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Design and prospective evaluation of a risk-based surveillance system for shrimp grow-out farms in northeast Brazil

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ABSTRACT

The farming of Pacific white shrimp *Litopennaeus vannamei* in northeast Brazil, has proven to be a promising sector. However, the farming of Pacific white shrimp in Brazil has been affected negatively by the occurrence of viral diseases, threatening this sector's expansion and sustainability. For this reason, the drafting of a surveillance system for early detection and definition of freedom from viral diseases, whose occurrence could result in high economic loses, is of the utmost importance. The stochastic model AquaVigil was implemented to prospectively evaluate different surveillance strategies to determine freedom from disease and identify the strategy with the lowest sampling efforts, making the best use of available resources through risk-based surveillance. The worked example presented was designed for regional application for the state of Ceará and can easily be applied to other Brazilian states. The AquaVigil model can analyse any risk-based surveillance system that considers a similar outline to the strategy here presented.

1. Introduction

The growing global demand of aquatic animals and aquatic animal products has led to high rates of production and trade frequency and increased concern over the occurrence and spread of viral diseases affecting various cultured species. As a result, many nations have adopted surveillance strategies to protect their aquaculture sector (FAO, 2014). The threat to aquaculture sustainability and safe international trade has also led countries to apply trade standards based on their own aquatic animal health status (FAO, 2014). When able to demonstrate that a particular disease agent is absent, a country can facilitate trade or apply import risk analysis (FAO, 2014; WTO, 2014).

The absence of infection, from here on referred to as freedom from disease, can be determined through the aggregation over time of negative outcomes generated from a surveillance system. Documenting freedom from disease requires a large sample frame and so surveillance activities should selectively target the high-risk strata of the population through risk-based surveillance (RBS) (Cameron, 2009). In this paper, a stochastic model based on scenario tree modelling was implemented to determine the probability of freedom obtained for certain surveillance efforts, so that the best strategy can be determined prospectively. The model outputs will provide decision makers with the information to implement surveillance efforts to achieve a desired probability of freedom. The surveillance system will also ensure early disease detection.

In northeast Brazil, the farming of Pacific white shrimp *Litopennaeus vannamei* has been an important source of income for large-scale producers and also the main or supplementary income-generating activity for the poorest rural communities and their small-scale farmers. In many cases, the occurrence of viral diseases has lead to the abandonment of farming activities (Ostrensky et al., 2008). There is to date, unclear knowledge on the geographic extent and impact to which viral diseases have affected the countries shrimp aquaculture sector. From the list of notifiable viral diseases in shrimp populations drafted by the Brazilian Ministry of Fisheries and Aquaculture (MPA), the Centre for Environment, Fisheries and Aquaculture Science (Cefas) references the presence of White Spot Syndrome Virus (WSSV), Infectious Myonecrosis Virus (IMNV), Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV) and Taura Syndrome Virus (TSV), initially ruling out efforts for determining country-level freedom. Meanwhile, other

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viral pathogens such as Yellowhead Virus (YV) have yet to be identified at a national level (CEFAS, 2014; DOU, 2015).

The MPA has recognized the threat of viral diseases to the aquacultured shrimp populations and the need to strengthen disease surveillance (MPA, 2011). The needed surveillance system must encounter international acceptance and therefore follow World Organisation for Animal Health (OIE) surveillance guidelines (Corsin et al., 2009; OIE, 2014a). Implementing surveillance efforts to declare disease-free status can lead to early disease detection and identification of disease-free zones. The model can be applied to any one of the listed notifiable viral diseases, as the epidemiology, pathogenicity and many clinical features are similar among them.

2. Methods

2.1. Model overview

The AquaVigil model evaluates the results of implementing two types of surveillance system components that are activities that generate the needed information to determine freedom from disease: one active surveillance system component (ActiveSC) and one passive surveillance system component (PassiveSC). Surveillance system sensitivity (SSe), that is, the probability of the surveillance system detecting disease if it were present, can be estimated considering the joint contribution of the two surveillance components that make up the surveillance system: the PassiveSC sensitivity (SePassiveSC) and the ActiveSC sensitivity (SeActiveSC).

The model was developed in R environment and is available as the AquaVigil function in the Supplementary Document 1 with example data in the Supplementary Document 2 and using the mc2d, plyr, ggplot and Hmisc packages (R Development Core Team, 2008). The simulation comprised of 10,000 iterations and set a fixed random number seed for reproducible random results. Model inputs necessary for analysis are a comma-separated values (CSV) file with an ID column, four columns characterizing the presence (1) or absence (0) of four risk factors (RFs) and a fifth column specifying the number of samples retrieved from each farm. Prospectively, we can determine the SePassiveSC, the SeActiveSC, the SSe, the probability of freedom obtained through surveillance, the sample size for the ActiveSC and campaigns needed to achieve a desired probability of freedom. Other model outputs include a correlation analysis for surveillance system component sensitivities, the achieved probability of freedom after a single surveillance campaign and the sensitivity ratio for the ActiveSC (SR).

2.1.1. Data sources

A past census of the productive, technological, economical, social and environmental aspects of Brazil's aquaculture sector was drafted for the year of 2011 and the data provided by shrimp grow-out farms when questioned for this census was the data here used. From the available data, the worked example presented for determining disease freedom for the state of Ceará accounts for 325 grow-out farms, parameterized for the presence and absence of the selected RFs. The census data provided the coordinates for 273 of the 325 farms. To roughly illustrate the density of farmed areas, a map of such farms is provided in Fig. 1. From this map, the main farming areas are visible along the Jaguaribe River and delta, to the South, and the Acaraú River delta, to the North (ABCC/MPA, 2013).

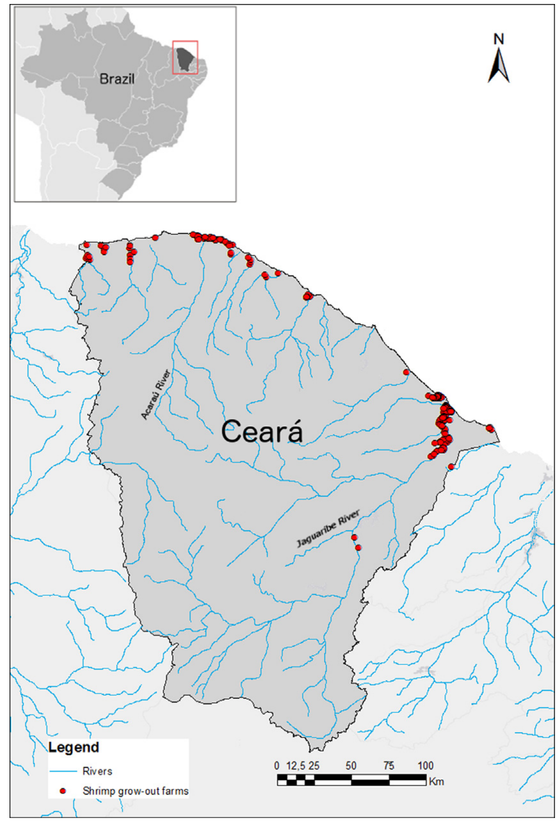

Fig. 1. Map of shrimp grow-out farms in the state of Ceará.

2.1.2. States to define disease-free zones

Dispersion of infectious agents through water occurs frequently and at a rapid rate (Hoa et al., 2011; Lotz, 1997; Moss et al., 2012). This would strongly suggest the rapid spread of the pathogens between farms in interconnecting water systems. Therefore, the level at which disease freedom can be defined should be reasonably large. Furthermore, shrimp grow-out farms will frequently use post-larvae (PL) from PL suppliers in their state. Given the previous considerations, the state level was considered to define disease freedom. The state level will also allow a more efficient organizational approach to surveillance. A worked example of the AquaVigil model for Brazil's state of Ceará is presented, as this was determined as one of the leading states for aquacultured shrimp production (ABCC/MPA, 2013).

2.1.3. Surveillance of farmed populations

The "Report of the meeting of the Task Force on Animal Disease Surveillance Brussels, 24 and 25 June 2009" addressed how to demonstrate disease freedom from WSSV. The task force discussed how surveillance at the farm level would suffice when the disease is well known and the population in the farms is representative of both wild and farmed populations (European Commission, 2009). Taking into account the aforementioned conditions and the data available, only sampling of shrimp from grow-out farms was considered.

2.1.4. Time period for analysis

Australian authorities considered one campaign as sufficient to determine disease freedom for WSSV (East et al., 2004, 2005). Here we consider a single campaign both sufficient and most desirable to determine a cost-effective surveillance strategy, given the contribution of both surveillance system components. The water temperatures that could determine a higher probability of clinical signs of disease at certain time periods, are relatively constant for Brazil's northeast states, and so there is no time of year recommended to perform surveillance activities (Nunes et al., 2005). Therefore, the time periods for analysis of the surveillance system results will cover one year of surveillance.