

1 **Design and Implementation of a Collaborative Epidemiological Surveillance System for**
2 **Aquaculture (VECA)**

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4 Short running title: **Collaborative Epidemiological Surveillance System (VECA)**

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17 **Abstract**

18 Syndromic surveillance and participatory epidemiology are nowadays taking part in the public
19 health system because they can be very interesting tools to complement the classical ones.

20 Although syndromic surveillance could be nonspecific, it is usually based on real-time data
21 analysis to provide early warnings. Participatory Epidemiology can bring us different and
22 interesting approaches that we can use to better understand the problem.

23 VECA implements an epidemiological surveillance system, validated by experts and users,
24 which allows collecting real-time information of each facility on production data, origin of
25 animals, environmental parameters, disease status and therapeutic and prophylactic measures.

26 Based on the data collected and the results of preliminary epidemiological analyses have been
27 selected to design the most relevant indexes, which will set different levels of health warning, to
28 help those responsible for aquatic animal health and producers to make the right decisions.

29 The platform can be used by owners or those responsible of farms who wish to collaborate in
30 the development of this system of epidemiological alert and to prevent future diseases that cause
31 incalculable losses in the sector.

32

33 **Key words:** surveillance, aquaculture, syndromic, epidemiology, participatory, alert

34

35 **Introduction**

36 The development of aquaculture and its industrialization occurred in Spain from the 90s; thus, it
37 can be considered as a very young industry with a large increment in production in the past 25
38 years, especially in marine aquaculture (APROMAR, 2015).

39 Unfortunately, this development has not occurred in the field of Animal Health in the same way.
40 This gap has resulted in an increment in emerging diseases, which currently cause important
41 economic losses to the industry and represents in many potential species the limiting factor for
42 aquaculture diversification.

43 During the last years, there were a lot of examples of emergent pathogens. *Tetracapsula*
44 *bryosalmonae* (aetiological agent of Proliferative Kidney Disease, PKD) affected to cultured
45 and feral salmonid populations (Wahli et al, 2002; Zimmerli et al, 2007). *Streptococcus iniae*
46 has been detected in marine and freshwater fish species (Agnew & Barnes, 2007; El Aamri et al,
47 2015). Besides, recently the Salmonids Alphavirus (SAV) causing Pancreatic Disease and
48 Sleeping Disease has been included in the OIE list (Graham et al, 2007; Snow et al, 2010).
49 Other examples to illustrate the relevance of emerging pathogens in Spain are *Vagococcus*
50 *salmoninarum* affecting in summer to rainbow trout broodstocks (Ruiz-Zarzuola et al, 2005),
51 and *Enteromyxum scophthalmi* causing important losses in cultured turbot (Quiroga et al, 2006;
52 Palenzuela, 2006). But, perhaps the most controversial disease has been the Winter Disease in
53 sea-bream (*Sparus aurata*) and its association with *Pseudomonas anguilliseptica* with a relevant
54 influence of the environmental conditions (Doménech et al, 1997; Blanco et al, 2002).

55 The control of fish diseases becomes a complex task to be done with rigorous criteria, and
56 which should optimize the early detection of diseases in an efficient way (Peeler et al, 2006).

57 The late detection of an outbreak of an emerging disease in some countries, like Spain, could
58 cause serious consequences in international trade. For these reasons, since 1994, FAO
59 established the programme "Emergency Prevention System for Transboundary Animals and
60 Plants Pests and Diseases (EMPRES)". In this programme, FAO informs about the importance
61 of disease prevention in aquaculture, since the lack of control in the international trade of

62 animals and aquaculture products is causing serious outbreaks and once the pathogen is
63 introduced and established in the natural environment, it is very difficult to treat and/or to
64 eradicate (<http://www.fao.org/ag/againfo/programmes/en/empres/home.asp>).

65 In order to improve the aquatic animal health, it is necessary to know properly the epidemiology
66 of the diseases. Epidemiology brings us within the components of a disease, more practical
67 information when establishing prevention and control.

68 Due to this rising of emerging diseases, the industry is claiming for advice and training in this
69 field to increase their productivity through improved animal health. The European legislation in
70 this area was developed in Directive 2006/88/EC on animal health requirements for animals and
71 aquaculture products, as well as the prevention and control of certain aquatic animal diseases
72 which implements a risk-based on the surveillance system for aquatic populations in order to
73 improve the efficiency of early detection of notifiable diseases in aquatic populations.

74 Also, recently it has shown the potential of surveillance systems based on risk for early
75 detection of emerging diseases in aquaculture through the development of epidemiological
76 models (Thrush et al., 2011).

77 These tools are based on the correlation between the presence of infectious and parasitic agents
78 and production quality. This information collected systematically and georeferenced can
79 become a very efficient control system (Gai, 2003; Staubach et al, 2003; Cameron, 2004). The
80 early detection of suboptimal production records allows triggering an epidemiological
81 investigation to identify the aetiological agents, and to apply appropriate contingency plans
82 (Rodríguez-Prieto et al., 2015).

83 Nowadays, there are a lot of different kinds of surveillance systems that can complement each
84 other. For example, the syndromic surveillance is implemented as a supplementary tool that can
85 detect some events that could not have been detected by other kinds of surveillance systems.

86 The Triple-S project defines syndromic surveillance as the real-time (or near real-time)
87 collection, analysis, interpretation and dissemination of health-related data to enable the early

88 identification of the impact (or the absence of impact) of potential human or veterinary public
89 health threats which require effective public health action (Triple-S project, 2011).
90 So, the syndromic surveillance is not based on laboratory confirmed diagnoses of disease and
91 normally the data are collected for other purposes. Although it could be nonspecific, it can be
92 sensitive and usually utilised real-time data analysis to provide early alerts of outbreaks (Triple-
93 S project, 2011).
94 Another approach is the participatory epidemiology, it uses participatory methods to improve
95 understanding of diseases and strategies for animal disease control (Catley et al., 2012). In this
96 situation, it is very important to discuss the value of the contributions of the participants. When
97 participatory epidemiology is applied to disease search, it is known as participatory
98 surveillance, which is considered a type of active surveillance (Rodríguez-Prieto et al., 2015).
99 The project VECA (*Vigilancia Epidemiológica Colaborativa en Acuicultura* = Collaborative
100 Epidemiological Surveillance in Aquaculture) was born regarding the need mentioned by the
101 producers through the Federación Española de Agrupaciones de Defensa Sanitaria de
102 Acuicultura (FEADSA) in 2010 with the goal to improve the surveillance aquaculture system in
103 Spain. So, the main objective of this project is to develop an interactive and participatory
104 epidemiological alert system in aquaculture, applied to characterize diseases that currently
105 concern and affect the Spanish aquaculture sector and lay the foundation to prevent future
106 diseases that cause significant economic losses.

107

108 **Materials and methods**

109 *Design of the platform*

110 An efficient collection of information involves the design and optimization of a database that
111 allows storing all structured data required for the project. After several meetings with experts
112 from FEADSA, ACUIVAL (Agrupación de Defensa Sanitaria Acuicultura de la Comunitat
113 Valenciana) and ASEMA (Asociación de Empresas de Acuicultura Marina de Andalucía)
114 discussing about the purpose of the tool and the availability of data, a proposed structure as the

115 first approach was designed to be validated by the project participants before starting its
116 implementation by the staff of the Universidad de Zaragoza.

117 In general terms database consists of four basic entities:

118 - Users: It includes basic information corresponding to different kinds of users like farmers,
119 health managers, veterinarians, technicians and administrators of the platform. The
120 registration of users should be made only by the administrators of the application under the
121 request of the project partners.

122 - Farms: It includes data about the type of farm and spatial information (UTM coordinates).

123 - Production units: In order to make easier the data input of each structure that may contain
124 fish (ponds, cages, estuaries...), it may set links between units of production. Generic data
125 from one are automatically propagated to all connected units of production and if it is
126 necessary.

127 - Batch of animals: It is defined as a group of individuals who have a common origin and
128 evolution.

129 A scheme of the relationships among main entities in the database is shown in Figure 1. Each
130 user can access to one or more farms, and a farm could be accessed by one or more users.

131 One feature of this system was that assign to users different levels of privileges. Sometimes the
132 owner of the farms is not the person who introduces the data into the platform. So, the users can
133 input, modify and/or view data. Moreover, depending on access level, different kinds of reports
134 are generated regarding information about all units of production.

135 Finally, four levels of access were defined: 1) view summaries of a farm, 2) view summaries of
136 a farm and its production units, 3) view summaries of a farm, its production units and its batches
137 of animals and 4) view all summaries, modify data of a farm, create and modify its production
138 units and its batches of animals and assign the level of access to other users. Additionally, a
139 superuser was created with privileges to create farms and users.

140 Finally, this platform was designed as a relational database implemented using PHP language
141 on a MySQL database allowing online access to data and results.

142 *Working scheme*

143 Participants ask for the inclusion of a new farm in the platform and the superuser included it
144 defining the name, official identification number and type of farm (earthen ponds, cages,
145 outdoor ponds and indoor tanks) intended to further stratified data analysis. GPS coordinates are
146 optional, but they would be relevant to further implementation of spatial epidemiological
147 analysis.

148 Each farm is assigned to a user with level 4, and then he can create the production units. Each
149 production unit is designated by a unique name and classified in different types (earthen ponds,
150 cage, circular pond, raceway, irregular pond, outdoor tank or indoor tank). Surface and/or
151 volume of the unit are defined depending on the type of pond and different measurement units
152 are available (diameter in meters, areas in square meters or hectares, volumes in cubic meters or
153 liters...). In order to simplify data input, each production unit could be linked to another one.

154 Next step is to define a batch of animals: denomination, reared species, start and end dates,
155 production unit where is located, initial and current census. Different methods to create the
156 batch are available: a new batch from the same or another farm and by transference of animals
157 from/to another batch. The census will be modified taking into account movements of animals:
158 transfers, mortalities, and harvests. Additionally, information about previous diseases,
159 vaccination and treatments can be provided. Most important challenges at this point were to
160 allow more than one species in the same production unit and to warrant the traceability of a
161 batch.

162 Once the production units and batches of animals were created, a quarterly tracking is carried
163 out. Environmental data were collected as minimum and maximum values for temperature,
164 salinity, dissolved oxygen and pH (these variables could vary depending on the type of
165 production unit). Also, it can be recorded the presence of high winds, storms, rain, strong tides,
166 releases from dams and other incidents. All these data can be propagated automatically to linked
167 units. Furthermore, management data were collected: presence of predators, feeding rate and
168 change of nets.

169 Other management data are related to the batch of animals, like transfers and harvest (number of
170 days and number of animals), estimated average weight (if it is available) and losses of animals
171 (escapees). But the most important data from batches were related to health management: any
172 detected problem (abnormal mortality o decrease of growth) and the number of deaths (and their
173 average weight). The suspected aetiology of the outbreak could be included (one or more
174 causes), and it can be confirmed later when laboratory results were received. Additionally, the
175 application of treatments and vaccination was recorded, including product, type of treatment
176 (antibiotic, antiparasitic, water hygienization or vaccine), administration way and effectiveness
177 (null, low, moderate or high).

178 All these data should be confirmed before to be used for further analysis, and it is not possible
179 to input data from a new quarter until the data were completed. However a partial confirmation
180 it is possible in case of sanitary data because laboratory results could be delayed.

181

182 *Implementation of confidentiality measures*

183 These kinds of data are really sensitive to the people in the sector because the knowledge of
184 some specific results can vary the price of products with the consequent impact on the
185 aquaculture system.

186 In order to difficult the reading of the code and the data collection server access, it was decided
187 to use an encryption algorithm which is applied to the variables of access to the database server
188 and mail server. Also, in the identifying fields, it has been disabled autofill option.

189 Additionally, the data tables and the names of the variables are devoid of meaning to be more
190 difficult to interpret if someone access to the MySQL server. Also in some cases it has
191 obfuscated the relationship between tables by adding a value to the relational code (e.g.
192 EA022.COD = EA002.V3 + 2), that practice destroys the referential integrity of the database
193 and can only be restored through the SQL code.

194

195 **Results and discussion**

196 The system provides tools to generate four different reports: qualitative environmental variables,
197 quantitative environmental variables, husbandry management, and health management. The
198 reports can be generated at different levels: farm, production unit, and batch of animals; and
199 they include relative frequencies for qualitative variables, and mean, standard deviation,
200 minimum and maximum for quantitative variables, also differences between means and extreme
201 values of maximum and minimum records are calculated for these variables. Depending on their
202 level of access, the users can select the reporting period to obtain overall statistics. In the case of
203 farms the statistics are also calculated for each quarter. However, at the level of production units
204 or batches of animals, all recorded data are listed in order to provide information about
205 traceability.

206 Furthermore the users can carry out an estimation of risk factors taking into account only data
207 from its farm or using data from all farms with the same features. The studied events could be
208 abnormal mortality, decreased growth or both, considering if the cause is confirmed or not,
209 affecting to all present species or one of them. About analysed factors, all variables included in
210 the database could be checked.

211 It is possible to apply three survey designs: cross-sectional (factor and event occurred during the
212 same quarter), case-control (factor corresponds to the previous quarter when the event occurs)
213 and cohort (factor corresponds to the previous quarter when the event occurs, but the event did
214 not occur previously).

215 The exposed group is defined selecting a category for qualitative variables or defining a
216 customized cutoff value for quantitative variables (descriptive statistics for farm and global are
217 provided as reference). So, for example, it would be possible to assess if the minimum
218 temperature lower than 10°C during the previous quarter is related to abnormal mortalities
219 caused by *Aeromonas salmonicida* in rainbow trout farms.

220 Finally, the adequate disease measurement (prevalence or incidence) for each group and risk
221 estimator (prevalence ratio, odds ratio and/or relative risk) are calculated with their 95%
222 confidence interval.

223 Also, the subjective effectiveness of treatments could be assessed as relative frequencies at farm
224 and global level. First the user selects the type of treatment and the treated species, then he
225 selects the administration way (oral, bath, immersion, intraperitoneal, other or all of them), the
226 product and the aim of the treatment (therapeutic, prophylactic, water hygienization or all of
227 them).

228 The final structure of the platform was designed by the group of experts after several meetings
229 taking into account the surveillance aquaculture system in Spain, the observations realised by
230 different project participants and according to the specific requirements of the sector. So, we can
231 consider VECA as a tool based on participatory epidemiology because a lot of people were
232 participating in the design of the structure and the data collection.

233 Participatory surveillance was first implemented in Indonesia as a pilot programme for Highly
234 Pathogenic Avian Influenza (HPAI) in 2006 (Jost et al., 2007) and also Sudan applied this
235 approach to HPAI and Newcastle disease later (Mariner et al., 2014). Although, there are some
236 examples about participatory surveillance, its application is not really common in aquaculture.

237 Currently, in the aquaculture sector in Spain does not exist an informational tool regarding
238 diseases affecting production. For this reason, we have developed an interactive system of
239 epidemic alert, with access through the web for the detection of disease outbreaks at the regional
240 and local levels, based on real-time information of aquaculture production.

241 We have taken as reference the Epidemiological Alert System and Aquaculture Management
242 (SAEMA) developed as a passive surveillance system, which detects changes in production
243 levels of shrimp farms in the inner estuary of the Gulf of Guayaquil (Ecuador) (Bayot, 2008).

244 The main difference between SAEMA and VECA is that our tool has been designed to take into
245 account the specific needs of the Spanish fish farms, including the specific characteristics of the
246 different production systems: nurseries, tanks, ponds...

247 The reports are created taking into account the information provided by the different owners and
248 they can check it in a delayed way with the aim that it cannot affect the price product in the
249 aquaculture sector.

250 The functionality of the platform could be extended in order to include an early warning system
251 comparing environmental and production data of production units with cutoff values
252 corresponding to the risk factor assessment already implemented. Some examples to illustrate
253 this concept are Triple-S project (<http://www.syndromicsurveillance.eu/>) and SAEMA
254 (<http://www.saema.espol.edu.ec/>). The Triple-S is a project about syndromic surveillance
255 systems with the purpose to increase the capacity of European countries to develop real-time
256 surveillance systems to complement and improve public health.
257 Unfortunately, the participation of fish farmers was very limited, despite the use of the platform
258 was free, and only nine farms introduced data. So finally the system was not able to provide us
259 enough data to validate the platform.
260 It could be really interesting at that point try to obtain a greater sample size to validate it and
261 due to its flexibility, VECA can be adapted to different production systems.

262

263 **Conclusions**

264 The key factors for success of a syndromic surveillance system based on participatory
265 epidemiology are the usability of the platform, the confidentiality of the data and results, costs
266 of implementation and use of the platform, and a wide participation of stakeholders. In our case,
267 the recruitment and participation of fish farmers have been the “*Achilles' heel*” of this project.

268

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276

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358 Figure 1. Relationship between entities