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Improving early detection of exotic or emergent oyster diseases in France: identifying factors associated with shellfish farmer reporting behaviour of oyster mortality

C. Lupo[a, *], A. Osta Amigo[a], Y.V. Mandard[b], C. Peroz[c, d], T. Renault[a]

[a] Ifremer–SG2M-LGPMM Laboratoire de Génétique et Pathologie des Mollusques Marins–Avenue Mus de Loup, 17390 La Tremblade, France
[b] DDTM17 - Departmental Direction for Territories and Sea - 89 avenue des cordeliers, 17018 La Rochelle cedex, France
[c] LUNAM Université, Oniris, Ecole nationale vétérinaire, agroalimentaire et de l'alimentation Nantes-Atlantique, UMR Biologie, Epidémiologie et Analyse de Risque en santé animale, BP 40706, F-44307 Nantes, France
[d] INRA, UMR1300, F-44307 Nantes, France

*: Corresponding author : C. Lupo, tel.: +33 5 46 76 26 10 ; fax: +33 5 46 76 26 11 ; email address : clupo@ifremer.fr

Abstract:

Farmers' vigilance is essential for the detection of epidemics, including potential emerging diseases, in marine shellfish. A field study was conducted to investigate oyster farmers' reporting practices and behaviour, and to identify factors influencing the reporting process of oyster mortality, with the ultimate aim of improving early detection of unexplained oyster mortality outbreaks.

A retrospective case-control study of oyster farmers from Charente-Maritime (France) was designed, based on interviews with 27 non-reporting and 89 reporting farmers, further split into 40 formerly-reporting and 49 currently-reporting farmers. Information about farmer and farm characteristics, farming practices, farm health history and related financial compensation on the farm, knowledge of the mortality reporting system and reporting behaviour was collected. Sampling design was considered in the calculations and farmers' reporting behaviour was modelled using an ordinal logistic regression (continuation-ratio model).

Notification procedures were fairly well known among farmers and the reporting system was well accepted overall. Nevertheless, a lack of awareness of the aims of the reporting system was revealed, which contributed to late reporting. Factors identified as driving a farmer's decision to report oyster mortality concerned their lack of awareness of mortality reporting (production type, farm size, location of the production cycle, accessibility of the leasing grounds) and willingness to report (possibility and extent of financial compensation, a feeling of not being involved, whether it was first year of reporting). Overall classification performance of the model built in this study was 64%. In particular, financial compensation for oyster production losses appeared to be a clear incentive for reporting, but was countered by a habituation effect combined with a lack of awareness of the aims of the reporting system: oyster farmers looking for benefits for themselves in reporting, rather than early detection of a disease outbreak.

Both economic compensation and the farmers' non-economic values and perceptions should be considered to improve oyster farmers' reporting compliance and sustainability of the reporting system. Education and participatory approaches could help to change these attitudes and thus improve oyster farmers' compliance with reporting duties, resulting in improved early detection of epidemics and emerging or exotic oyster diseases.

Highlights

► Oyster farmers' reporting practices and behaviour towards oyster mortality were investigated. ► Notification procedures were fairly well known. ► A lack of awareness of the aims of the reporting system was revealed, contributing to late reporting. ► Both economic and non-economic factors were identified as drivers for farmer reporting decision.

Keywords : Case-control study ; Ordinal logistic regression ; Surveillance ; Notification ; Shellfish diseases

1. Introduction

In France, the current surveillance system for marine mollusc health is mainly based on the observation of any increased shellfish mortality by shellfish farmers and its immediate mandatory notification to the local competent authority (European Union, 2006; French Ministry of Agriculture, 2008). But, although immediate notification of any observed mortality event is mandatory, the current definition of an increased shellfish mortality does not include objective criteria and mortality estimation is not straightforward: *"'increased mortality' means unexplained mortalities significantly above the level of what is considered to be normal for the […] mollusc farming area in question under the prevailing conditions. What is considered to be increased mortality would be decided in cooperation between the farmer and the competent authority"* (European Union, 2006). Shellfish farmers have to complete a standardized notification sheet (French Ministry of Agriculture, 2010a). This mandatory document is a pre-tabulated paper form, which is filled in (usually by hand-writing) by the farmer. This form has to be immediately transmitted to the local competent authority. The national mollusc disease surveillance network (Repamo) then becomes involved, for anamnesis and laboratory diagnosis based on biological samples (Dufour and Hendrickx, 2009).

This system notably aims to early detect the appearance of any exotic or emerging pathogen in the territorial waters. Indeed, as diseased shellfish seldom show symptoms, any unexplained mortality is a potential indicator for pathogen introduction or emergence. This was well illustrated in 2008, when mortality notification data represented one of the rare data sources that both acted as an alert and described the extent of the mass mortality outbreaks which occurred in the spat of Pacific oyster, *Crassostrea gigas* (Miossec et al., 2009), associated with the detection of a newly described genotype (μVar) of the Ostreid herpesvirus (OsHV-1) (European Food Safety Agency, 2010; Segarra et al., 2010). Unfortunately, this infection has become endemic (Lupo et al., 2011b), showing that control of the spread of this emerging pathogen has failed.

Early detection of pathogen introduction or emergence in shellfish is crucial, as openness and connectivity of marine systems enable rapid disease spread (McCallum et al., 2004) and successful control of disease is very unlikely once established in shellfish populations (Lupo et al., 2012a). The use of drugs is not possible; therapeutic levels cannot be obtained economically or without unacceptable environmental impacts. Vaccination cannot be used because shellfish lack a true adaptive immune system, relying totally on their innate immune system to overcome diseases (Renault, 2009). However, there exists a window of opportunity to limit spread, which would need to be done mainly by restricting shellfish movements (European Union, 2006), and possibly by eliminating a pathogen early in an epidemic.

Like in any animal health surveillance system relying on the reporting of suspicious events, shellfish farmers are the best placed to inquire into and notify authorities of any suspicion of disease in the field (Dufour and Hendrickx, 2009). Their active involvement in this surveillance system is fundamental to make it effective, i.e. sensitive and timely to provide early alerts. However, a recent study has shown that participation of French oyster farmers in the mortality notification system was not sustained over the 2007–2010 time period (Lupo et al., 2012b). Since 2010, financial incentives have been implemented, with mortality notification becoming mandatory to qualify for financial compensation (French Ministry of Agriculture, 2010b). It is necessary to identify the incentives and barriers to the farmers' participation in the surveillance system in order to design an improved means of reporting (World Bank, 2010) and to help sustain farmers' motivation to report.

A few studies have investigated the reasons for farmer under-reporting diseases in livestock (Limon et al., 2013), cattle (Palmer, 2009; Bronner et al., 2013a; Bronner et al., 2013b), sheep (Hopp et al., 2007), swine (Elbers et al., 2010a) and poultry (Elbers et al., 2010b) but, to our knowledge, this has never been investigated in shellfish farming. Thus, a study was conducted to investigate farmers' reporting practices and behaviour, and to identify factors influencing the reporting process of oyster mortality, with the ultimate aim of improving early detection of unexplained oyster mortality outbreaks.

2. Material and methods

2.1. Study design and population

The study was designed as a retrospective case-control study of oyster farmers from Charente-Maritime (France), using the oyster farmer as the epidemiological unit. Charente-Maritime is the main production region of Pacific oysters, *Crassostrea gigas*, in France, home to one third of all French oyster farms (Agreste, 2005). In particular, this is the main area of spat collection, supplying all the other regions with spat (Buestel et al., 2009). The study was conducted from March to December 2012.

Control farmers were randomly selected (by lottery using computer generated pseudo-random numbers) from the list of the oyster farmers who had notified authorities of at least one mortality event on their oyster production between January 2007 and December 2011 in Charente-Maritime. This list was provided by the Departmental direction for territories and sea of Charente-Maritime (i.e. the local competent authority).

Case farmers were randomly selected from the list of oyster farmers licensed for leasing grounds, run by the Departmental direction for territories and sea of Charente-Maritime, who had not notified authorities of any oyster mortality event between January 2007 and December 2011.

Only the oyster farmers farming the oyster species *C. gigas*, who were active at the time of the study and having a farm located in Charente-Maritime were considered in this study. Other shellfish farmers and oyster farmers located in other regions with leasing grounds in Charente-Maritime were excluded.

2.2. Sample size

A sample size of 36 cases and 108 controls was calculated to provide a 95% level of confidence for detecting an odds ratio of 3 with 80% statistical power, assuming a 1:3 ratio of case to control farmers and a random notification process, i.e. a 50% probability of reporting observed oyster mortality. Sample size was increased by 15% to account for non-participation rate observed in previous and recent studies conducted in the same population (Lupo et al., 2011a; Carlier et al., 2013), leading to a total of 41 cases and 124 controls, out of 165 and 703 eligible oyster farmers, respectively.

2.3. Data collection

Each selected farmer was sent a personally addressed letter to explain the survey objective and to tell them that they would receive a telephone call. An appointment was made during the telephone call to collect data. The farmer was informed about the data collection procedure, which would be based on a personal face-to-face interview that would take about 45 minutes to complete. The farmers who refused to take part were asked the reason why and were compared with those farmers who agreed to participate.

These interviews were based on a standardized questionnaire (Table 1) that was piloted with three oyster farmers and modified according to the feedback. The questionnaire (available in supplementary file) contained 28 questions (54% closed, 7% semi-closed and 39% open-ended) that collected data related to socio-demographics, farm characteristics, farming practices, health history on the farm since 2007, knowledge of the oyster mortality reporting system and reporting behaviour. For control farmers, 12 additional questions (4 closed, 4 semi-closed and 4 open-ended) collected data related to their reporting practices and attitudes.

The previously trained, experienced interviewers (AOA and CL) conducted the pilot interviews together to ensure standardization in interview method and all questions were clarified beforehand to reduce information bias due to the interviewer. Questions were asked exactly as stated in the questionnaire and only non-directive guidance was given. All the interviews were recorded with the oyster farmer's authorisation.

Information on the leasing grounds (location, accessibility measured by the tide coefficient, number per farm and area per farm) was obtained from the public maritime area register, run by the Departmental direction for territories and sea of Charente-Maritime.

All data were entered by the two interviewers into a purpose built Microsoft© Access 2007 database.

2.4. Statistical data analysis

All statistical analyses were conducted using SAS statistical software (version 9.3 © 2002-2010, SAS Institute Inc., Cary, NC, USA).

2.4.1. Outcome variable

As the reporting behaviour of control farmers appeared to be heterogeneous, reporting farmers were split into two subgroups. A three-category ordered outcome variable was thus created based on the oyster farmers' reporting practices of oyster mortality: Reporting, Formerly-reporting and Non-reporting farmers. Reporting farmers were defined as farmers who had always reported massive mortality outbreaks since 2008. Formerly-reporting farmers were defined as farmers who used to report observed mortality events before 2010 but who had stopped reporting since. Non-reporting farmers were defined as farmers who observed but did not report any oyster mortality. Farmers who observed no oyster mortality whether mortality occurred or not were excluded from the analysis (N=4).

2.4.2. Explanatory variables

The notification process falls into three steps: occurrence of the event, its detection and its notification by the farmer. Because the objective of the present study was to evaluate the potential for improvement to incite oyster farmers to report, only the detection and notification steps were studied.

A total of 50 potential explanatory variables were considered in this study.

Qualitative data from the open-ended questions were analysed using content analysis (Franzosi, 2004) to identify thematic categories. For this purpose, all the interviews were transcribed on a dedicated thematic grid and anonymised. Each respondent's transcripts were read by both interviewers to ensure familiarity with the raw data and to identify key themes and issues. An interpretative coding of the responses was used, which was driven by the data itself and not by pre-determined categories (Franzosi, 2004). Responses were then grouped together by thematic categories. The first transcripts to be analysed were coded meticulously and subsequent interviews were coded according to the thematic categories established by the initial coding process, incorporating any additional emerging issues. Saturation was reached when no new issues were raised and previously-raised issues being repeated.

All explanatory variables were binary or ordinal apart from six which were continuous quantitative, namely: age, surface area and number of leasing grounds, average tide coefficient of leasing grounds, proportions of leasing grounds accessible even at neap and only at strong tide.

Potential explanatory variables were described in terms of frequency distribution (qualitative data) or median and range (quantitative data), classified by the outcome variable.

2.4.3. Outcome modelling

An ordinal logistic regression analysis was conducted to investigate factors associated with the three previously defined farmer reporting behaviours, using a continuation-ratio model (Fienberg, 1980; Dohoo et al., 2009). This model predicts (1) the probability of a non-reporting behaviour, using Equation 1, and (2) the conditional probability of a formerly-reporting behaviour, given that the farmer had already reported at least once, using Equation 2, and can be written as follows:

$$\log \frac{\pi_1 (x_i)}{\pi_2 (x_i) + \pi_3 (x_i)} = \alpha_1 + \beta_1 x_i \qquad \text{(Equation 1)}$$

$$\log \frac{\pi_2 (x_i)}{\pi_3 (x_i)} = \alpha_2 + \beta_2 x_i \qquad \text{(Equation 2)}$$

where x_i designates the explanatory variables, {π1, π2, π3} are the probabilities for the realization of each of the reporting behaviour category, respectively non-reporting, formerly-reporting and reporting behaviour, with the constraint $\pi_1 + \pi_2 + \pi_3 = 1$.

The effect of an explanatory variable is supposed to be heterogeneous across the reporting behaviour category transitions . An unconstrained continuation-ratio model was fitted (Cole and Ananth, 2001), producing two sets of coefficients (β_1 and β_2) for the explanatory variables being investigated, one set for each of the outcome categories above the baseline, i.e. the formerly-reporting versus the Reporting farmer categories, and non-reporting versus the merged categories formerly-reporting and Reporting farmers. The exponentiated regression coefficients (e^{β}) produced odds ratio (OR) as a measure of effect (Dohoo et al., 2009).

As sampling design was outcome-driven, the probability of a farmer being sampled was not the same for all reporting behaviour categories, leading to potentially biased results

(Greenland, 1994; Scott et al., 1997). The sampling design was therefore taken into account in the analysis (SURVEYLOGISTIC procedure, SAS Institute Inc.). A sampling weight was applied to each observed farmer: the contribution of an observation to the calculation was weighted by the inverse of the probability of it being observed (Ciol et al., 2006).

As sampling rates were not small enough to ignore, a finite population correction factor was included in the analysis to provide valid variance estimates.

The dataset was suitably restructured to allow the fitting of two separate binary logistic regressions, from which estimates of the continuation-ratio model were derived (Armstrong and Sloan, 1989). A similar variable selection method was applied in both models.

In an initial screening step, univariate ordinal logistic regression analyses were carried out separately for each explanatory variable.

Continuous quantitative variables were categorised according to their quartile values to explore the shape of their relationship with the outcome variable. When the linearity assumption was violated, their best-fitting form was determined by merging logical categories or categories that reflected changes in regression estimates.

Based on the Wald's type 3 test, p-value for variable selection and entry into the multivariate model was 0.25. Any strong colinearity (χ^2 test for nominal variables, $p<0.05$) between explanatory variables was checked, and the most significant variable or the most biologically related to the outcome variable was chosen.

The retained variables, with <5% missing values, were then introduced into a multivariate ordinal logistic regression model fitted with a manual backward-selection procedure (Wald's test, $p<0.05$). Confounding was assessed by checking that the discarded variables induced <20% changes in the coefficients of the other variables. Biologically plausible two-way interactions of the explanatory variables in the final model were tested and retained if significant ($p<0.05$).

2.4.4. Model evaluation

An overall goodness-of-fit statistic pertaining to the simultaneous fitting of the two models was provided by the sum of the two separate deviance statistics (Agresti, 2002), with a non-significant p-value, suggesting a good fitting of the model.

Individual goodness-of-fit, i.e. predictive ability of the model, was assessed by computing its overall classification performance. This was evaluated by comparing the predicted reporting behaviour category (identified as the category with the highest predicted probability for each farmer) with the actual reporting behaviour category. Predicted probabilities of the occurrence of each outcome category were calculated, accounting for the sampling design, to allow a direct interpretation.

3. Results

3.1. Samples description

Due to logistical constraints, only 139 farmers were effectively contacted, of which 31 cases and 89 controls agreed to participate in the study, representing participation rates of 84% and 86%, respectively. Six cases and 13 controls refused a visit, mainly declaring lack of time. Neither farmer (gender, age) nor farm characteristics (geographical location, size, number of leasing grounds, location of the production cycle) differed significantly according to the farmer participation status.

Four case farmers did not experience any mortality event in their oyster production during the 2007–2011 period, and were consequently excluded. Of the 89 reporting farmers, 55% had always reported the observed mortality events since 2008 and 45% used to report mortality events but had stopped reporting since 2010, when mortality notification became related to eligibility for the financial compensation. Thus, the results that follow refer to 27 non-reporting, 40 formerly-reporting and to 49 reporting farmers.

The characteristics of the 116 oyster farmers interviewed are summarized in Table 2. Most of these farmers were male and older than 40. The farms included in the samples were mostly located in the south of the production area and specialized in oyster rearing, with activities related to all production stages. Most farmers had detected mortality events between 2007 and 2011 and the control farmers had first reported a mortality event mainly in 2007 or 2008 (Table 2).

3.2. Description of farmer's practices and perceptions

3.2.1. Description of an oyster mortality event according to the farmers

Most farmers described a mortality event by qualitative criteria involving different senses, such as nauseating odour, observation of empty shells or a specific noise when manipulating the oyster bags (Table 2).

Counting dead oysters to estimate a mortality rate was a common practice and a threshold value was often given to distinguish an "abnormal" mortality event from a usual one, although this varied greatly from one farmer to another.

3.2.2. Oyster mortality reporting practices

In total, 81 control farmers provided responses about their reporting practices. No statistically significant differences were observed between responses of formerly-reporting and reporting farmers.

The reporting process of an oyster mortality event was divided into two steps for 70% of control farmers: they first report the event and then they formally notify it. They were 59% to report to their colleagues, 35% to the Departmental direction for territories and sea and 21% to the local farmer's representatives. Other structures such as Ifremer, collective farmers' society, technical institutes or accountants were also cited, but by less than 5% of interviewed farmers. Farmers mainly report in person (70%), by phone (32%), or by fax (7%).

Notification procedures were fairly well-known by the reporters. They were 60% (47/80) to obtain the notification sheet from the local farmer representatives, 34% from the local competent authority and 5% from their accountant. Most of them (96%; 78/81) transmitted the sheet to the local competent authority and 6% to the local farmer representatives. The notification sheet was mainly delivered to addressee in person (60%; 46/80), by postal mail (89%), by fax (16%) or by email (1%).

Only 5% (4/80) of the reporters transmitted the notification sheet the day or the following day after the mortality detection, 18% did this during the following week and 15% during the following month. Half of them (54%) waited for the *'end of the mortality season'*, i.e. the end of the summer. The remainders (9%) waited until the 31st December of the year, which has been the deadline to submit application files for financial compensation since 2010.

3.2.3. Perceptions of the notification system

Most control farmers (70%; 55/79) considered that reporting oyster mortality events was 'very simple' or 'fairly simple'. However, even if they were 83% (52/63) to be generally satisfied with the reporting system, 63% (50/79) of them commented on its weaknesses: onerous data retrieval (56%), complex procedures (46%), time consuming procedures (30%), impractical data transfer (10%), and lack of guidance for filling in the notification sheet (6%).

About 85% (72/85) of control farmers felt 'very poorly satisfied' or 'poorly satisfied' with the information feedback about the mortality notification system; the reasons they cited were: absence of feedback (61%), too little information received (26%), feedback disparity between the farmers (10%), non-transparency (4%), lack of clarity and understanding of received information (3%).

The aim of the mortality reporting system of early warning was unclear to oyster farmers, in all the reporting behaviour categories. Only 3% (3/88) of the control farmers and none of the 27 case farmers knew that reporting an oyster mortality event was mandatory. The aims cited by the control farmers were: descriptive purpose (50%) and improvement of the understanding of the mortality phenomenon (45%), obtaining financial compensation (45%), sanitary surveillance (6%), and warning alert onset (3%). The case farmers cited: descriptive purpose (68%) and improvement of the understanding of the mortality phenomenon (58%), and obtaining financial compensation (35%).

"Understanding the how and the why, even if we can't do anything about it"-Case #71

Finally, 9% of control and 10% of case farmers believed that this system was useless:

"This can't avoid the problem, knowing what is going on won't change anything"-Control #19

3.2.4. Reasons for under-reporting

The main reasons for non-reporting an oyster mortality event stated by the case farmers were: the amounts of financial compensation were insufficient (39%; 9/23) or that mortality impact on their production was not sufficient enough to be reported (30%). Some of them made the comment *"It's not worth it"* or *"This can't avoid the problem, knowing what is going on won't change anything"-Control #19*

Another 13% believed that the mortality reporting system only concerned oyster spat. As their activity did not include this production stage, they did not feel involved in the system. They were 22% to evoke the complexity of the reporting procedures, which made them reluctant to report. Other reasons, such as feeling of state handouts, system rejection, negligence or missing information about the reporting process were stated by less than 10% of the case farmers.

Among the 89 control farmers, 40 were former reporters, i.e. they had stopped reporting the oyster mortality events they observed since 2010. Only 17 of them provided direct responses to the question of the reasons to stop reporting: 47% of them believed that the amounts of financial compensation were insufficient, 24% evoked the time given to reporting, 24% no longer felt involved because of pending retirement, 12% mentioned the complexity of the system, 12% referred to the decreasing mortality impact on their production in comparison with previous years, 6% felt discouraged because of the endemic situation, and 6% rejected the whole system.

3.3. Factors associated with the farmer reporting behaviour

A total of 29 variables were associated ($p<0.25$) with farmer reporting behaviour in the univariate analysis, of which 13 were included in both models (Table 3). Six of these 29 variables were related to farm characteristics, 12 were related to husbandry and mortality detection practices, six were related to the oyster mortality and economic history of the farm, two were related to mortality reporting history and three were related to farmer opinions of the reporting system.

Four explanatory variables were associated with farmer reporting behaviour in each of the final models (Table 4). Compared with the combined categories of formerly or currently reporting farmers, non-reporting farmers most often had smaller farms, with less than 20 leasing grounds in Charente-Maritime, and a production cycle based in Charente-Maritime but also involving other departments. They were more likely to produce only diploid oysters and had usually not received financial compensation in the years 2007–2009, when all the other variables are held constant. Compared with reporting farmers, former reporters most often had a smaller proportion of leasing grounds that were easily accessible, made their first mortality notification in 2008, thought more often that amount of financial compensation was insufficient and usually did not feel involved in the notification system, when all the other variables are held constant. There were neither confounding effects nor interactions for any of the variables in either of the final models.

The individual effects of the risk factors are illustrated in Figure 1, where the predicted probabilities are shown stratified by the levels of the risk factors

The overall goodness-of-fit statistic suggested that the overall model fitted the observed data well. When farmers were allocated to expected reporting behaviour categories according to predicted probability, the overall correct classification probability of the model was 64% (74/115), with 48% of non-reporting, 75% of formerly-reporting and 65% of reporting farmers correctly predicted (Table 5).

4. Discussion

To our knowledge, this study is the first to provide insights about oyster farmers' reporting practices and behaviour towards oyster mortality events, and the influencing factors.

4.1. Study validity

Random sampling ensured data representativity in both case and control samples. Satisfactory survey participation rates were achieved and non-respondents did not systematically differ from respondents, limiting selection bias. Thus, we can confidently say that the results of this study reflected farmers' reporting behaviour concerning oyster mortality in Charente-Maritime during the study period. However, although Charente-Maritime accounts for one third of the French oyster farms (Agreste, 2005), the present results could not be extended to the whole French oyster farming industry. Indeed, Charente-Maritime is the traditional region for oyster farming and, with Arcachon basin, is a principal site for spat collection in France (Agreste, 2005). As mortality outbreaks have mostly occurred in spat since 2008 (European Food Safety Agency, 2010; Segarra et al., 2010), the farmer reporting behaviour towards spat mortality may differ in other oyster farming regions that do not produce their own spat.

The well-known recommendations to ensure good data collection (Martin et al., 1987) were applied to minimize information bias. The questionnaire was standardized and pilot versions were tested before the study. Due to the declarative nature of the potential explanatory variables, a face-to-face approach was specifically chosen to increase cooperation, consistency and reliability of responses as well as data completeness.

The outcome status was based on the yearly official notification databases provided by the local competent authority. During the interview, we further confirmed this status by checking whether farmers recalled having reported at least one mortality event each year during the study period. Farmers with leasing grounds in other departments could have reported observed oyster mortality to the local competent authority of the other departments, leading to a misclassification bias, as reporters were identified through the local databases in the absence of a national one. However, none of the sampled farmers mentioned this possibility during the interviews. Therefore, misclassification bias is unlikely to have had a significant influence on the observed results.

In this study, the outcome variables modelled different levels of farmer reporting compliance from more to less compliant with the mandatory reporting of oyster mortality. Thus, the continuation-ratio model was a reasonable starting formulation, as it is designed for situations in which the ordered categories represent a longitudinal progression through stages (Ananth and Kleinbaum, 1997) and notably when individual categories of the outcome are of intrinsic interest (McCullagh and Nelder, 1989). Here, the interest lies in comparing non-reporting vs. reporting farmers, and inside the reporting category, whether reporters had stopped reporting. However, the reporting behaviour categories were not considered to be equidistant, being a former reporter is considered more similar to being a current reporter than a non-reporter. Thus, an unconstrained continuation-ratio model was built, consisting in simultaneously fitting two separate models (Armstrong and Sloan, 1989), to allow the possibility of transition-dependent explanatory variables (Allison, 2012).

Usually, sampling designs for ordinal outcome studies are based on a cross-sectional survey or longitudinal follow-up i.e. one sample further split into different outcome categories. Here, a case-control study, based on outcome-dependent sampling where individuals are sampled depending on their outcome status and exposure information is then collected on the sampled individuals, provided data for further outcome sub-classification. Naïve fitting of a continuation-ratio model under such a retrospective outcome-dependent sampling design would obtain biased parameter estimations (Greenland, 1994); whereas, with multiple outcome categories, coefficient estimates of the logistic regression are not modified by the sampling design, the intercept of the model is. This leads to biased and inaccurate predicted probabilities, as these are largely determined by the relative sample sizes for cases and controls. The sampling design was therefore taken into account in the analysis.

4.2. Reporting practices

The results of this study suggested that notification procedures were well known by the formerly and currently reporting farmers, a result that contrasts with those from Dutch pig farmers who felt uncertainty about them (Elbers et al., 2010a). The reporting system was generally well accepted. The majority of the respondents considered that reporting an oyster mortality event was simple but a minority found it time consuming and complex. However, farmers tended to be dissatisfied with the feedback from the reporting system, considering themselves as poorly informed.

A misunderstanding of the aims of the reporting system was highlighted, as only 3% of the reporting farmers mentioned its surveillance and early warning purposes. A confounding with the financial compensation for production losses was frequent in the three reporting behaviour categories. In addition, the length of time between mortality observation and reporting was very variable, only 23% of the control farmers reporting within the week following the mortality observation and most did this at the end of the summer. This lack of reactivity may be explained by the misunderstanding of the aims of the mandatory notification. Delayed reporting is still frequent in animal-disease surveillance systems (World Bank, 2010). Given the importance of this issue for early detection of disease outbreaks in shellfish production, because openness and connectivity of marine systems enhance disease spread (McCallum et al., 2004) and limit the use of classical control measures (Renault, 2009), farmers' lack of awareness about disease reporting warrants further attention. The farmers need to be better informed to encourage timely reporting of oyster mortality.

4.3. Factors associated with farmer reporting behaviour

While the reasons for under-reporting often differ from one animal disease surveillance system to another, a number of common factors prevail. Two main groups of factors can usually explain under-reporting: inability to report (either inability to detect the event or to access to the reporting channels) or unwillingness to report, usually related to the existence of disincentives (World Bank, 2010). In this study, two different sets of factors were identified driving a farmer's decision to report oyster mortality, pertaining to both of these two main groups.

Detection is the limiting factor more often than access to reporting channels, and is commonly the result of insufficient awareness of a disease or of its threats (World Bank, 2010). In the present study, the lack of awareness about mortality reporting was highlighted and this was suspected to occur more frequently than the inability to detect oyster mortality or to access the reporting channels, as all the non-reporters had observed oyster mortality at least once during the study period and complexity of reporting procedures was only mentioned by 22% of the non-reporting farmers.

Unclear case definition can hinder disease reporting (World Bank, 2010), as for abortion in livestock (Bronner et al., 2013a), or a lack of specificity of clinical signs if a particular disease must be reported, such as avian influenza (Elbers et al., 2010b) or classical swine fever (Elbers et al., 2010a). The regulatory oyster mortality definition is subjective and its estimation is not straightforward(European Union, 2006). In the present study, both qualitative and quantitative criteria used by the oyster farmers were collected to define an oyster mortality event. In particular, in the univariate analysis, counting dead oysters was significantly associated with compliant farmer reporting behaviour. This variable could be interpreted as an indicator of the attention farmers paid to their oysters, indicating a greater watchfulness of oysters by the combined categories of formerly- or currently-reporting farmers than by non-reporting farmers.

The model relating the probability of a non-reporting behaviour showed that the farmers producing exclusively diploid oysters were seven times more likely to under-report observed mortality than those producing triploid oysters. Production type highly influences husbandry management practices and the attention paid to the animals. This was also identified as an influencing factor for the under-reporting in the mandatory abortion notification system in cattle (Bronner et al., 2013b). Farmers producing exclusively diploid oysters often obtain sufficient spat resources from the sea, collecting "wild" spat in summer for free. Since the 1990s, hatcheries also sell oyster spat, which is either diploid or triploid, to oyster farmers throughout the year (Gérard, 1994). Purchasing oysters may lead farmers to watch their shellfish more closely, which increases the probability of mortality detection and, thus, reporting. Effectively, although farmers raising triploid oysters did not differ farmers producing only diploid oysters as regards their own characteristics nor the general items of their farms, they had a tendency to visit their leasing grounds more often (p=0.08). They were also more likely to count dead oysters (p=0.02).

The probability of a farmer under-reporting oyster mortality was higher in farms having less than 20 leasing grounds, which could be considered as a proxy of the farm size. The farmers owning these smaller farms often worked alone, performing all oyster farming activities without any employees, which would leave them with a smaller amount of time for oyster observation, thus decreasing the probability of mortality detection and of reporting. The farmers farming with a small area were older ($p<0.001$) and were less likely to count dead oysters ($p=0.03$) than farmers having more than 20 leasing grounds. Small farm size was also reported to be associated with a lower probability of reporting abortions in cattle (Bronner et al., 2013b) and scrapie suspicion in sheep (Hopp et al., 2007).

The farmers with a production cycle located both in Charente-Maritime and other departments were six times more likely to under-report observed oyster mortality than the ones with a local production cycle. This may also indicate that splitting farming activities between different locations reduces time for observation of oysters located in Charente-Maritime, decreasing the probability of mortality detection by the farmer and, thus, reporting.

Unwillingness to report is usually related to the existence of disincentives, such as bad consequences for trade or reputation or the lack of compensation for farmers (World Bank, 2010), or lack of trust in government (Palmer, 2009; Elbers et al., 2010a; Limon et al., 2013). In the present study, none of these were stated by the interviewed farmers, as, currently, mortality notification does not lead to truly penalizing consequences for oyster farmers. However, farmers who had never received financial compensation for oyster mortality before 2010 were eight times more likely to under-report oyster mortality than farmers who had already been compensated. This clearly illustrated the incentive effect of financial compensation for French oyster farmers, as previously reported for Dutch poultry farmers (Elbers et al., 2010b) or Norwegian sheep farmers (Hopp et al., 2007) but contrasts with Dutch pig farmers (Elbers et al., 2010a). However, even though compensation mechanisms were in place, some of the interviewed farmers had stopped reporting since 2010.

In fact, awareness and willingness to report should not be considered static. In the case of endemic diseases, people can often become accustomed to a situation (World Bank, 2010). This habituation effect may have occurred here; the farmers' motivation to report mortality may have been reduced by the lack of available and effective measures to control the spread of this emerging pathogen in open waters, leading to this infection becoming endemic (Lupo et al., 2011b).

The model relating the conditional probability of a formerly-reporting behaviour, given that the farmer had already reported oyster mortality, has shown that the farmers with a small proportion of leasing grounds that are easily accessible (i.e. even at neap tide) were four times more likely to stop reporting oyster mortality. This may indicate lassitude as regards the effort needed to regularly monitor their oysters in relation to the perceived benefit. Indeed, the probability for a farmer to stop reporting oyster mortality was higher when the farmers thought that the amount of financial compensation was insufficient, and if they did not feel involved by the reporting system. These supported the hypothesis that formerly-reporting farmers were unaware of the legal framework of shellfish disease surveillance and that they misunderstood the aims of the reporting system, confounding them with the financial compensation system.

The farmers who had first notified authorities of oyster mortality in 2008 were eight times more likely to stop reporting oyster mortality than the others. This may illustrate a lack of awareness of the legal framework of the disease surveillance, formerly-reporting farmers being mostly influenced by recent events, as 2008 is the year when severe mass mortality outbreaks occurred in spat of Pacific oyster, associated with the first description of the virus genotype OsHV-1 µVar (Segarra et al., 2010).

These results supported the hypothesis of a habituation effect combined with a lack of awareness of the aims of the surveillance system, oyster farmers looking for the self-interest in reporting, different from early detection of a disease outbreak. Such expectations have also been identified in French cattle farmers (Bronner et al., 2013a), Bolivian livestock smallholders (Limon et al., 2013) and Dutch pig farmers (Elbers et al., 2010a).

Many programs to improve compliance with reporting duties have failed because they addressed only one reason for under-reporting, while neglecting others (World Bank, 2010). In France, since 2008, a system for financial compensation for oyster production losses was put in place and, since 2010 mortality notification has become mandatory to access to the financial compensation (French Ministry of Agriculture, 2010b). The results of the present study suggest that financial compensation was a clear incentive for farmers to report oyster mortality. Despite this, some of the farmers have stopped reporting since 2010, suggesting that financial compensation was not sufficient to sustain their motivation to report oyster mortalities, as it was observed after the H7N7 highly pathogenic avian influenza epidemic in 2003 in the Netherlands (Elbers et al., 2010b). Indeed, the challenge is to find a strategy that is not only successful, but also sustainable (Hoinville et al., 2009). As previously observed in Norwegian sheep farmers (Hopp et al., 2007), this study has identified both economic and non-economic values that influence French oyster farmers' reporting behaviour. In particular, their reporting behaviour reflected a lack of knowledge about the major issue of timely reporting oyster mortality, as half of the reporters waited the end of the summer to report. These results suggest that financial incentive is not sufficient to achieve the aim of early detection of disease, notably because it does not account for the need of a timely reporting. These also suggest that, to ensure sustainable compliance of oyster farmers with reporting duties, their concerns about non-economic values should also be considered. In particular, oyster mortality reporting could be improved by changing these attitudes through farmer education concerning the aims of a surveillance system and the great importance of their vigilance and timely reporting for the detection of potential emerging or exotic diseases in shellfish. For this, participatory approaches are needed to ensure that the system will be responsive to stakeholders' needs and to increase their sense of ownership and commitment towards sustaining the system (Mariner et al., 2011). In addition, studies through participatory approaches about disease management in farmed marine shellfish, in particular measures to mitigate the effects of diseases on production, may constitute practical means for sustaining the motivation of oyster farmers to participate in the surveillance system.

4. Conclusion

This study provided some first insights into the factors driving a farmer's decision to report oyster mortality , pertaining to inability to detect the mortality event and to unwillingness to report. Financial compensation for oyster production losses appeared to be a clear incentive for reporting, but was countered by a habituation effect, combined with a lack of awareness of the aims of the reporting system: oyster farmers sought self-interest in reporting rather than the early detection of a disease outbreak.

Results showed that both economic compensation and farmers' non-economic values and perceptions should be taken into account to improve oyster farmer reporting compliance and sustainability. These findings are relevant from an educational as well as an animal-health perspective because they indicate that oyster mortality reporting could be improved by changing attitudes through education and participatory approaches.

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Conflict of interest statement

None.

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Table 1. Summary of the content of the questionnaire used to analyse factors associated with farmers' reporting practices and behaviour towards oyster mortality, Charente-Maritime, France, 2012

[Table 1 here]

Table 2. Descriptive results for potential explanatory variables associated with farmer reporting behaviour of oyster mortalities, Charente-Maritime, France, 2012

[Table 2 here]

Table 3. Explanatory variables for the farmer reporting behaviour retained at the univariate step, Charente-Maritime, France, 2012

[Table 3 here]

Table 4. Final multivariate continuation-ratio logit model[1] for farmer reporting behaviour concerning oyster mortality, Charente-Maritime, France, 2012

[Table 4 here]

Table 5. Contingency table for the classification performance of the final model for reporting behaviour categories

[Table 5 here]

Figure 1. Predicted probabilities[2] of the three reporting behaviour categories stratified by

[1] Deviance =22.34, model d.f.=15, Goodness-of-fit χ^2-test statistic p-Value = 0.10

[2] Using baseline case: <20 leasing grounds in Charente-Maritime; <25% leasing grounds accessible even at neap tide; production cycle located in Charente-Maritime and in other departments; only diploid oysters produced;

levels of the risk factors, based on the results from an ordinal logistic regression for farmer reporting behaviour concerning oyster mortality, Charente-Maritime, France, 2012

[Figure 1 here]

first mortality notification in 2008; no compensation received during 2007-2009; farmer did not feel involved in the notification system; and farmer thought that amount of compensation is insufficient.

Table 1. Summary of the content of the questionnaire used to analyse factors associated with farmers' reporting practices and behaviour towards oyster mortality, Charente-Maritime, France, 2012

Sociodemographics
Gender, age
Membership of a collective farmer's society
Farm characteristics
Other animal species produced, level of specialization
Farming practices
Rearing cycle: place and time for spat collection and growing
Types of production
Frequency of visits to leasing grounds
Oyster mortality history
Description of a mortality event, method used for detection
Time of occurrence, type and origin of concerned oysters
Perception of financial compensation for oyster mortality
Oyster mortality reporting system
Knowledge
Mandatory aspect of the mortality notification
Reporting procedures and tools, communication tools
Reporting practices and behaviour
Regularity, reporting time, time needed
Reasons for under-reporting
Attitudes toward the reporting system
Perceived usefulness, perceived simplicity, satisfaction level with the system, with the data feedback
Perceived drawbacks, desired improvements

Table 2. Descriptive results for potential explanatory variables associated with farmer reporting behaviour of oyster mortalities, Charente-Maritime, France, 2012

Variables and categories	Reporting behaviour		
	No. of responses (%) or median [range]		
	Reporter (N=49)	Former reporter (N=40)	Non reporter (N=27)
Characteristics of the oyster farmer			
Gender			
Male	43 (88)	37 (93)	27 (100)
Female	6 (12)	3 (7)	0 (0)
Age	48 [30-65]	49 [31-68]	49 [29-74]
29-41 years	11 (25)	8 (21)	4 (15)
41-47 years	11 (25)	9 (24)	8 (31)
48-52 years	9 (20)	10 (26)	6 (23)
53 and older	13 (30)	11 (29)	8 (31)
Member of a collective farmer's society			
Yes	19 (39)	14 (35)	10 (37)
No	30 (61)	26 (65)	17 (63)
General items related to the farm			
Geographical location of the farm headquarters			
North	7 (14)	6 (15)	1 (4)
South	42 (86)	34 (85)	26 (96)
Had side activity			
Yes	6 (12)	7 (17)	5 (19)
No	43 (88)	33 (83)	22 (81)
Other shellfish produced			
Yes	6 (12)	5 (12)	3 (11)
No	43 (88)	35 (88)	24 (89)
Farm size (total leasing area) in Charente-Maritime	280 [26-1197]	235 [45-612]	188 [6-967]
<200 m²	11 (23)	16 (40)	15 (56)
≥200 m²	37 (77)	24 (60)	12 (44)
Number of leasing grounds in Charente-Maritime	23 [1-70]	19 [5-50]	16 [1-31]
<20	15 (31)	22 (55)	21 (78)
≥20	33 (69)	18 (45)	6 (22)
Average tide coefficient of the leasing grounds	65 [30-84]	65 [32-87]	64 [38-82]
<55	8 (17)	5 (13)	8 (32)
≥55	39 (83)	34 (87)	17 (68)
Proportion of leasing grounds accessible only at strong tide (tide coefficient ≥70)	56 [0-100]	58 [14-100]	69 [33-100]
<60%	33 (70)	27 (69)	11 (44)
≥60%	14 (30)	12 (31)	14 (56)
Proportion of leasing grounds accessible even at neap tide (tide coefficient <70)	44 [0-100]	42 [0-86]	31 [0-67]

<25%	6 (13)	9 (23)	9 (36)
≥25%	41 (87)	30 (77)	16 (64)
Husbandry practices			
Location of the production cycle			
Only in Charente-Maritime	37 (76)	32 (80)	18 (67)
In Charente-Maritime and other departments	12 (24)	8 (20)	9 (33)
Production stages			
Spat collection + farming+ sending	40 (82)	32 (80)	17 (63)
Spat collection +/- farming +/- sending	9 (18)	8 (20)	10 (37)
Spat collection			
Yes	46 (94)	37 (92)	23 (85)
No	3 (6)	3 (8)	4 (15)
Growing			
Yes	48 (92)	38 (95)	23 (85)
No	1 (2)	2 (5)	4 (15)
Sending			
Yes	41 (84)	34 (85)	21 (78)
No	8 (16)	6 (15)	6 (22)
Spat selling			
Yes	47 (96)	37 (92)	22 (81)
No	2 (4)	3 (8)	
Oyster purchase			
Yes	30 (61)	21 (53)	7 (26)
No	19 (39)	19 (47)	20 (74)
Production type			
Only diploid oysters	17 (35)	19 (48)	22 (81)
Triploid +/- diploid oysters	32 (65)	21 (52)	5 (19)
Farming technique			
Off-bottom (plastic mesh bags set on trestles)	45 (92)	37 (92)	23 (85)
On-bottom (onto the intertidal seabed)	4 (8)	3 (8)	4 (15)
Frequency of visits to each leasing ground			
More often than twice a month	23 (47)	22 (55)	15 (55)
Once a month	19 (39)	11 (27)	8 (30)
Not predetermined	7 (14)	7 (18)	4 (15)
Detecting practices of an oyster mortality			
Nauseating odour			
Yes	26 (53)	29 (72)	13 (48)
No	23 (47)	11 (28)	14 (52)
Empty shells			
Yes	47 (96)	37 (92)	25 (93)
No	2 (4)	3 (8)	2 (7)
Flesh in shells[3]			
Yes	20 (41)	16 (40)	15 (56)
No	29 (59)	24 (60)	12 (44)

[3] In shellfish, death leads to detachment of the body (flesh) of the animal from its shell and this flesh is quickly carried away by the sea water currents. Thus, observation of flesh in the shell of the dead animal is an indicator of recent occurrence of mortality.

Specific noise when manipulating oyster bags			
Yes	6 (12)	4 (10)	6 (22)
No	43 (88)	36 (90)	21 (78)
Counting dead oysters			
Yes	43 (93)	32 (86)	17 (68)
No	3 (7)	5 (14)	8 (32)
Threshold mortality % considered abnormal			
<20%	15 (32)	10 (28)	11 (42)
≥20%	32 (68)	26 (72)	15 (58)
Mortality history of oyster production			
Mortality detection during 2008-2011			
Yes	44 (90)	38 (95)	23 (85)
No	5 (10)	2 (5)	4 (15)
Mortality detection in 2007			
Yes	12 (24)	8 (20)	5 (19)
No	37 (76)	32 (80)	22 (81)
Mortality detection in 2008			
Yes	44 (90)	39 (93)	23 (85)
No	5 (10)	1 (3)	4 (15)
Mortality detection in 2009			
Yes	45 (92)	40 (100)	25 (93)
No	4 (2)	0 (0)	2 (7)
Mortality detection in 2010			
Yes	46 (94)	39 (97)	26 (96)
No	3 (6)	1 (3)	1 (4)
Mortality detection in 2011			
Yes	46 (94)	39 (97)	26 (96)
No	3 (6)	1 (3)	1 (4)
Oyster mortality reporting history			
First notification in 2007			
Yes	17 (35)	5 (13)	0
No	32 (65)	35 (87)	0
First notification in 2008			
Yes	17 (35)	32 (80)	0
No	32 (65)	8 (20)	0
First notification in 2009			
Yes	6 (12)	1 (3)	0
No	43 (88)	39 (97)	0
First notification in 2010			
Yes	4 (8)	2 (5)	0
No	45 (92)	38 (95)	0
First notification in 2011			
Yes	5 (10)	0 (0)	0
No	44 (90)	40 (100)	0
Economic history of the farm related to financial compensation for oyster production losses			

Compensation received during 2007-2011			
Yes	48 (98)	35 (87)	12 (44)
No	1 (2)	5 (13)	15 (56)
Compensation received during 2007-2009 (before notification was mandatory to obtain compensation)			
Yes	46 (94)	34 (85)	11 (41)
No	3 (6)	6 (15)	16 (59)
Compensation received in 2007			
Yes	4 (8)	2 (5)	0 (0)
No	45 (92)	38 (95)	27 (100)
Compensation received in 2008			
Yes	43 (88)	28 (70)	9 (33)
No	6 (12)	12 (30)	18 (67)
Compensation received in 2009			
Yes	46 (94)	31 (77)	6 (22)
No	3 (6)	9 (23)	21 (78)
Compensation received in 2010			
Yes	45 (92)	26 (65)	4 (15)
No	4 (8)	14 (35)	23 (85)
Compensation received in 2011			
Yes	46 (94)	20 (50)	3 (11)
No	3 (6)	20 (50)	24 (89)
Perceptions towards mandatory notification of oyster mortality			
Farmer thought the notification system too complex[4]			
True	22 (45)	22 (55)	7 (26)
False	27 (55)	18 (45)	20 (74)
Farmer did not feel involved in the notification system[1]			
True	2 (4)	7 (18)	8 (30)
False	47 (96)	33 (83)	19 (70)
Farmer adopted a fatalistic and discouraged attitude with regard to the current situation [1]			
True	7 (14)	3 (8)	5 (19)
False	42 (86)	37 (92)	22 (81)
Confounded mortality notification system for surveillance with compensation system for losses[1]			
True	31 (63)	28 (70)	20 (74)
False	18 (37)	12 (30)	7 (26)
Farmer thought the amount of compensation insufficient[1]			
True	48 (98)	31 (77)	20 (74)
False	1 (2)	9 (23)	7 (26)

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[4] These variables were built transversally from the responses to different questions.

Table 3. Explanatory variables for the farmer reporting behaviour retained at the univariate step, Charente-Maritime, France, 2012

Variables and categories	Former reporter vs. Reporters				p-Value	Non reporters vs. (Former reporters and Reporters)				p-Value
	β_1	SE(β_1)	OR_1	OR_1 $CI_{95\%}$		β_2	SE(β_2)	OR_2	OR_2 $CI_{95\%}$	
General items related to the farm										
Geographical location of the farm headquarters South vs. North	0.029	0.285	1.06	0.35-3.23	0.92	-0.746	0.498	0.22	0.03-1.58	0.134
Farm size (leasing area in Charente-Maritime) <200 m² vs. ≥200 m²	0.404	0.223	2.24	0.94-5.37	0.070	0.519	0.212	2.82	1.23-6.47	0.014
Number of leasing grounds <20 vs. ≥20	0.495	0.211	2.69	1.18-6.14	0.019	0.787	0.239	4.82	1.89-12.33	0.001
Average tide coefficient of the leasing grounds <55 vs. ≥55	-0.166	0.292	0.72	0.23-2.25	0.57	0.486	0.248	2.64	1.00-6.97	0.050
Proportion of leasing grounds accessible only at strong tide (tide coefficient ≥70) <65% vs. ≥65%	-0.023	0.223	0.95	0.40-2.29	0.92	-0.539	0.220	0.34	0.14-0.81	0.015
Proportion of leasing grounds accessible even at neap tide (tide coefficient <70) <25% vs. ≥25%	0.359	0.275	2.05	0.70-6.01	0.191	0.490	0.238	2.66	1.05-6.78	0.040
Husbandry practices										
Location of the production cycle Charente-Maritime and other departments vs. only in Charente Maritime	-0.130	0.244	0.77	0.30-2.01	0.59	0.273	0.226	1.73	0.71-4.18	0.23

Production stages Spat collection + farming+ sending vs. spat collection +/- farming +/- sending	-0.053	0.256	0.90	0.33-2.45	0.84	-0.456	0.226	0.40	0.17-0.97	0.043
Spat collection Yes vs. no	-0.109	0.400	0.80	0.16-3.86	0.79	-0.573	0.306	0.32	0.10-1.06	0.061
Growing Yes vs. no	-0.463	0.588	0.40	0.04-3.97	0.43	-0.803	0.376	0.20	0.05-0.88	0.033
Spat selling Yes vs. no	-0.322	0.444	0.53	0.09-2.99	1.47	-0.536	0.334	0.34	0.09-1.27	0.108
Oyster purchase Yes vs. no	-0.178	0.204	0.70	0.32-1.56	0.38	-0.672	0.229	0.26	0.11-0.64	0.003
Production type Only diploids vs. triploids +/- diploids	0.266	0.206	1.70	0.76-3.82	0.20	0.934	0.253	6.48	2.40-17.48	0.002
Detecting practices of an oyster mortality										
Nauseating odour Yes vs. no	0.423	0.215	2.33	1.00-5.42	0.049	-0.278	0.208	0.57	0.25-1.30	0.18
Flesh in shells Yes vs. no	-0.017	0.205	0.97	0.43-2.16	0.93	0.305	0.208	1.84	0.81-4.16	0.14
Specific noise when manipulating oyster bags Yes vs. no	-0.114	0.323	0.80	0.22-2.83	0.72	0.407	0.268	2.26	0.79-6.46	0.13
Counting dead oysters Yes vs. no	-0.403	0.364	0.45	0.11-1.86	0.27	-0.742	0.269	0.23	0.08-0.65	0.006

Value of the mortality % abnormal threshold <20% vs. ≥20%	-0.099	0.231	0.82	0.33-2.03	0.67	0.266	0.218	1.70	0.72-4.01	0.22
Notification history of oyster mortality										
First notification in 2007 Yes vs. no	-0.657	0.267	0.27	0.09-0.77	0.014	NA[5]	NA	NA	NA	NA
First notification in 2008 Yes vs. no	1.010	0.235	7.53	3.00-18.88	<0.0001	NA	NA	NA	NA	NA
Mortality history of the oyster production										
Mortality detection in 2008 Yes vs. no	0.744	0.528	4.43	0.56-35.11	0.16	-0.439	0.323	0.42	0.12-1.47	0.17
Economic history of the farm related to compensation for oyster production losses										
Financial compensation received during 2007-2009 No vs. yes	0.498	0.351	2.71	0.68-10.71	0.16	1.280	0.247	12.93	4.90-34.07	<0.001
Financial compensation received in 2008 No vs. yes	0.561	0.263	3.07	1.10-8.60	0.034	1.033	0.228	7.89	3.23-19.28	<0.0001
Financial compensation received in 2009 No vs. yes	0.747	0.334	4.45	1.20-16.47	0.025	1.556	0.262	22.46	8.06-62.60	<0.0001

[5] Not available

Financial compensation received in 2010										
No vs. yes	0.901	0.292	6.06	1.93-19.04	0.002	1.561	0.283	22.68	7.49-68.62	<0.0001
Financial compensation received in 2011										
No vs. yes	1.365	0.319	15.33	4.39-53.51	<0.0001	1.567	0.309	22.96	6.85-76.94	<0.0001
Perceptions toward mandatory notification of oyster mortality										
Farmer felt the notification system was too complex										
True vs. false	0.514	0.229	2.79	1.14-6.84	0.025	-0.203	0.203	0.67	0.30-1.47	0.32
Farmer did not feel involved in the notification system										
True vs. false	0.803	0.694	4.99	1.07-23.34	0.041	0.660	0.258	3.74	1.36-10.28	0.011
Farmer thought the amount of compensation insufficient										
True vs. false	1.317	0.510	13.94	1.89-102.9	0.010	0.509	0.260	2.77	1-7.65	0.050

Table 4. Final multivariate continuation-ratio logit model[6] for farmer reporting behaviour concerning oyster mortality, Charente-Maritime, France, 2012

Variables and categories	**Former reporters vs. Reporters[7]**				**p-Value**	**Non-reporters vs. (Former reporters and Reporters)[8]**				**p-Value**
	β_1	$SE(\beta_1)$	OR_1	OR_1 $CI_{95\%}$		β_2	$SE(\beta_2)$	OR_2	OR_2 $CI_{95\%}$	
Intercept	2.089	0.765				-1.234	0.238			
Number of leasing grounds <20 vs. ≥20						0.801	0.314	4.96	1.45-16.97	0.011
Proportion of leasing grounds accessible even at neap tide <25% vs. ≥25%	0.724	0.325	4.26	1.19-15.20	0.026					
Location of the production cycle In Charente-Maritime and other departments vs. only in Charente-Maritime						0.926	0.295	6.37	2.00-20.26	0.002
Production type Only diploid oysters vs. triploid +/- diploid oysters						0.985	0.274	7.18	2.45-20.99	0.0003
First mortality notification in 2008 Yes vs. no	1.063	0.289	8.37	2.69-26.02	0.0002					
Financial compensation received during 2007-2009 period No vs. yes						1.011	0.306	7.55	2.28-25.04	0.0009
Farmer did not feel involved in the notification system True vs. false	0.997	0.398	7.34	1.54 -34.96	0.012					

[6] Deviance =22.34, model d.f.=15, Goodness-of-fit χ^2-test statistic p-Value = 0.10
[7] Number of observations = 39 Formerly reporting and 47 Reporting farmers, Deviance =5.29, model d.f.=6
[8] Number of observations = 27 Non-reporting farmers and 86 Formerly-reporting or Reporting farmers, Deviance =17.05, model d.f.=9

Farmer thought the amount of compensation insufficient					
True vs. false	1.427	0.720	17.34	1.03-291.21	0.047

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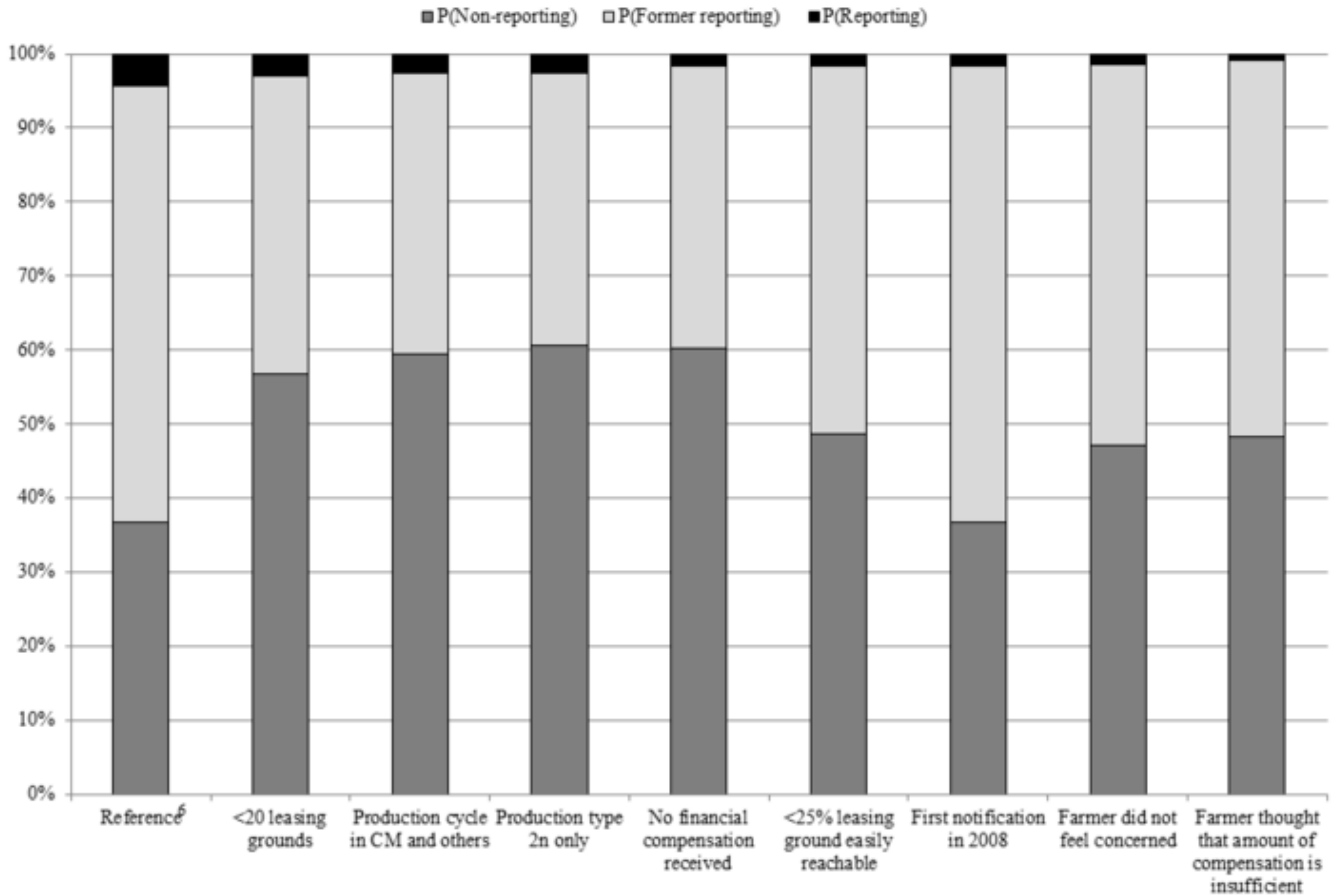
Table 5. Contingency table for the classification performance of the final model for reporting behaviour categories

Observed outcome category	**Observed number**	**Predicted outcome category**		
		Reporting farmer	Formerly-reporting farmer	Non-reporting farmer
Reporting farmer	48	31	17	0
Formerly-reporting farmer	40	5	30	5
Non-reporting farmer	27		14	13

Figure 1



P(Non-reporting)
P(Former reporting)
P(Reporting)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Reference[6]
<20 leasing grounds
Production cycle in CM and others
Production type 2n only
No financial compensation received
<25% leasing ground easily reachable
First notification in 2008
Farmer did not feel concerned
Farmer thought that amount of compensation is insufficient