Risk assessment for the design of a risk-based surveillance programme for fish farms in Switzerland (in accordance with Council Directive 2006/88/EC of the European Union)

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Summary

Swiss aquaculture farms were assessed according to their risk of acquiring or spreading viral haemorrhagic septicaemia (VHS) and infectious haematopoietic necrosis (IHN). Risk factors for the introduction and spread of VHS and IHN were defined and assessed using published data and expert opinions. Among the 357 aquaculture farms identified in Switzerland, 49.3% were categorised as high risk, 49.0% as medium risk and 1.7% as low risk. According to the new Directive 2006/88/EC for aquaculture of the European Union, the frequency of farm inspections must be derived from their risk levels.

A sensitivity analysis showed that water supply and fish movements were highly influential on the output of the risk assessment regarding the introduction of VHS and IHN. Fish movements were also highly influential on the risk assessment output regarding the spread of these diseases.

Keywords

Aquaculture – Infectious haematopoietic necrosis – Risk analysis – Risk factor – Viral haemorrhagic septicaemia.

Introduction

Council Directive 2006/88/EC on animal health requirements for aquaculture animals and products thereof, and on the prevention and control of certain diseases in aquatic animals (1), became operative on 1 August 2008 in all countries of the European Union (EU). This new Directive for aquaculture replaced older ones, which were part of the bilateral treaties between Switzerland and the EU. According to these treaties, Switzerland must achieve equivalence with the legislation of the EU and therefore with Directive 2006/88/EC (1), which prescribes *inter alia* the active, risk-based surveillance of fish farms. Guidelines for risk-based animal health surveillance schemes provided for in the Directive are published in the Commission Decision 2008/896/EC of 20 November 2008 (2). The Decision proposes a model for classifying the individual risk level of farms as low, medium or high. The risk level determines the frequency of farm inspections. At present, surveillance of aquaculture farms in Switzerland is based on notification of disease, not on active inspections of farms to measure their health status. The Federal Veterinary Office therefore called for a project to develop a risk-based surveillance system adapted to fish-farming conditions in Switzerland but also equivalent to the EU Directive for aquaculture.

According to the Directive (1, 3), the risk-based animal health surveillance scheme shall aim to detect diseases listed in Part II of Annex IV. The following non-exotic diseases are listed: viral haemorrhagic septicaemia (VHS), infectious haematopoietic necrosis (IHN), koi herpes virus (KHV) disease and infectious salmon anaemia (ISA). The diseases VHS and IHN have been integrated in the risk assessment presented here because of their importance in both Switzerland and the EU. To date, ISA has never been detected in Switzerland and KHV is, for historical reasons, not included in the list of notifiable diseases in the Swiss legislation, because carp (*Cyprinus carpio*) farming has no relevance in Switzerland. Although the keeping of ornamental koi carp is increasing in popularity and KHV is at times diagnosed in ponds stocked with koi, there is no indication that Switzerland will change its list of notifiable diseases in the near future.

Viral haemorrhagic septicaemia is a major cause of mortality in farmed salmonids (Salmonidae) in fresh water, above all in rainbow trout (*Oncorhynchus mykiss*). All salmonids of the genera *Salmo*, *Oncorhynchus*, *Salvelinus* and *Thymallus* are susceptible to VHS, which is caused by a rhabdovirus. In farmed fish, transport, fluctuations of water temperature, high population density or other stress factors can induce the disease if the temperature is below 18°C. Three disease phases of VHS have been described. The acute phase involves high mortalities. Although many fish do not show external changes, others are darkened and lethargic, showing exophthalmia and fine haemorrhages in the skin, eyes, musculature and internal organs. The chronic phase is characterised by a moderate, protracted mortality. Fish are dark in colour, with anaemia and exophthalmia. In the nervous phase, fish exhibit a looping swimming behaviour, but mortality is low. In Switzerland, laboratory confirmation of the presence of the infectious agent is a prerequisite for official disease-control measures. The method of choice is culture of the virus on cell lines and its subsequent identification. There is no effective therapy for the disease. After detection of infected fish, the destruction of all stocks at the relevant farm, followed by disinfection, is compulsory. Disinfection and quarantine are the most effective prophylactic means of controlling VHS epidemics (4, 5, 6).

Infectious haematopoietic necrosis is a major cause of mortality in young salmonids farmed in fresh water and is caused, as for VHS, by a rhabdovirus. The disease occurs at a range of water temperatures between 8°C and 15°C. The typical presentation of IHN is increased mortality among fry and fingerlings, whereas adult fish have lower mortality and may not show clinical signs. The fish develop dark colouration, exophthalmia, haemorrhage at the base of the fins and in the skin, and petechiation of the musculature, visceral fat, mesenteries, peritoneum, swim bladder, meninges and pericardium. Fish that survive an infection acquire immunity to reinfection but are considered lifelong carriers. As in the case of VHS, Swiss legislation requires detection of the pathogen for diagnosis of IHN. There is also no effective therapy for the disease. As is the case for VHS, demonstration of IHN infection necessitates the destruction of all fish stocks at the relevant farm. Disinfection and quarantine are the only proven prophylactic means of controlling IHN epidemics (4, 6). The high cost of complete disinfection after demonstration of VHS or IHN virus can compromise the existence of an aquaculture farm (7).

Risk-based veterinary surveillance has been defined as a surveillance programme in the design of which exposure and risk-assessment methods are applied together with traditional design approaches in order to assure appropriate and cost-effective data collection. The principal objectives are to identify surveillance needs, set priorities, and allocate resources effectively and efficiently. Such a programme offers an efficient approach for early detection and management of disease (8). A risk assessment evaluates the likelihood and the biological, environmental and economic consequences of the occurrence of a potential hazard. Risk analysis can be quantitative, qualitative or semi-quantitative as in our model. A qualitative risk assessment is essentially a reasoned and logical discussion of the relevant commodity factors and epidemiology of a hazard where the likelihood of its release and exposure and the magnitude of its consequences are expressed using non-numerical terms such as ‘high’, ‘medium’, ‘low’ or ‘negligible’. This type of assessment is suitable in the majority of cases and is in practice the most common type of assessment undertaken to support routine decision-making.

Nevertheless, regardless of which method is adopted, it is important to appreciate that risk assessment inevitably includes a degree of subjectivity (9). Thus, a clear benefit of risk analysis is the requirement for transparent documentation of the evidence and assumptions used. Risk analysis incorporates risk communication, which should allow all stakeholders to participate in the analysis, thus building understanding around the conclusion and risk-management decisions. Stakeholders gain a degree of ‘ownership’ in the process (10).

Risk assessment in aquatic animal health has been used mainly to assess the risk of disease introduction through the importation of live animals or their products (import risk analysis) and thus to justify trade restrictions. However, risk assessment approaches can also be used to identify the most relevant diseases for surveillance and control at national or international (e.g. EU) level (11). In this way, models have been developed for risk-based surveillance of fish farms in the United Kingdom (12, 13, 14) and in Germany (7).

In this study, a risk assessment model was developed for ranking Swiss aquaculture farms according to the risk they present concerning VHS and IHN. The scores obtained from the risk assessment will determine the frequency of farm inspections, as laid down in EU Directive 2006/88/EC.

Materials and methods

Risk factors

In accordance with Commission Decision 2008/896/EC (2), the risks of introduction and spread of disease were assessed separately. Six risk factors for the introduction of VHS and IHN and seven factors for the spread of these diseases were identified, based on published data, on models developed in other countries and on expert opinions (Tables I and II). The factors 'species' and 'biosecurity' could contribute to both the introduction and the spread of disease, therefore both factors were included in each of the two assessments. Among the six factors relating to the risk of introduction of the diseases, two factors (characterising the plant and the purchase) were themselves based on two factors using a combination table (Table III). The same approach was used in assessing disease spread for one factor (characterising the plant) (Table III). The risk for each factor was evaluated as null = 0, low = 1, medium = 2 or high = 4 at farm level.

The means of transmission of the rhabdoviruses causing VHS and IHN are similar. The National Fish Disease Laboratory (NAFUS) of the University of Bern, which is the national reference laboratory for notifiable fish diseases in Switzerland, has diagnosed VHS and IHN simultaneously or separately several times in the same fish farms. Consequently, in analogy with the model of Kleingeld (7), where fish farms were ranked for VHS, IHN and KHV simultaneously, our model was developed with the same risk scores for VHS and IHN and the farms were ranked for the two diseases combined.

<Table I> <Table II> <Table III>

The selection and assessment of risk factors is an important phase of the process, because it forms the basis of the categorisation of farms. Lack of scientific data on which to weight the routes of introduction and spread have limited the development of risk ranking schemes (14). This also applies to our model and risk factors were therefore assessed by expert collaborators of the NAFUS, based on published data. In the future, however, selection and assessment of risk factors can be easily adapted in accordance with new scientific knowledge. In the following paragraphs the reasons for the inclusion of particular risk factors are explained.

Species

Commission Decision 2008/896/EC (2) proposes that farms be considered as having a low level of risk if they do not keep species susceptible to any of the listed non-exotic diseases. However, as those farms may have differing levels of risk for the contraction and spread of such diseases or of emerging diseases, the Decision allows Member States to classify such farms according to their risk level and thus differentiate their level of surveillance and inspection. This possibility was chosen for our model, and fish species other than salmonids were also included as they are known to pose a risk in that they can be carriers of the relevant disease agent without developing disease symptoms or showing any mortality. To this end, the lists of fish susceptible to VHS and IHN according to European legislation (3, 15) were combined with the lists of the World Organisation for Animal Health (OIE) (16, 17). An example justifying this approach is that *Salvelinus* species are absent from the EU list, although they have been demonstrated as susceptible to VHS (7), whereas brook trout (*Salvelinus fontinalis*) and lake trout (*S. namaycush*) are listed as susceptible to VHS by the OIE (17). Thus, species that are susceptible were classified as high risk, because they clearly represent the greatest risk to the spread or introduction of the two diseases. Species considered to be carriers were defined as medium risk and the other species as null risk, because they do not represent any danger concerning VHS and IHN.

Water supply

An aquaculture farm supplied with spring or ground water has no pathogen or pathogen carrier (fish) in the inflow (18), therefore there is no risk of introduction of VHS or IHN and null risk was attributed to this parameter. River water abstracted by a farm may be contaminated with pathogens present in farmed or wild fish upstream of the farm (14, 19). In the other models (7, 14) the factor ‘exposure via water’ has been considered as the second highest risk. In our model, the parameter ‘surface water’ was identified as medium risk.

Fish movements

There is general agreement on the crucial role of fish movement as a factor in the introduction and spread of epizootic diseases (7, 14). The highest possible risk in our model (high) was therefore attributed to this factor. The likelihood of a farm becoming infected through the movement of live fish largely depends on the disease status of the source farms (12). The system of classification of aquaculture farms based on their health status according to Directive 2006/88/EC (1) is not established in Switzerland and therefore could not be relied on for our model. Thus, the risk factor ‘acquisition of fish’ had to be determined using the frequency of acquisitions and number of contractors. The likelihood of introduction will increase with the number of sources and consignments (14). For Switzerland, where in general there are fewer fish movements than in other EU countries, the risk factor was determined as null (no purchase), and low, medium or high according to the frequency of acquisitions and the number of suppliers. This classification is in accordance with the expert opinion. For the risk of spreading disease through fish movements, the type of fish sale (dead fish, living fish for consumption, living fish for other farms or stocks) was regarded as having the highest importance. Sales of fresh or live aquacultured species have the potential to spread pathogens and microbes. Of most concern are sales to live-haulers, because the fish and the transportation water may be transferred to a naive system (19). Through stocking or transfer of fish to other farms, sale animals have contact, or potential contact, with other fish and therefore represent the most important risk (high) of spreading disease. The sale of living fish for consumption is less dangerous (medium risk), because all animals will be slaughtered. Direct sales to consumers are of even less concern because these sales are usually made for home consumption (19), thus the sale of dead fish was attributed low risk. Fish farms that do not sell animals received null risk for this parameter.

Other plants

Taking extreme care in preventing the introduction of pathogens helps little when no preventive measures are used in the next farm up- or downstream. For this reason, geographical location in relation to other farms is of particular importance. The number of aquaculture farms in the neighbourhood and the proximity of the farms to each other is also a factor that increases, at least theoretically, the risk of pathogen introduction (18). If several fish farms are situated on the same watercourse, the distance between the farms is an important factor in the propagation of pathogens through the water and also via fish-eating predators such as birds (20). Field experiments have demonstrated that rainbow trout (*O. mykiss*) in a cage 640 metres downstream of an infected farm were infected with the same VHS virus as fish in the farm. Fish in a cage 220 metres upstream of an infected farm also showed contamination with VHS (21). In accordance with the expert opinion, the following parameters were included in the risk factor ‘other plants’: distance in kilometres to the next plant situated upstream/downstream (risk factor ‘plant 1’); number of plants in a circle of 5 km independent of the water system (risk factor ‘plant 2’). Accordingly, the risk of attracting a pathogen from a neighbouring farm or of spreading a disease to a neighbouring farm via different possible pathways (water, fish-eating predators, visitors etc.) was graded from null (no farm in the proximity) to high.

Fish processing

On-site processing, especially the processing of fish originating from a different fish farm, is a further risk factor for the introduction of a pathogen. The farmed population sharing the site with the processing plant may be exposed to pathogens released through the discharge of waste water or unsafe disposal of solid waste (14). Processing fish originating from other farms was determined to be of medium risk.

Biosecurity

In addition to acquisition, biosecurity is certainly a most important factor (18). Pathogens may be transmitted via a large array of mechanical routes, such as visitors (e.g. contaminated shoes, clothes), animals (e.g. piscivorous birds, predatory and scavenging mammals), farm equipment or fish transporters (14). Several parameters are included in the assessment of biosecurity. Practices such as disinfecting vehicles, equipment and personnel have important effects on the local spread of disease (20). Because vehicles can act as vectors, it is important that delivery vehicles passing from one fish farm to another do not enter the production part of the farm. Scavenging animals such as wild birds can act as disease vectors (22) and it has been demonstrated that VHS virus can survive for more than two hours in the crop of herons (*Ardea cinerea*) (23). Bird netting can help prevent infection via this route of exposure (14). To protect the farm from trespassers and wild animals, the facility should be enclosed and access controlled. Lastly, although quarantining newly bought stocks cannot prevent the introduction of an infection, this method offers a good means of detecting pathogens in new stocks before they can infect resident fish.

The biosecurity level of a fish farm indicates the awareness of the farmer regarding epizootic diseases. The best biosecurity measures cannot prevent the introduction or spread of a pathogen in every case, but well-applied measures are one of the most important aspects in minimising risk in a fish farm. For these reasons, 'biosecurity' was designated as low, medium or high risk according to the number of parameters present or absent on a particular farm.

Water runoff

A farm where fish are infected with VHS or IHN will spread the viruses in the environment through its effluent if it discharges in surface water. In the opposite case, if the water runoff of the farm is connected to a sewage plant (rarely the case) the risk of spread is limited. Rainbow trout were exposed to water from a sewage plant that had received water containing VHS and IHN viruses for a period of 62 days. No infection of fish occurred, indicating that these viruses do not survive the three-step purification process (21). Discharging in a sewage plant was therefore considered as null risk and discharging in surface water as medium risk.

Flooding

Pathogens may be spread through flooding (18) as a result of aquaculture ponds overflowing and fish escaping. This movement of animals to new locations results in contacts that would not have occurred otherwise, increasing the likelihood of the spread of pathogens and other microbes (19). However, as flooding is a fairly rare event, this parameter was assessed as a low risk.

Soil type

Pathogens in fissures or deep in mud are protected from chemical or ultraviolet-light disinfection. Thus, viruses in an aquaculture farm with natural soils can survive more readily than in a facility with concrete raceways or synthetic tanks, despite thorough disinfection measures. Concrete and synthetic soils therefore represent a smaller (low) risk than natural soils (medium risk).

Risk assessment

In 2009, the 357 known Swiss aquaculture farms received a questionnaire in order to quantify the relevant factors. Participation was voluntary. Farmers who did not return the questionnaire in time were contacted by phone in spring 2010. This resulted in a 95.2% response rate. Non-responses were translated into the highest risk score for the corresponding factor. As the factor 'biosecurity' cannot be estimated from a questionnaire and has to be evaluated during inspection, a high score for this factor was attributed in the first run of the model in all farms. In order to achieve full risk categorisation with all risk factors for at least some fish farms, a sample of 20 randomly chosen plants was visited to collect the relevant information for the factor 'biosecurity' and the model was re-run for these farms.

Scores for the risk of introducing VHS or IHN in a particular farm were summed and divided by the number of factors. The same procedure was applied for factors relevant to spread of the diseases. In contrast to the method described in Commission Decision 2008/896/EC (2), where the overall risk was calculated by combining risk of introduction with risk of spread using a combination table, in the present study the risk was calculated for each farm by summing the two separately assessed values. This methodology allowed us to increase the accuracy of the model: for example, a fish farm that has high values in the medium range of risk for both introduction and spread of disease will still have a medium overall risk by combining the two risks, but will have a high risk by summing the two values.

In our model, two theoretical trout farms supplied only or partly with surface water and possessing a runoff in surface water (the typical fish farm in Switzerland) were finally characterised as representing the upper limit for low-risk farms and the upper limit for medium-risk farms, in order to define three categories of farm (low, medium, high). Because the two theoretical farms were breeding a species susceptible to VHS and IHN, they were determined as high risk for the factor 'species'. As they were supplied with surface water and had a runoff in surface water, medium risk was attributed for the factor 'water' (enter and spread). Flooding is quite a rare incident, therefore a null risk for this factor was attributed to each of the farms, and because processing of fish from other farms applies to only a few plants in Switzerland, a null risk was attributed for this factor. For all other factors, a low or medium risk was set to calculate the upper limit for low- or medium-risk farms respectively (Table IV).

Risk level and disease outbreaks in recent years

Risk assessment was tested with regard to Swiss cases of VHS and/or IHN diagnosed during the past 12 years at the NAFUS. The method used by NAFUS comprises culture of the virus on fish cell lines and subsequent identification of the virus in an immunofluorescence antibody test. All diagnosed cases were in fish sent to the laboratory by fish farmers or veterinarians because of suspected viral disease or because of health problems in the fish.

Sensitivity analysis

The effect of a factor on the output of the model was determined by exclusion of individual factors from the risk assessment one at a time. The final score was recalculated for each farm and the modified ranking was compared with the rank of the baseline model. To determine the importance of each factor in comparison with others, the sums of the absolute difference in rank between the modified model and the original one were calculated for each farm.

Results

The results of the survey with regard to the distribution of risk factors in Swiss aquaculture farms are given in Table IV. Overall, 348 of the 357 fish farms bred species susceptible to VHS and/or IHN. Only 28 fish farms processed fish from other plants and only 30 plants did not possess a runoff in surface water. Because of the lack of information on the risk factor 'biosecurity', the maximum value was set in the 357 farms the first time.

<Table IV>

From the model, the mean risk value of the 357 farms for introducing the diseases was 1.9 (0.8–3.3) and for spreading disease from a facility it was 2.2 (1.1–3.0) (Table V). The mean risk value for the combined score of introducing and spreading the disease was 4.0 (2.1–6.3). The two theoretical farms had a value of 2.9 for the upper limit of low risk and of 4.0 for the upper limit of medium risk.

The 357 fish farms were allocated to the three risk categories using the theoretical farms as reference: six farms were considered as representing low risk, 175 were medium risk and 176 were high risk (Fig. 1).

<Table V> <Figure 1>

Twenty plants were visited in order to collect parameters of biosecurity. Before the visit, ten plants were classified as high risk and ten as medium risk (with a high risk for 'biosecurity'). After having collected the required data, 13 were reclassified as medium risk for biosecurity and seven as low risk. This induced a change of the overall risk level in 15 plants: nine originally classified as high risk were reclassified as medium risk; six originally classified as medium risk received a low risk. Five plants (four with medium risk, one with high risk) did not change their risk level.

Since the year 2000, NAFUS has diagnosed VHS and IHN 19 times in 16 different farms. In our model, 11 of these farms were classified as high risk and five were medium risk.

Evaluating the weight of each factor for the output of the risk assessment showed that the water source and the purchase of fish had the greatest influence on the introduction of disease into a facility. The parameter 'sales' had high influence potential for the spread of disease out of the fish farm. The presence of other plants in the proximity also had relatively high influence in our model, on both introduction and spread of disease. In contrast, the factors 'species' and 'processing' had low weight for introduction of disease in the risk assessment (Fig. 2).

<Figure 2>

Discussion

Risk level in Swiss aquaculture farms

Based on data gathered from questionnaires sent to fish farmers, 176 (49.3%) farms were classified as high risk, 175 (49.0%) as medium risk and six (1.7%) as low risk (Fig. 1). The high percentage of farms in the high-risk category in our model is biased by the fact that the factor ‘biosecurity’ was set at maximum value, because this factor was not included in the questionnaire for practicability reasons. Biosecurity has important weight in our model, because it is part of the risk of introduction and spread of disease. The influence of this factor on the outcome of assessment was demonstrated by the change in risk level in 15 of 20 farms after their risk classifications were recalculated with the parameters for biosecurity included. Nevertheless, although the selection of these 20 farms was random, the result should be considered as an example and cannot be claimed as representative.

As it was not possible to collect the necessary information to score ‘biosecurity’ in all the aquaculture farms using the questionnaires or other means, these values will be assessed through the first inspection of the farms. In parallel with on-site assessment of biosecurity measures, data missing from the questionnaires returned by the fish farmers will also be obtained during the first visit. Risk factors in a facility can change over time and therefore it will be essential to periodically re-evaluate the risk for VHS/IHN, rerunning the model with the most recent data from individual farms. This means that farmers can influence the risk category of farms, for example, by improving the on-site situation by changing biosecurity measures or purchasing behaviour (e.g. fewer suppliers).

Eleven of 16 (68.7%) fish farms where VHS and/or IHN was diagnosed during the period 2000 to 2011 were classified as high risk in our model, the other five (31.3%) were in the medium-risk category. This suggests a ratio of 2:1 for the frequency of inspections in high- and medium-risk farms.

Comparison with existing models

Two models have been developed by Kleingeld (7): the model proposed in Commission Decision 2008/896/EC (2) and a modified analogue model. However, some of the parameters used in those models were not available in our dataset and therefore could not be used to calculate risk in comparison with our model. For the same reason, the Swiss farms could not be ranked using the model of Oidtmann *et al.* (14).

The most important difference between our model and those of Oidtmann *et al.* (14) and Kleingeld (7) is the weighting of the risk factors, which is more complex in the other models. Oidtmann *et al.* weighted 'live fish and egg movements' with 63% and distributed the remaining 37% between four other factors (14). In our model, risk factors were weighted only by attributing the risk levels null, low, medium or high according to the composition of the parameters. For example, when a flood-risk exists, 'flooding' is regarded as low risk because it is a less important parameter; 'purchase' is a null risk for a farm that does not buy fish and high risk for a plant that purchases fish six times a year from three different suppliers. In using simple words such as 'high' or 'low' for weighting, instead of per cent values, a less complex model was developed. This resulted in decreased accuracy but increased comprehensibility of the model for the decision makers. Thus, our model has been developed for ranking a farm for risk-based surveillance but cannot be used to attribute an absolute risk of introduction and spread of VHS and IHN for each farm.

The influence of weighting risk-factors was assessed by comparing two models, although they were not based on identical factors and calculations. To this end, our model was weighted with the same percentages as in the model of Oidtmann *et al.* (14); for example, 63%

for fish movements. A comparison of risk ranking with and without weighting (Fig. 3) showed a correlation of 45%. The extreme values in low-risk and high-risk farms in the two models were more or less equivalent, whereas medium values showed more variability. Farms that were high risk with the weighting and low risk without weighting were farms breeding species that were not susceptible to VHS or IHN and farms where there was no information on fish movements, as well as farms that were high risk only for the factors ‘purchase’ and ‘sales’. In contrast, farms with fewer fish movements (e.g. those that bred only their own fish using artificial rearing techniques) but having a high risk for other factors (e.g. farms using surface water and having natural soil in ponds) were high risk without weighting and low risk with weighting. However, in risk-based surveillance, plants with the lowest and the highest risks are the ones of most interest.

Comparison of the rankings of farms where VHS and/or IHN was diagnosed during the period 2000 to 2011 showed analogous values in the two models.

<Figure 3>

Sensitivity analysis

The most influential factor in our model was ‘fish movements’ (purchase and sale), followed by the factor ‘water supply’ and in third place by the risk-factor ‘plant’ (Fig. 2). The low influence of ‘biosecurity’ in our assessment was due to the attribution of the same value (high) to all farms, because of the lack of necessary information. With the availability of the relevant data after the first inspection, ‘biosecurity’ is expected to have a clearly higher influence in the model. This assumption is supported by findings in 20 farms that have been visited and where the risk has been recalculated with the inclusion of ‘biosecurity’.

Fish species were of low influence in the model because most farms in Switzerland produce salmonids, which are susceptible to VHS and IHN (Table IV), and thus the factor ‘species’ was the same high risk for most farms. Factors that did not show important variability in distribution among the farms (species, fish processing, water runoff, flooding and – before the first inspection – biosecurity) (Table IV) were therefore not very influential in our model.

Comparison of different models is possible only when they concern the same or at least similar diseases. Our model was developed to assess the risk of VHS and IHN. Using the model for other diseases would imply selection and assessment of risk factors specific to the new disease and which might differ from those used for VHS and IHN. Indeed, a viral disease does not have exactly the same modes of transmission as, for example, a parasitic disease. Nevertheless, in principle our model could be used for every fish disease, given that some adaptations were made.

Conclusion

A total of 357 fish farms corresponding to all known farms in Switzerland were ranked in the risk categories high, medium or low risk for the introduction or spread of the two fish diseases VHS and IHN. Using this baseline information, a risk-based surveillance system adapted to fish farming conditions in Switzerland and in accordance with Council Directive 2006/88/EC (1) can be developed. Based on analysis of disease outbreak data, a ratio of 2:1 for the frequency of inspections in high- and medium-risk farms is suggested.

In the model presented here, fish movements and water supply were demonstrated as having key roles in the introduction and/or spread of two viral diseases. Nevertheless, the risk presented by other fish farms in the proximity should not be underestimated. Because of incomplete information on biosecurity in the fish farms studied, the influence of this factor could not be tested for all the farms in Switzerland but was assumed to be important.

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Table I
Factors considered in the assessment of risk of infection with viral haemorrhagic septicaemia and/or infectious haematopoietic necrosis in fish farms

Factor	Comments	Risk score	
Species	Susceptibility to VHS and/or IHN of species kept (Directive 2006/88/EC; Commission Regulation 1251/2008/EC; OIE Manual of Diagnostic Tests for Aquatic Animals)	No susceptibility:	Null
		Vector:	Low
		Susceptible:	High
Water	Type of water supply	Source or ground water:	Null
		Surface water:	Medium
		Both:	Medium
Purchase 1 (frequency)	Number of purchases per annum	No purchase:	Null
		<3 purchases:	Low
		3 to 5 purchases:	Medium
		≥6 purchases:	High
Purchase 2 (suppliers)	Number of suppliers	No purchase:	Null
		1 purchase:	Low
		2 to 3 purchases:	Medium
		≥4 purchases:	High
Plant 1 (distance to the next plant)	Distance in km to the next plant situated upstream or downstream	No other plant:	Null
		1 to 5 upstream / 0.2 to 0.5 downstream:	Low
		0.5 to 1 upstream / 0 to 0.2 downstream:	Medium
		≤0.5 upstream:	High
Plant 2 (number of plants)	Number of plants in a circle of 5 km, independently of the water system	No other plant:	Null
		1 other plant:	Low
		2 to 4 plants:	Medium
		≥5 plants:	High
Processing	Processing of fish from other farms	No:	Null
		Yes:	Medium
Biosecurity	Biosecurity was determined on the basis of eight criteria (Yes or No) that could affect the status of a farm 1. Presence of a foot bath? 2. Disinfection of equipment? 3. Disinfection of vehicles? 4. Fencing around the facility? 5. Presence of an entrance gate? 6. Existence of protection against birds? 7. Limited van access to production area? 8. Quarantine, isolation possibility?	0 to 2 No:	Low
		3 to 5 No:	Medium
		≥6 No:	High

Table II

Factors considered in the assessment of risk of spread of viral haemorrhagic septicaemia and/or infectious haematopoietic necrosis in fish farms

Name	Comments	Risk score	
Species	Susceptibility to VHS and/or IHN of species kept (Directive 2006/88/EC; Commission Regulation 1251/2008/EC; "*Manual of Diagnostic Tests for Aquatic Animals*" of the OIE)	No susceptibility:	Null
		Vector:	Low
		Susceptible:	High
Water	Type of water runoff	No water runoff:	Null
		Sewerage:	Null
		Surface water drainage:	Medium
		Both:	Medium
Sales	Type of fish sales	No sale:	Null
		Dead fish:	Low
		Living fish for consumption:	Medium
		Living fish for other plant:	High
Plant 1 (distance to the next plant)	Distance in km to the next fish farm situated upstream / downstream	No other plant:	Null
		1 to 5 downstream / 0.2 to 0.5 upstream:	Low
		0.5 to 1 downstream / 0 to 0.2 upstream:	Medium
		≤0.5 downstream:	High
Plant 2 (number of plants)	Number of fish farms in a circle of 5 km independently of the water system	No other plant:	Null
		1 other plant:	Low
		2 to 4 plants:	Medium
		≥5 plants:	High
Flooding	Flooding of the farm in the past	No:	Null
		Yes:	Low
Soil type	Type of the soil at the farm	Concrete / synthetic:	Low
		Natural:	Medium
		Both:	Medium
Biosecurity	Biosecurity was determined on the basis of 8 criteria (Yes or No) that could affect the status of a farm 1. Presence of a foot bath? 2. Disinfection of equipment? 3. Disinfection of vehicles? 4. Fencing around the facility? 5. Presence of an entrance gate? 6. Existence of protection against birds? 7. Limited van access to production area? 8. Quarantine, isolation possibility?	0 to 2 No:	Low
		3 to 4 No:	Medium
		≥5 No:	High

Table III
Combination tables for 'purchase' parameters and 'plant' parameters

Number of suppliers (purchase 2) \ Frequency of purchase (purchase 1)	Null	Low	Medium	High
Null	Null	n/a	n/a	n/a
Low	n/a	Low	Low	Medium
Medium	n/a	Low	Medium	High
High	n/a	Medium	High	High

Number of plants in a 5km circle (plant 2) \ Distance to the next plant (plant 1)	Null	Low	Medium	High
Null	Null	n/a	n/a	n/a
Low	Low	Low	Medium	High
Medium	Low	Medium	High	High
High	Low	Medium	High	High

n/a: not available, combination not possible

Table IV
Distribution of risk scores in 357 Swiss aquaculture farms for each risk factor (determined from a questionnaire)
Risk factors relate to the risk of disease introduction (enter), disease spread (spread) or to both risks (both). The last two columns indicate values set in order to define the upper limits of low-risk and medium-risk farms

Factors in the risk assessment	Null	Low	Medium	High	Low limit	Medium limit
Species (both)	2	7	n/a	348	High	High
Water (enter)	162	n/a	195	n/a	Medium	Medium
Purchase (enter)	100	184	21	52	Low	Medium
Plant (enter)	114	221	11	11	Low	Medium
Processing (enter)	329	n/a	28	n/a	Null	Null
Biosecurity (both)	n/a	0	0	357	Low	Medium
Water (spread)	30	n/a	327	n/a	Medium	Medium
Sales (spread)	53	70	24	210	Low	Medium
Plant (spread)	114	195	28	20	Low	Medium
Flooding (spread)	270	87	n/a	n/a	Null	Null
Soil type (spread)	n/a	143	214	n/a	Low	Medium

n/a: not available, classification of risk does not exist for this factor

Table V

Distribution of the scores obtained for the 357 fish farms in the frame of the risk assessment

Outcome of risk assessment (range of possible values)	Min	25%	50%	Mean	75%	Max
Risk of introduction (0.2;3.3)	0.8	1.7	1.8	1.9	2.0	3.3
Risk of spread (0.3;3)	1.1	2.0	2.3	2.2	2.4	3.0
Combined risk (0.5;6.3)	2.1	3.7	4.0	4.0	4.4	6.3

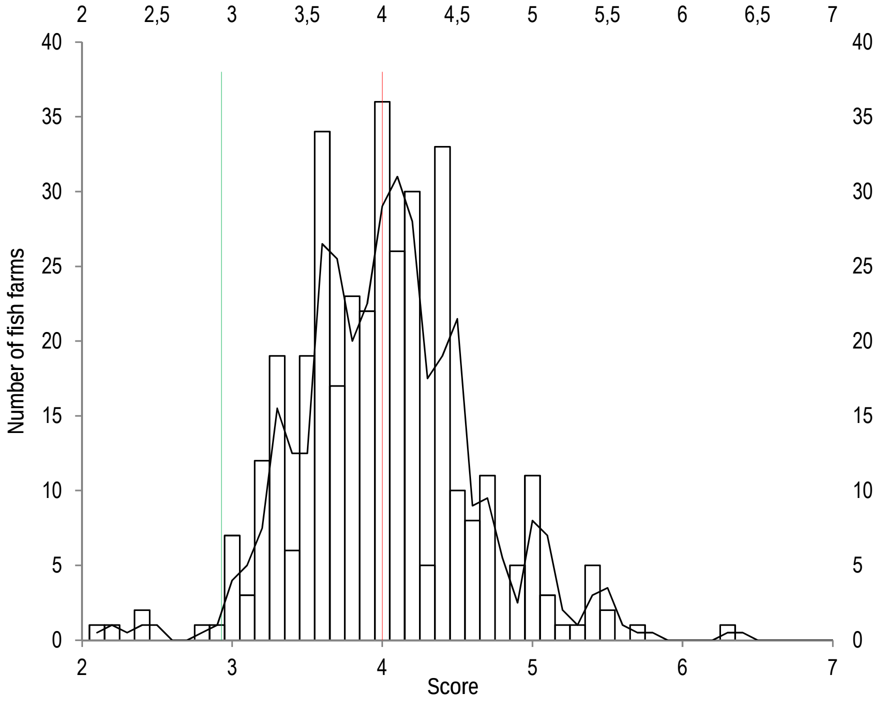

Fig.1

Distribution of combined scores obtained from the risk assessment of the 357 fish farms

The green line represents the upper limit of the low risk category and the red line the upper limit of the medium risk category according to expert opinion

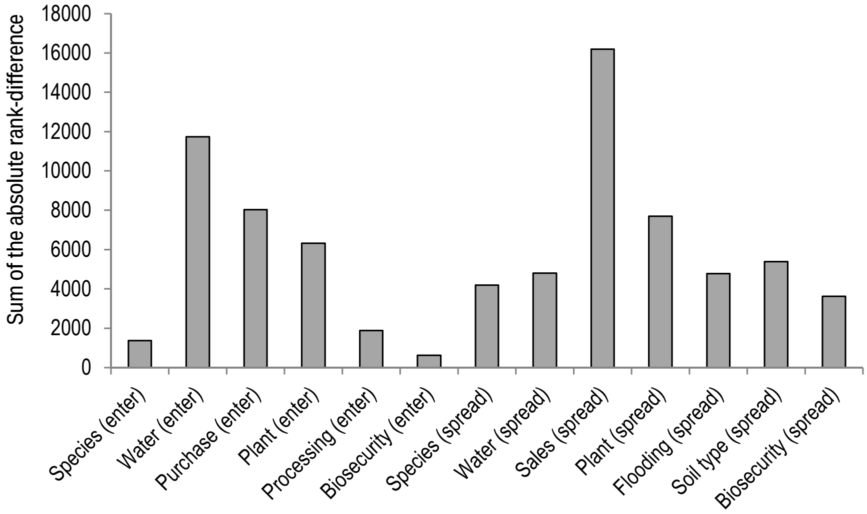

Fig. 2

Sensitivity analysis of the risk assessment model comparing the effect of individual factors on the output of the risk assessment

The y axis represents the sum of the absolute difference in rank for each farm between the rank obtained from the baseline model and the model with factor exclusions. The higher the value, the greater the impact of the risk factor on the final rank

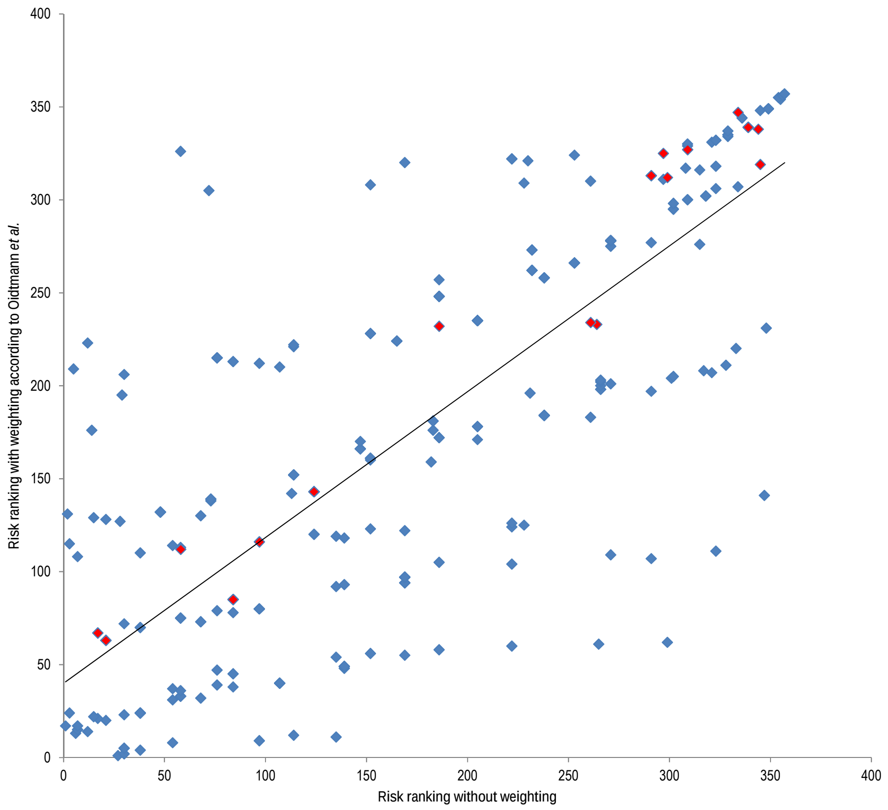

Fig. 3

Correlation between risk ranking with weighting according to Oidtmann *et al.* (y axis) and without weighting (x axis)

The red points represent fish farms where viral haemorrhagic septicaemia and/or infectious haematopoietic necrosis was diagnosed during the period 2000 to 2011