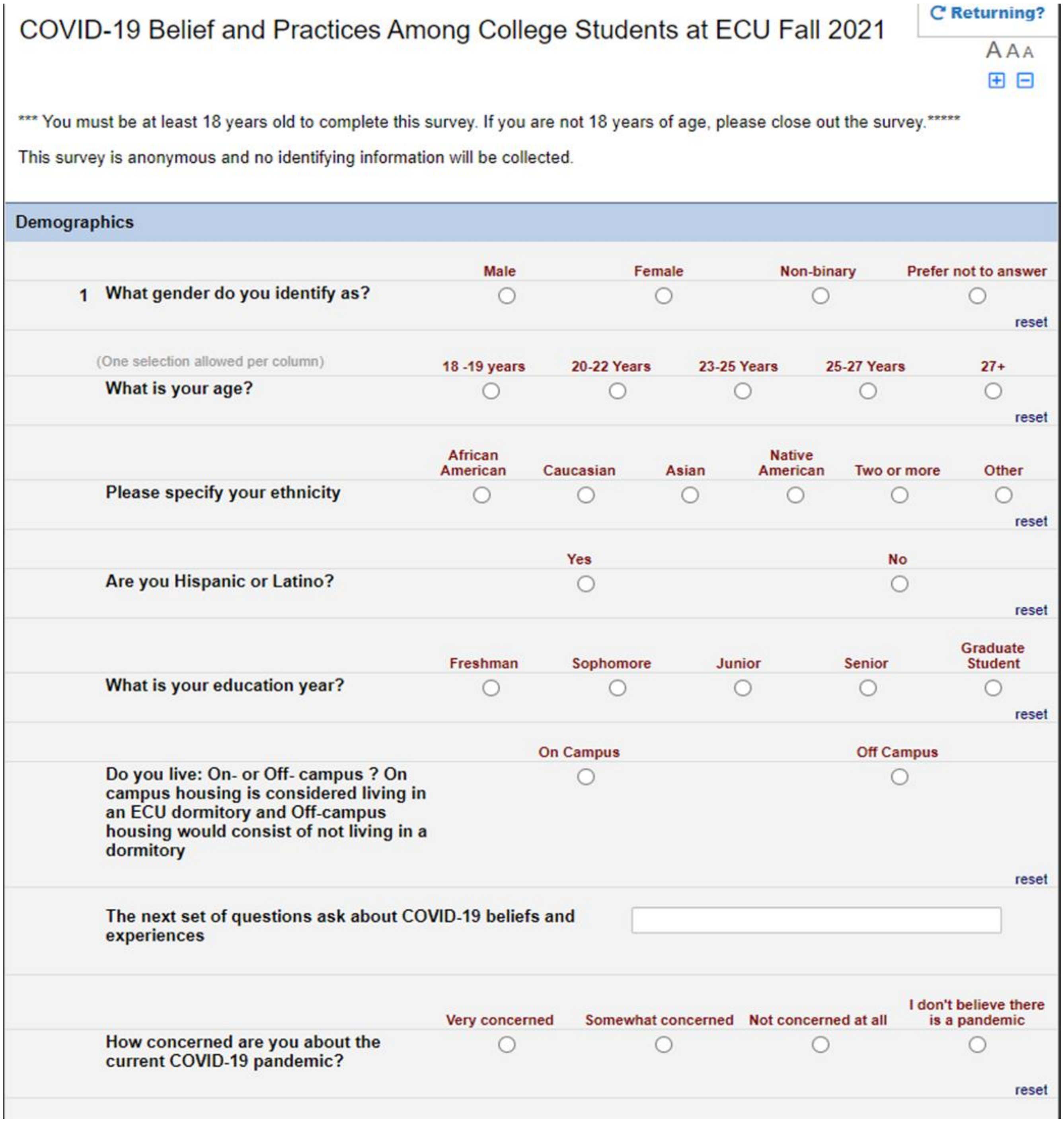


Figure 4.4. COVID-19 Weekly mean SARS virus copies obtained from students living dormitories compared to percent of students vaccinated between 03 September 2021 and 19 November 20215



COVID-19 Belief and Practices Among College Students at ECU Fall 2021

Returning?

AAA

*** You must be at least 18 years old to complete this survey. If you are not 18 years of age, please close out the survey.*****

This survey is anonymous and no identifying information will be collected.

Demographics

	Male	Female	Non-binary	Prefer not to answer
1 What gender do you identify as?	○	○	○	○

reset

(One selection allowed per column)

	18 -19 years	20-22 Years	23-25 Years	25-27 Years	27+
What is your age?	○	○	○	○	○

reset

	African American	Caucasian	Asian	Native American	Two or more	Other
Please specify your ethnicity	○	○	○	○	○	○

reset

	Yes	No
Are you Hispanic or Latino?	○	○

reset

	Freshman	Sophomore	Junior	Senior	Graduate Student
What is your education year?	○	○	○	○	○

reset

	On Campus	Off Campus
Do you live: On- or Off- campus ? On campus housing is considered living in an ECU dormitory and Off-campus housing would consist of not living in a dormitory	○	○

reset

The next set of questions ask about COVID-19 beliefs and experiences

	Very concerned	Somewhat concerned	Not concerned at all	I don't believe there is a pandemic
How concerned are you about the current COVID-19 pandemic?	○	○	○	○

reset

Figure 5.1A. Shows some of the questions included on the survey on COVID-19 Beliefs and Practices disseminated to students during Spring and Fall Semester 2021

How would you characterize the transmissibility of COVID-19?	○	○	○	○

reset

	Yes	No
Have you ever been diagnosed with COVID-19?	○	○

reset

	Yes	No
Do you know anyone who has been diagnosed with COVID-19?	○	○

reset

	Yes	No
Do you know anyone who has died as a result of COVID-19?	○	○

reset

	Yes	No	I was not going to live on-campus regardless of COVID-19
Did COVID-19 concerns and/or regulations affect your ability to stay on campus?	○	○	○

reset

(One selection allowed per column)	Yes	No	Not applicable
Do you feel safe staying on campus during the pandemic?	○	○	○

reset

	Yes, very safe in taking it	A little safe, but would still take it	Not safe, but would still take it	Not safe and would not take it
Do you feel safe taking the COVID-19 vaccine?	○	○	○	○

reset

Are you currently vaccinated? This survey is anonymous and your vaccination status will not be reported to anyone. This is strictly for informational purposes only.

○ Yes
○ No
○ Prefer not to answer

reset

	Yes	No	Unsure
Would you consider yourself an "anti-vaxxer" (someone who is opposed to vaccination)?	○	○	○

reset

Figure 5.1B. Shows some of the questions included on the survey on COVID-19 Beliefs and Practices disseminated to students during Spring and Fall Semester 2021

	Always	Most of the time	Sometimes	Never
Do you wear a mask when you have visitors?	○	○	○	○

reset

	Always	Most of the time	Sometimes	Never
When you have visitors, do you follow recommendations to distance 6- feet apart?	○	○	○	○

reset

	Yes	No
Do you allow visitors to use the restroom when they are in your residence?	○	○

reset

	Daily	Only after I have visitors	Twice a week	Weekly	Bi-weekly
How often do you clean high touch areas (e.g. door knobs, light switches, faucets, etc.)	○	○	○	○	○

reset

	Daily	Weekly	Bi-Weekly	Monthly	I don't congregate in groups of 5 or more persons
Aside from work or class, how often are you in groups of 5 persons or more? This may include study groups, parties, small get-togethers.	○	○	○	○	○

reset

	Yes	No
Do you work at a job where you have to face customers (e.g. restaurant, retail, childcare)?	○	○

reset

	Yes	No
Have the potential exposure risks you have at your job increased the safety precautions (i.e. washing hands, changing out masks) you take before returning to your place of residence?	○	○

Figure 5.1C. Shows some of the questions included on the survey on COVID-19 Beliefs and Practices disseminated to students during Spring and Fall Semester 2021

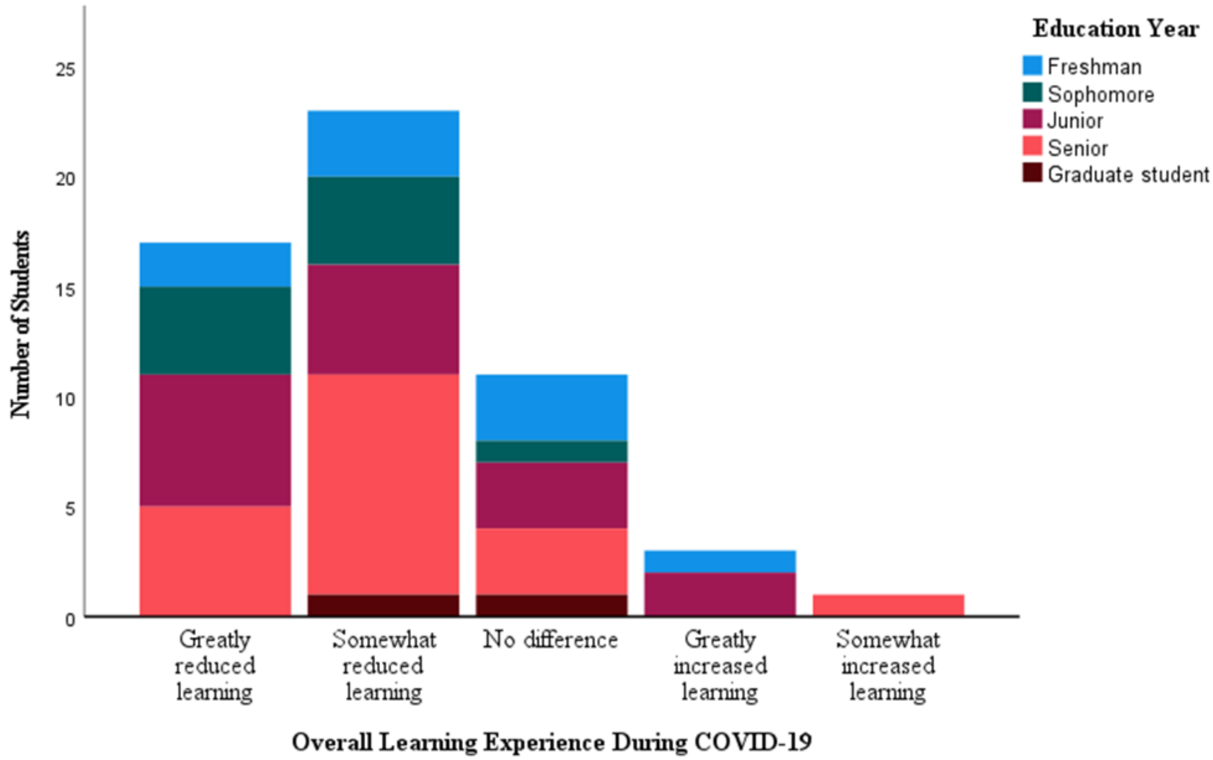


Figure 5.2. Figure 2. Overall learning experience during COVID-19 pandemic by education year

Tables

**The first number in the figure caption denotes the respective chapter, followed by the figure number within the chapter*

Chapter III

Table 3.1. COVID Incidence Rates for Sampled Dormitories Between 15 February 2021 and 01 May.

Dormitory	February Covid %	March Covid %	April Covid%	Semester Covid %
Greene	4%	3%	0%	7%
Scott	1%	3%	0%	4%
Jones	1%	4%	1%	5%
Legacy	1%	3%	2%	5%
Tyler	0%	3%	0%	4%
Ballard East	1%	3%	1%	4%
Ballard West	0%	3%	1%	3%
White	0%	1%	0%	1%
Clement	0%	0%	0%	1%

Table 3.2. COVID Incidence Rates for sampled Dormitories Between 30 August 2021 and 19 November 2021

Dormitory	September Covid %	October Covid %	November Covid%	Semester Covid %
Clement	12%	0%	0%	12%
Legacy	7%	0%	0%	8%
Fletcher	8%	0%	0%	8%
Scott	4%	0%	0%	5%
Jones	4%	1%	0%	6%
Greene	5%	0%	0%	5%
Ballard East	4%	1%	1%	5%
Tyler	4%	0%	0%	4%
Umstead	9%	0%	0%	9%
Ballard West	4%	0%	0%	4%
White	4%	0%	0%	4%
Cotten	5%	0%	0%	5%
Garrett	3%	0%	0%	4%
Fleming	5%	0%	0%	5%
Jarvis	3%	0%	0%	3%

Chapter V

Table 5.1A. Demographic Data from Student Spring 2021 COVID Attitude, Beliefs, and Practices Survey

Gender		n	%
	Male	22	21.6
	Female	79	77.5
	Prefer not to answer	1	1
Race			
	African-American	15	14.7
	Caucasian	66	64.7
	Asian	8	7.8
	2 or More	6	5.9
	Other	7	6.9
Ethnicity			
	Hispanic or Latino	6	5.9
	Not Hispanic of Latino	96	94.1

Table 5.1B. Demographic Data from Student Fall 2021 COVID Attitude, Beliefs, and Practices Survey

Gender		n	%
	Male	23	23.2
	Female	74	74.7
	Non-Binary	2	2
Race			
	African-American	17	17.2
	Caucasian	68	68.7
	Asian	3	3
	Native American	1	1
	2 or More	1	1
	Other	9	9.1
Ethnicity			
	Hispanic or Latino	15	15.2
	Not Hispanic of Latino	84	84.8

Table 5.2A. Demographic breakdown of ECU student population for Fall 2021 compared to survey demographics

Race	ECU %	Survey %
African-American or Black	16.7	16
Caucasian	63.8	66.7
Hispanic	8	10.5
Asian	2.8	5.5
Other	8.7	8.5

Table 5.2B. Gender breakdown of ECU student population for Fall 2021 compared to survey demographics

Gender	ECU %	Survey %
Male	41	22.4
Female	59	76.1

Table 5.3. Student Concern about the COVID-19 Pandemic During Spring and Fall 2021 Semester

Semester	Very concerned	Somewhat concerned	Not concerned at all	I don't believe there is a pandemic	Total
Spring	36	47	18	1	102
Fall	30	46	22	0	98
Total	66	93	40	1	200

Table 5.4 . Student Concern about COVID-19 Virus Transmissibility During Spring and Fall 2021 Semester

Semester	Very transmissible	Slightly transmissible	Not very transmissible	Total
Spring	63	36	3	102
Fall	56	38	5	99
Total	119	74	8	201

Table 5.5 . Overall Vaccine Safety Perception by Race

Race	Yes, very safe in taking it	A little safe, but would still take it	Not safe, but would still take it	Not safe, and would not take it	Total
African American	14 (15.2)	8 (16.7)	5 (21.7)	5 (13.2)	32 (15.9)
Caucasian	60 (65.2)	33 (68.8)	16 (69.6)	25 (65.8)	134 (66.7)
Asian	7 (7.6)	2 (4.2)	1 (4.3)	1 (2.6)	11 (5.5)
Native American	0	1 (2.1)	0	0	1 (0.5)
2 or More	3 (3.3)	2 (4.2)	0	2 (5.3)	7 (3.5)
Other	8 (8.7)	2 (4.2)	1 (4.3)	5 (13.2)	16 (8.0)
Total	92	48	23	38	

Table 5.6. Vaccine Safety Perception by Gender

	Yes, very safe in taking it	A little safe, but would still take it	Not safe, but would still take it	Not safe, and would not take it	
Gender					Total
Male	22 (23.9)	4 (8.3)	8 (34.8)	11 (28.9)	45 (22.4)
Female	69 (75)	43 (89.6)	15 (65.2)	26 (68.4)	153 (76.1)
Non-binary	1 (1.1)	1 (2.1)	0	0	2 (1)
Prefer not to answer				1 (2.6)	1 (0.05)
Total	92	48	23	38	201

Table 5.7. Frequency of Visitors

	Frequency Others Visit You			
		Semester		
		Spring	Fall	Total
Visitation Frequency	1-2 Times	43	35	78
	3-4 Times	17	19	36
	5-6 Times	1	11	12
	Daily	5	12	17
	I don't have visitors	35	22	57
	Total	101	99	200

Table 5.8. Reported Mask Wearing Among Students When Having Visitors Compared to their Perceptions on Virus Transmissibility.

	Transmissibility Characterization			
	Very transmissible	Slightly transmissible	Not very transmissible	
Mask Wearing				Total
Always	11	2	0	13
Sometimes	46	25	1	72
Never	34	38	7	79
Most of the time	27	7	0	34
Total	118	72	8	198

Table 5.9. Reported Frequency of Group Gatherings Among Students Compared to their Perceptions on Virus Transmissibility

	Transmissibility Characterization			
Visitation Frequency	Very Transmissible	Slightly Transmissible	Not Very Transmissible	Total
Daily	16	17	1	34
Weekly	36	25	2	63
Bi-weekly	20	13	0	33
Monthly	17	8	0	25
I don't congregate in groups of 5+	29	11	1	41
Total	118	74	8	200

Table 5.10. Perception of the Effects of COVID-19 on the Spring 2021 and Fall 2021 Semesters

Perception of the Effect of COVID-19 on Social Activity During the Spring and Fall 2021 Semesters			
	Semester		
Social Activity	Spring	Fall	Total
Greatly Reduced	42	27	69
Somewhat reduced	26	49	78
No Difference	12	23	35
Total	83	99	182