Response to scientific peer reviews of two modeling reports:

1) Modeling Assessment of Spreading of the Scituate Waste Water Treatment Plant in the North-South Rivers, Massachusetts

2) Estimation of the Sewage Water Dilution from Wastewater Treatment Plants in New Bedford and Fairhaven, Massachusetts

Reviewers were also provided additional related resources from the Chen lab.

Provided by: Massachusetts Division of Marine Fisheries ("DMF")

Select comments and responses from review #1

Major concerns surrounding the treatment of *uncertainty* in the products provided:

Reviewer Comment: How have the authors proposed uncertainty be represented in the analysis product? For example, the model was only run for one year and the maps provided average over significant lengths of time for such a widely varying system. The issue surrounding temporal uncertainty- how representative 2021 is, and if the current simulation should be considered that - is important to consider when using these results to decide regualtion. Could the standard deviation over each seasonally averaged period be showcased as a map? Can the authors do the same with salinity from the same embayment and compare that to a longer run they have already? This would at least speak to the interannual variation expected in this region over time. This point is critical for the evaluation of event-based discharges as was asked of us in the review process. The products are currently insufficient as provided to evaluate events as they are largely time-averaged currently.

DMF Response: Time-averaged products were asked of Dr. Chen's group because DMF is using the output to inform the overall classification of shellfish growing areas around wastewater treatment plant outfalls. Assigned classifications speak to the overall sanitary quality and potential public health risks associated with consuming shellfish from the growing area and are semi-permanent in nature (i.e., do not change due to discrete events) . Currently, the model is not being used to respond to discrete events. However, future use of the model could include making status change closures (not long-term classification closures) informed by nowcast output driven by contemporary parameter values. The fact that the model simulation covers only a single year is a valid concern. However, results from additional years would likely support either that closures based on 2021 forcings sufficiently capture the variability or that broader Prohibited areas are required.

Reviewer Comment: process-based uncertainty emerges with the design of the inert tracer. It seems likely that the tracer was allowed to behave passively, when in reality the wastewater would degrade or be naturally broken down as it is exposed to light (Dizer et al. 1993, others) as well as it exists in the natural environment. This timescale was not included in the considerations for the residence times or dilution metrics provided.

DMF Response: Dr. Chen was not charged with modeling biological parameters such as pathogen decay because the dilution ratios for sanitary classification require accounting for chemicals or otherwise poisonous or deleterious substances like pharmaceuticals or industrial chemicals (e.g., PFAS) that are not removed during the treatment process, not monitored, and that persist in the marine environment. Pathogen decay is very pathogen specific. For example, fecal bacteria is more likely to persist and propagate in warmer months and viruses are more likely to persist in colder months. Thus, the high-risk season is different for different pathogens and does not overcome the need to dilute chemicals. Additionally, the classification of shellfish growing areas is meant to be stable and not change from season to season. DMF takes the efficacy of pathogen effluent removal into consideration when choosing which level of dilution is appropriate for the Prohibited buffer zone.

Reviewer Comment: Finally, the analysis currently largely lack of consideration for the habitat or organism at the center of concern and management. While the authors provide some output on the bottom, which seems like the natural location for them to reside, there is not much attention made to the organism's phenology and or their potential ability to clear the material from its system?

DMF Response: Model output provided dilution contours for the surface and bottom because there is floating aquaculture in the domain receiving the effluent discharges. Phenology is not relevant to this analysis and because the discharge is continuous (not discrete events) and some pathogens such as norovirus have a zero tolerance and cannot be tested/monitored continuously organism clearing rates would not factor into shellfish growing area classification decisions. It would however factor into closure duration decisions for discrete emergency discharge events.

Reviewer Comment: Why are monthly average maps the appropriate product to use to address this issue?

DMF Response: As mentioned earlier, classification designations are not dynamic like emergency discharge closures implemented by changing the status to closed. DMF asked for monthly and seasonal averages for dilution contours because the area classified as Prohibited dictates long-term closures in all seasons. DMF has to err on the side of public health when it comes to human sewage discharges, but taking the worst-case scenario is a bit too draconian and would have put long-existing aquaculture operations out of business. Seasonal and monthly average dilution contours allowed DMF to visualize effluent dilution and dispersal patterns in a manner that helped inform long-term classification decisions that aim to balanced public health protection with minimizing closure impacts to industry.

Reviewer Comment: Doesn't fecal coliform bacteria degrade with UV? Did the modelers consider adding this kind of decay to their tracer design? A sensitivity to this kind of forcing – an example can be found in these works (Kragh et al. 2022; Delre et al 2023) could be implemented in the longer run and help contribute to the process based evaluation or the uncertainty/confidence interval discussion.

DMF Response: See earlier comment on chemicals in WWTP effluent that do not degrade at relevant time scales.

Recommendations –

Reviewer Comment: Work to further define this threshold with the biology in mind. For example, the WWTP discharge is highest in the autumn in New Bedford but the model suggests that the dilution thresholds experience seasonality and are most severe in winter through spring in 2021. If you were to bring in the biology of the oysters and other shellfish – what months are they harvested, when are they growing the fastest and eating the most? How long does the bacteria from the WWTP remain a threat to humans within the shellfish after they ingest it? Could the farms remain open but harvest delayed in certain months?

DMF Response: Shellfish are harvested year-round. Dilution zones around WWTP outfalls are a precautionary measure mandated by the National Shellfish Sanitation Program to account for a plethora of different pathogens including some that have a zero tolerance in food products and for any number of known and unknown toxics that could be introduced into the waste stream and are not tested. The only feeding rate that would matter is periods of no feeding at all and there is no practical way to monitor that. If the shellfish are pumping, they are potentially accumulating pathogens/toxins. Thus far, no farms have been closed as a result of reclassifications due to dilution zones around WWTP outfalls.

Reviewer Comment: In line with this last question above – the model estimates are largely provided at the surface with some attention paid to the bottom conditions, but where are the farms mostly? Are the organisms growing at the surface in the intertidal or are they mostly at the bottom and what depths typically do they reside? Can the dilution estimates be expanded in the subsurface to better align with their habitat? Is bottom appropriate or do the farms allow the cages to reside higher up in the water column?

DMF Response: See earlier comment

Select comments and responses from review #2

However, since the dilution model results will inform shellfish growing area classification and support potential decision-making processes, it is crucial to ensure that the simulated dilution maps are accurate and able to quantify the uncertainties. For example, is it possible to evaluate the model simulated 1:1,000 contour with observations, such as Rhodamine dye injections as described in True (2008), the reference provided by Dr. Chen, and quantify the uncertainty in the spatial location of the 1:1,000 contour?

DMF Response: The New Bedford WWTP is up for permit renewal and the EPA is planning to conduct a dye study that would offer an opportunity for model validation.

Reviewer Comment: WWTP contaminant decay rate: Is it necessary to consider the decay rate of contaminants discharged from WWTP? To what extent does the decay of tracer affect the accuracy of the simulated contour lines at 1:1,000 and 1:100,000?

DMF Response: Dr. Chen was not charged with modeling biological parameters such as pathogen decay because the dilution ratios for sanitary classification require accounting for chemicals or otherwise poisonous or deleterious substances like pharmaceuticals or industrial chemicals (e.g., PFAS) that are not removed during the treatment process, not monitored, and that persist in the marine environment. Pathogen decay is very pathogen specific. For example, fecal bacteria is more likely to persist and propagate in warmer months and viruses are more likely to persist in colder months. Thus, the high-risk season is different for different pathogens and does not overcome the need to dilute chemicals. Additionally, the classification of shellfish growing areas is meant to be stable and not change from season to season. DMF takes the efficacy of pathogen effluent removal into consideration when choosing which level of dilution is appropriate for the Prohibited buffer zone.

Reviewer Comment: The flooding/drying capability, as detailed in Document 03, indicate that model can simulate areas that are periodically flooded by tide or occasionally inundated by extreme storm conditions. However, I lack experience with the FVCOM model and am unsure how FVCOM handles the CSO discharges and its overall model stability. In addition to measuring the discharge from CSO, it would be important to measure the concentration of contaminates to inform the concentration of the released passive dye, rather than assuming a concentration of 1 (as mentioned in Document 03). Furthermore, evaluating the model simulated hydrodynamics in regions where CSO discharges occur, comparing the simulated dilution maps against available observations, and identifying potential uncertainties associated with model configurations would be important.

DMF Response: While DMF is not currently using model output to inform closure decisions around CSO discharges, if DMF pursued that the simulation would be constrained by discharge volumes reported by flow meters in the CSOs and assumed fecal bacteria concentrations informed by DMF testing of discrete CSO point source discharges.

Select comments and responses from review #3

Reviewer Comment: The validation of the Mass Coastal FVCOM model results is limited, although the parent model, NECOFS, has been extensively validated. In Section 4, the model's tidal amplitude and phase were successfully validated against observations from 18 tidal gauges. However, the evaluation could be strengthened by incorporating validation of additional physical parameters, such as current speeds, water temperature, and salinity. Furthermore, the external validation section (file: *USCG_Annual_Report_2024_model_validation_section.pdf*) focuses exclusively on the NECOFS results from 2017. Conducting a comprehensive validation of the Mass Coastal FVCOM model results for 2021, with a broader range of features, would enhance the assessment of its performance and improve reliability.

DMF Response: EPA dye study of New Bedford WWTP outfall planned.

Reviewer Comment: Page 4, 4th paragraph. Is it better to validate the model before presenting the dilution maps?

DMF Response: With limited funding and the need to make classification decisions ASAP based on the best available science, DMF asked for the dilution maps.

Reviewer Comment: I believe this model is well-suited for establishing shellfish classification areas in the near future. However, the report appears to lack detailed quantification of the areas covered by the 1000:1 dilution lines. It would be helpful to include temporal plots of the prohibited, conditionally approved, and approved areas for shellfish farming. For instance, visualizing changes in the prohibited area within Buzzards Bay or within the 5 m isobath could provide valuable insights.

DMF Response: The classification decisions are made by DMF and take into consideration many factors outside the model results. For example, effectiveness of treatment in deactivating

viruses, whether the plant has holding capacity in the event of treatment disruption, redundancy in alarms to alert operators to failure, and demonstrated effectiveness in communicating with DMF.

Reviewer Comment: In the "Summary and Suggestions" section, suggestions to shellfish industry should be provided.

DMF Response: This study represents just a fraction of the information used to inform shellfish growing area classification decisions. Dr. Chen was tasked with simulating the dispersal and straight dilution of WWTP discharges. DMF as regulators must consider all standards and considerations of the National Shellfish Sanitation Program in final classification decisions.