Aplicativo *web* para previsão de riscos microbiológicos em águas utilizadas para o cultivo de moluscos na costa de Santa Catarina

Web application for prediction of microbiological risk in waters used for shellfish aquaculture in the coast of Santa Catarina

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Summary
Mathematical models have been increasingly used around the globe to predict water quality and communicate to the public when pathogens in hazardous concentrations are likely to be present. A validated regression based model was used to develop a web application that allows the prediction of microbiological quality of waters used for shellfish aquaculture in the coast of the Brazilian state of Santa Catarina. The web application was developed using the package “Shiny” from R. Using two slide buttons the user can set the solar radiation and rainfall observed during the previous days and the application returns a raster database containing the predictions in terms of faecal indicator bacteria per 100 mL. The application is practical, does not demand data about the hydrodynamics of the target area, and requires very little computational power and time to make predictions.

Keywords: early warning system, faecal pollution, online, mathematical modelling.

Introduction
Consumption of raw or lightly cooked bivalve shellfish harvested from waters contaminated with sewage pollution can pose significant human health risks (Prüss, Kay, Fewtrell, & Bartram, 2002). To reduce these risks, public health officials and water resource managers are increasingly using mathematical models to predict water quality and communicate to the public when pathogens in hazardous concentrations are likely to be present in the waters. Regression-based models link a set of input (explanatory) variables and an output (concentrations of faecal indicator organisms - FIOs) based on regression analysis. Such models can be used to predict the FIO concentrations in coastal areas under different environmental conditions after validation (EPA, 2019), that is to say, after having their predictive power assessed.
This article describes the use of a validated regression based model to develop a web application that allows the prediction of microbiological quality of waters used for shellfish aquaculture in the coast of Santa Catarina. The application is part of a pilot project from *Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina* – Epagri.

Methodology

The web application was developed using “Shiny” (RSTUDIO, 2019a). Shiny is an R package that allows the development of interactive web apps straight from R, combining the computational power of the mentioned programming language with the interactivity of the modern web. A mathematical (regression) model was used to predict the concentrations of faecal indicator organisms in the waters used for shellfish farming in the bays of the Santa Catarina Island. The model used in the app was developed by Souza et al. (2018) and it predicts the FIO levels in water (Y) based on human population in catchments with outlets located within 3.1 km from points (X_1), cumulative solar radiation of 53 h (X_2), and cumulative rainfall of 158 h (X_3). The model equation is the following:

$-1/(Y^{0.5}) = -1.218 + 2.683e\text{-}02*(\sqrt{X_3}) - 1.650e\text{-}05*X_2 + 1.852e\text{-}01*(X_1)$

Slide buttons were designed to allow users to set up the cumulative solar radiation and rainfall, two of the input data required by the model. The third input is a raster database containing the combined human population of catchments with outlets located within 3.1 km for each of the raster’s pixels. Based on the three inputs, the application returns a raster database containing the results in terms of faecal indicator bacteria (most probable number) per 100 mL. The application was hosted in a virtual server from R Studio (RSTUDIO, 2019b) for this pilot project. The Portuguese language is adopted to attend the local users from the state of Santa Catarina, Brazil.

Results and discussion

The application can be accessed using any internet browser through a computer or a smartphone, through an internet link. The link is not provided in this article because it is preliminary. The application interface is presented in Figure 1. The two slide buttons are positioned in the top of the app and the output is presented below a map indicating the geographical area covered by the application. The output is updated in real time as a consequence of the movement of the slide buttons. Additional information such as reference values for rainfall and solar radiation and validation parameters of the model are provided below the model output.

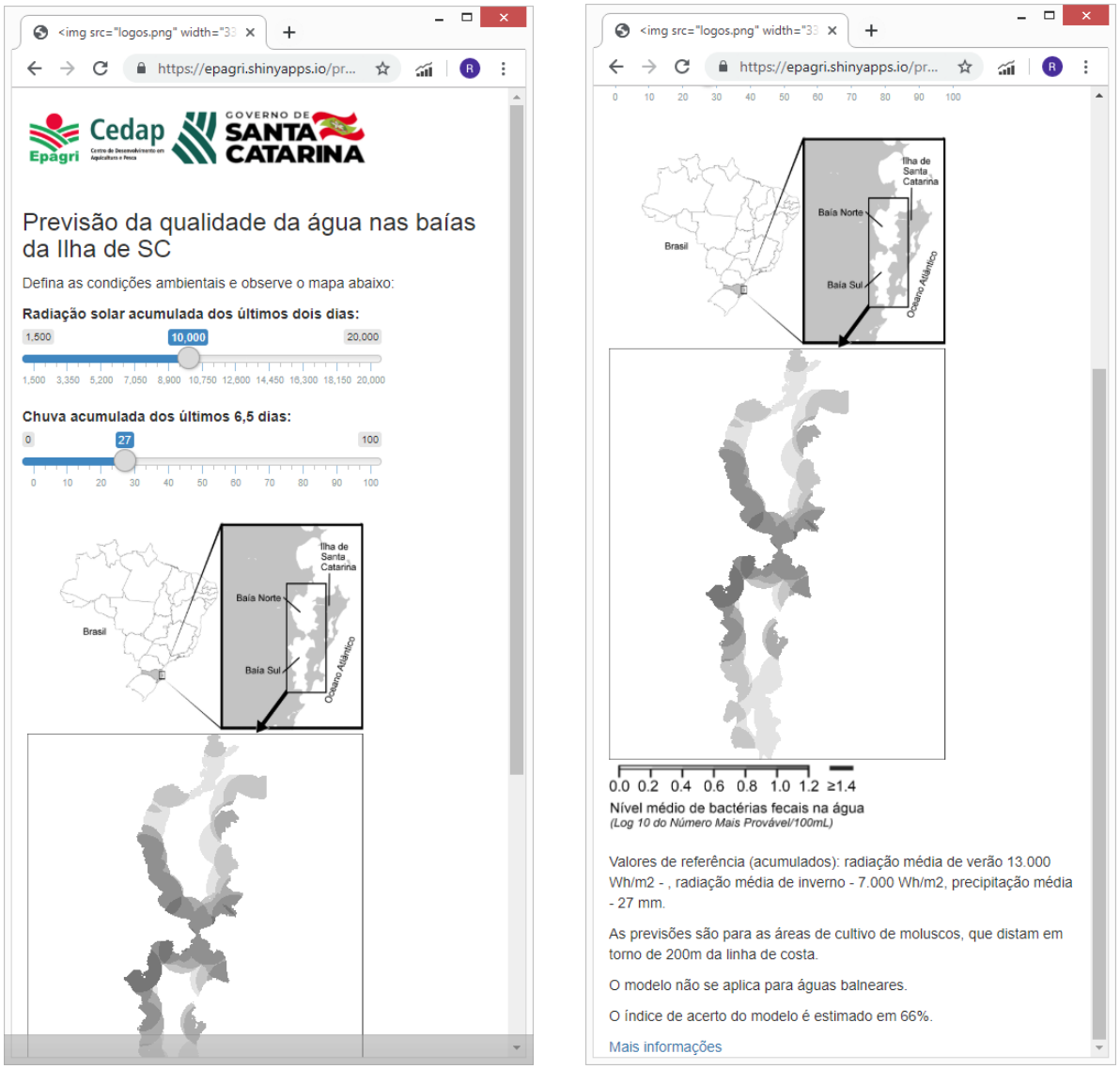

FIGURE 1. Application interface. The two slide buttons are used to set the meteorological parameters and the application returns the raster database presented below the indicative map.

Giving to the simplicity of both the application and the adopted model, it takes approximately one second after moving the slide buttons to obtain the model output. This is a very fast result when one compares it with complex mechanistic models, that can require hours to generate similar outputs. Many mechanistic models aimed at predicting water quality in coastal areas are described in the literature (Irvine Bay, Scotland - Kashefipour et al. (2006), Charles River in Boston, USA - Hellweger & Masopust (2008), Bray Beach, Ireland - Bedri et al. (2016)). It is important to notice that despite the simplicity, the model used to create the web application described in this article has good prediction power. Souza et al. (2018) show that the index of agreement between the model results and the concentrations of coliforms measured during the validation period was 66%; the mean error was 0.43 $\log_{10}$ and the mean square error was 0.58 $\log_{10}$ most probable number (MPN) per 100 mL. According to those authors, the validation results are comparable to models developed for other

parts of the world (KASHEFIPOUR et al., 2006; HELLWEGER & MASOPUST, 2008, BEDRI et al. 2016). These validation results were obtained for shellfish production areas, that are usually located more than 200 metres from the coastline. Therefore, the predictions are not immediately applicable to bathing areas.
Figure 2 give some examples of the model outputs generated by the web app considering different meteorological conditions. It is possible to observe that much lower levels of faecal bacteria in the water are predicted under conditions of low rainfall and high solar radiations, and the opposite is true.

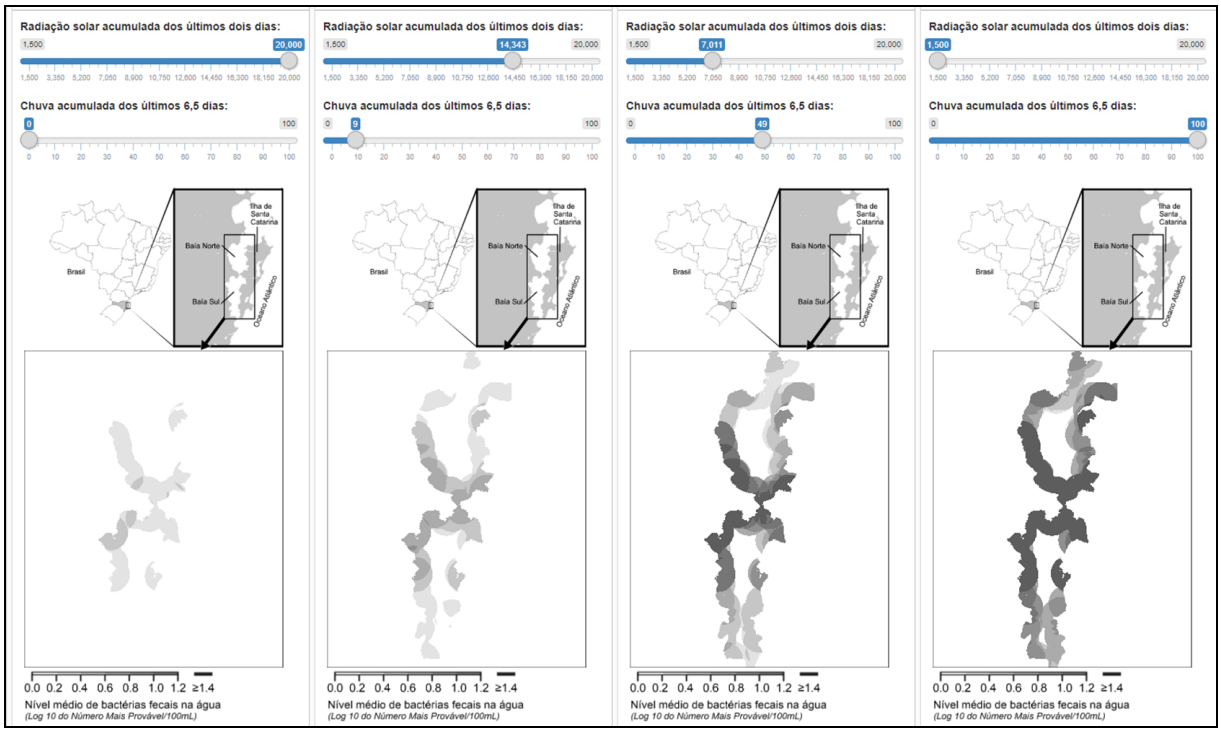

Figure 2 – Model outputs generated by the web application, considering different meteorological conditions that were set up using the slide buttons (on the top of the figures).

Conclusions

The developed application is practical, allowing the prediction of the microbiological quality of the waters used for shellfish aquaculture in the coast of Santa Catarina by applying a mathematical equation to meteorological data and a raster database of human population in the coast. The model does not demand information about the hydrodynamics of the target area and requires little computational power and time to make predictions.

References

BEDRI, Z., CORKERY, A., O'SULLIVAN, J.J., DEERING, L.A., DEMETER, K., MEIJER, W.G., O'HARE, G., MASTERSON, B. Evaluating a microbial water quality prediction model for beach management under the revised EU Bathing Water Directive. **Journal of Environmental Management**, v. 167, p. 49–58, 2016.

EPA. **Six Key Steps for Developing and Using Predictive Tools at Your Beach**. Available at: https://www.epa.gov/beach-tech/six-key-steps-developing-and-using-predictive-tools-your-beach - Access in: 19/08/2019

HELLWEGER, F.L., MASOPUST, P. Investigating the fate and transport of Escherichia coli in the Charles River, Boston, using high-resolution observation and modelling. **Journal of American Water Resources Association**, v. 44, p. 509–522, 2008.

KASHEFIPOUR, S.M., LIN, B., FALCONER, R.A. Modelling the fate of faecal indicators in a coastal basin. **Water Research,** v. 40, p. 1413–1425, 2006.

PRÜSS, A., KAY, D., FEWTRELL, L., & BARTRAM, J. Estimating the burden of disease from water, sanitation, and hygiene at a global level. **Environmental Health Perspectives**, v. 110, n.5, p. 537–542, 2002.

RSTUDIO. **Shiny from RStudio**. Available at: https://shiny.rstudio.com – Access in: 19/08/2019a.

RSTUDIO. **Share your Shiny Applications Online**. Available at: https://www.shinyapps.io/ - Access in: 19/08/2019b.

SOUZA, R. V.;CAMPOS, C. J. A.;GARBOSSA, L. H. P.;SEIFFERT, W. Q. Developing, cross-validating and applying regression models to predict the concentrations of faecal indicator organisms in coastal waters under different environmental scenarios. **Science Of The Total Environment**, n. 630, p. 20-31, 2018.