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Overview on the Biosecurity Measures of Salmonid Fish Farms: A Case Study in Italy

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Abstract: Italy is one of the main European producers of trout fish, and the most important producing area is the Autonomous Province of Trento (APT) in the North East. The objective of the study was to obtain a snapshot of the trout farms of the APT by identifying biosecurity factors, objectifying them, and classifying the establishments accordingly. Data from 62 salmonid farms were collected using a national checklist in which biosecurity elements were identified and assessed using the method of expert elicitation. The purpose was to evaluate the levels of biosecurity of a trout farm in order to rank the risk of introduction and spread of infectious fish diseases. The main critical factors identified during this study were as following: (i) cleaning and disinfection of the cargo truck; (ii) regular collection, storage, and disposal of dead fish; (iii) presence of anti-bird nets; (iv) use of dedicated equipment for the different sectors of the farm; and (v) presence of external areas dedicated to the loading of dead fish.

Keywords: fresh water; expert opinion; fish farming

Key Contribution: Use of expert opinion approach to evaluate the importance of biosecurity measures to define a ranking method for freshwater farms.

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1. Introduction

In recent decades, the aquaculture sector has undergone considerable changes in terms of structural and production growth, with a clear increase in supply complexity and dynamics [1].

Fisheries and aquaculture production have become critically important to meeting the growing demand for resources for human consumption [1,2]. On a world scale, the contribution of aquaculture to total fisheries and aquaculture production has climbed steadily, reaching 49.2% in 2020, on par with captures [1]. According to the latest FAO data (2020), of the 178 million tonnes produced in 2020, 90.3 million tonnes were from capture fisheries and 87.5 million tonnes from aquaculture, 54.4 Mt in freshwater and 33.1 Mt in marine water.

Focusing on salmonids data and trout in particular, world trout production stood at 1,022,000 tonnes in 2020 [1], reaching the highest production level in the last 10 years. World production of trout is 99% focused on the rainbow trout species (*Oncorhynchus mykiss*), of which 77% is freshwater farmed, while 22% comes from marine production, with the remaining 1% being other trout species [1].

In 2020, Iran was the main producer of trout, accounting for 20% of the whole world production, followed by the EU-27, Turkey, Norway, and Chile [2–4]. The sum of the Iran, EU-27, and Turkey production covered more than half (54%) of the global production that year. Trout production has increased significantly over the last decade in Norway (+64%), Peru (+171%), the Russian Federation (+140%), and China (+104%), with a production ranging between 37,000 and 96,000 tonnes for each country in 2020.

In the European Union (EU), the aquaculture sector is mainly concentrated in Spain, France, Greece, and Italy [3,4]. Rainbow trout is the most widely farmed freshwater species, both in terms of volume and value. The largest trout-producing EU Member States are Italy, France, and Denmark, accounting for 54% of the total production, followed by Spain and Poland [2,5,6].

The Italian Fish Farmers' Association (Associazione Piscicoltori Italiani—API) published the production data output for year 2022, showing the total production in aquaculture exceeding 53,900 t, of which 29,000 t (53.8%) were from rainbow trout [7]. Most of the trout farms in Italy are mainly located in the northeast (50%) and cover about 70% of the national production [8].

Unlike other production sectors, Italian aquaculture is mostly fragmented, composed of several small- and medium-sized enterprises (50–100 t/year), and characterized by a great variety of farmed species, each with very different characteristics and needs [8].

Disease prevention is of paramount importance; therefore, biosecurity has become a strategic tool in farm management [9,10]. Biosecurity is a set of management and physical measures designed to reduce the risk of introducing pathogens into an aquatic animal population [11]. If efficient biosecurity measures are in place, it is possible to detect the emergence of new or previously unrecognized pathogens. Thus, by minimizing the consequences of diseases, there will be a direct increase in farm productivity [11]. The objective of the study was to obtain a snapshot of the trout farms of the Autonomous Province of Trento (APT) by identifying biosecurity factors, objectifying them, and classifying the establishments accordingly.

2. Materials and Methods

2.1. Farms Selection

For the development of this work, all the aquaculture establishments of the APT were downloaded from the National Data Bank (BDN). A selection of the farms of this area, historically devoted to trout farming, was made considering the following:

- Activity status ("currently active" in the BDN);
- Type of production (fattening, hatchery or pre-growing);
- Direct contact with veterinarians of the Local Competent Authority (LCA), who selected the farms included in the project according to the annual total production, excluding the smaller ones.

A total number of 62 farms were considered for the study.

2.2. Checklist Data Collection

The data for this study were collected before the entry into force of Regulation 2019/429, and the checklist used was provided by the Italian Decree no. 148 of 4 August 2008 (Annex F), which was the implementation of Council Directive 2006/88/EC of 24 October 2006 on animal health requirements for aquaculture animals and products thereof, and on the prevention and control of certain diseases in aquatic animals.

In 2016, a team of experts developed this checklist, which includes several sections (farm registry data, farm activities, structural features of the farm, biosecurity, disease prevention, welfare, feed, drugs and disinfectants, fishing and fish load, recordings, employees training). It was easily adopted for the project due to its completeness and because it is a well-known and validated tool for veterinarians.

The checklists are usually filled in by the veterinarians of the LCA during health visits to farms, which take place from the end of winter, the beginning of spring, and autumn periods (in order to have the appropriate water temperature for the detection of the viral diseases). For the study, we asked the LCA to provide checklists for the data acquisition of the selected farms. The checklists received covered the period from October 2019 to May 2022, the extended period being due to the fact that data from all 62 farms were collected. All the checklists were digitally stored, and data were reported in a unique Microsoft Excel file.

2.3. Expert Opinion

From the original structure of the checklist, elements referring to different aspects that may affect the biosecurity level of a salmonid farm were retrieved. Through simple operations of direct selection, aggregation, or separation of the elements of interest in the questions, a list of factors/variables was compiled and then submitted to the experts through a questionnaire during the expert elicitation. The final list of items used during the expert elicitation was divided into seven macro aspects: structural features of the farms, biosecurity, diseases prevention, feed and medicines, fishing and fish load, registrations, and employees training.

The panel of experts was constructed using the "direct call" method [12] thanks to the personal knowledge of the authors, identifying a total of 12 experts in the aquaculture sector, belonging either to the public health or the production sector.

Expert elicitation is a method employed to obtain scientific consensus where there is a lack of a solid quantitative basis or where the data are unreliable due to logistical difficulties or lack of resources. Elicitation by experts can help to gather and synthesize knowledge derived from multiple sources and/or experiences, allowing for "parameterization" and a plausible hypothesis of a given object studied [13,14].

The expert elicitation was performed in-person with a single expert per occasion. In order to support the expert in assessing the various elements, a hypothetical trout farm was proposed as a scenario to refer to during the exercise. Through the compilation of the questionnaire, the expert assigned a value to the various elements considered in the exercise with regard to the influence that each element might have on the biosecurity level of a farm and, consequently, on the risk of introduction and spread of animal health issues.

During the elicitation, each expert was asked to assign a value of importance to each identified factor/variable, with five descriptive values from "low" to "high", and the certainty in the answer was indicated with another set of five descriptive values from "definitely uncertain" to "very sure".

2.4. Data Analysis

Once all the experts' answers were acquired, the anonymous data were then converted into numerical values, both for the importance of the factors ("low" = 1, "medium-low" = 3; "medium" = 5; "medium-high" = 7; "high"= 9), and for the certainty in the answer ("definitely uncertain" = 1; "uncertain" = 3; "neutral" = 5; "sure" = 7; "very sure" = 9).

All the experts' answers were combined to obtain a final average evaluation of factors/variables (weighted by certainty). Subsequently, the checklist results were combined with the average values obtained from the expert elicitation. Values were then added together to calculate the final score for each farm which describes the level of biosecurity in accordance with the importance of the factors defined by the experts.

All the results were analyzed using R software 4.3.1 [15] to describe the farms in the study area and obtain a numeric summary. After the combination with the results of the expert elicitation, farms were classified in five "biosecurity levels" (from "low" to "high") accounting for equal interval classes.

Scores and classes were stored in a dedicated geodatabase to allow for the creation of a specific spatial dataset of farms, which also includes the classification of biosecurity. The geodatabase was implemented in the Database Management System (DBMS) Post-

GreSQL [16], with PostGIS extension [17], to allow for the versioning and updating of the scores in case of further expert elicitation or updates to the checklist results.

3. Results

3.1. Picture of the Trout Farming Sector in APT

According to Council Directive 2006/88/EC, farms were classified into five sanitary categories for the listed diseases affecting salmonids (Viral Hemorrhagic Septicemia—VHS; Infectious Hematopoietic Necrosis—IHN). Figure 1 shows the distribution of the 62 farms according to their sanitary category. Moreover, the classification of the risk level [18] displayed 31 farms in "low risk" class, 17 in "medium risk", and 13 in "high risk" class (1 was not classified). No correlation was found between sanitary category and biosecurity level rank.

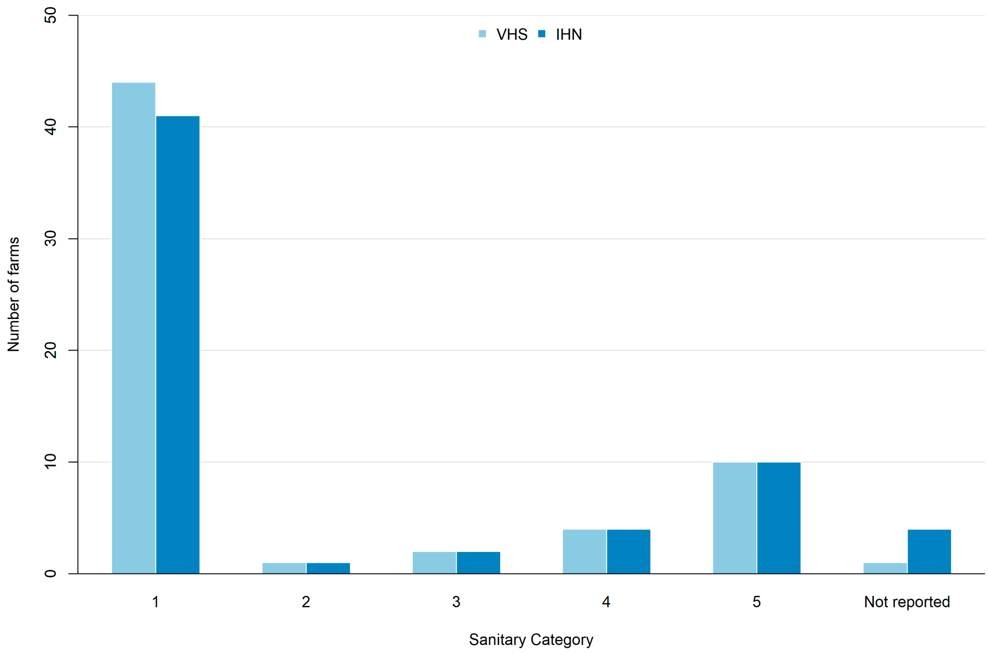

Figure 1. Distribution of the number of farms according to their sanitary category for VHS and IHN diseases.

Of the 62 farms, 37 reared more than one salmonid species, while 18 farms bred one species of salmonids; only 1 farm reported salmonids, cyprinids, and sturgeons. Six farms did not indicate the species reared. The main farmed species were rainbow trout (*Oncorhynchus mykiss*) (in 39 out of 62 farms), brown trout (*Salmo trutta*) (in 23 out of 62 farms), brook trout (*Salvelinus fontinalis*) (in 14 out of 62 farms), and marble trout (*Salmo marmoratus*) (in 11 out of 62 farms); other reported species were common whitefish (*Coregonus lavaretus*) and grayling (*Thymallus thymallus*). Figure 2 represents the species reared in the farms included in the study.

3.2. Biosecurity Aspects

Data on biosecurity were retrieved from each section of the checklist.

3.2.1. Structural Features of the Farm

Almost all the facilities visited (90.3%) had a fence intended to limit access to the farming areas. Farms where it was possible to identify an area outside the farm dedicated to unloading feed (51.6%), disinfecting vehicles (38.7%), and loading dead animals (48.4%) were not highly represented. On the other hand, most farms had a dedicated area for storage of equipment (96.8%), feed (91.9%), medicines, and disinfectants (90.3%). A total of 71% of the farms had a physical separation of the different areas; in 59.6% of cases, there was a filter area (locker rooms and bathrooms). In 16 premises (25.8%), there was a specific area dedicated to retail. In eight companies (12.9%), there was a dedicated facility for fish processing. In 95.2% of the farms, a downstream grid was reported to be in place to prevent wild fish intrusion or reared fish escaping. Only 54.8% had installed anti-bird nets to protect the farmed fish from predators (ichthyophagous birds) (Table 1).

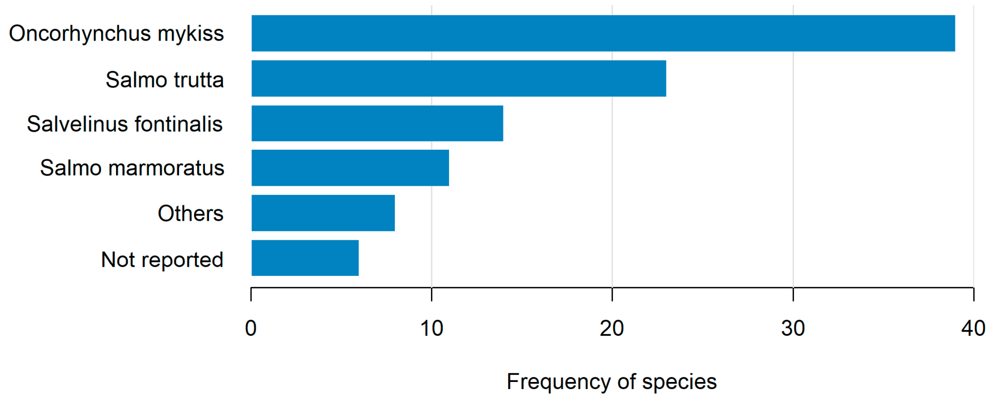

Figure 2. Salmonid species recorded in the checklist during data collection.

Table 1. List of questions in the checklist regarding "Structural features of the farm", with the percentage of affirmative responses.

Description	Percentage
Presence of fence and controlled access to the breeding areas.	90.3
Unloading of feed takes place outside the breeding area.	51.6
Presence of dedicated areas for disinfecting vehicles outside the breeding area.	38.7
Presence of dedicated areas for loading dead fish outside the rearing area.	48.4
Presence of a physical separation of the different facilities of the farm (e.g., hatchery, fattening, breeding stock).	71.0
Presence of a dedicated and separate area for storing equipment.	96.8
Presence of a dedicated and separate area for feed.	91.9
Presence of a dedicated and separate area for medicines and disinfectants.	90.3
Presence of a filter area/changing rooms and separate toilets.	59.7
Direct sales area separated from the breeding area.	25.8
Presence of a fish processing plant.	12.9
Presence of barriers are in place to prevent the upwelling of wild fish and escape.	95.2
Protection of farms from fish-eating birds by anti-bird nets.	54.8

3.2.2. Biosecurity

A total of 88.7% of farmers use a manual of good hygiene practice. Vehicle inspection and disinfection was conducted for 64.5% on entry and 51.6% also on exit from the farm. Disinfection of footwear before entering the hatchery/fish fry sector was conducted in 67.7% of cases. Disposable footwear and gowns were provided to visitors in 45.2% of the farms. Equipment was cleaned and disinfected following an established protocol in 79% of the visited farms, and dedicated equipment for the different sectors was present in 67.7% of cases. Only 27.4% of the farms had installed signage with operational directions. In only one farm (1.6%) was the fish fry sector water sanitized (Table 2).

Table 2. List of questions in the checklist regarding "Biosecurity", with their percentage of affirmative responses.

Description	Percentage
Compliance with a good hygiene practice manual.	88.7
Checking of transport vehicles and their disinfection before entering.	64.5
Checking of transport vehicles and their disinfection before leaving the company.	51.6
Disinfection of footwear before entering the hatchery or fish pre-growing.	67.7
Disposable footwear and/or gowns used by visitors.	45.2
Equipment (waders, tanks, etc.) cleaned and disinfected.	79.0
Presence of signs with operational instructions.	27.4
Dedicated equipment used for the different areas of the plant.	67.7
The water entering the hatchery is sanitized.	1.6

3.2.3. Disease Prevention

Egg disinfection was performed in 43.5% of the farms, which followed a written protocol in 22.6% of cases. Mortality was regularly recorded in 93.5% of farms. Likewise, dead fish were collected and stored regularly in 91.9% of cases; moreover, the container used for collecting animal by-products (ABPs) was correctly identified in 79% of premises. The surveillance program required by current legislation was documented in 88.7% of farms, and in 79%, traceability of clinical or laboratory diagnosis was maintained. A total of 69.4% of the farms' employees worked exclusively on one premise (Table 3).

Table 3. List of questions in the checklist regarding "Disease prevention", with their percentage of affirmative responses.

Description	Percentage
Eggs are disinfected according to a protocol.	43.5
Mortality is regularly recorded.	93.5
Documentation of the execution of the health surveillance programme provided for in Article 11 of Legislative Decree No. 148/2008.	88.7
Presence of traceability of the clinical/laboratory diagnosis made by the breeder/health professional.	79.0
Dead fish are collected, stored, and regularly disposed in well identified containers.	91.9
Operators work exclusively on a farm.	69.4

3.2.4. Feed and Medicines

In 95.2% of the farms, feed was stored separately from disinfectants and other chemicals. A treatments logbook was present in 91.9% of the farms.

3.2.5. Fishing and Fish Load

In the majority of farms (95.2%), dead fish were removed before fishing. In 32.3% of the farms, the all-in–all-out (AIAO) method was applied without sorting at the fishing phase. For 66.1% of cases, live fish were loaded onto trucks with stocking water. The equipment used during the fishing and loading phases was easily washed and disinfected (98.4%). Regarding the means of transportation used, in 72.6% of cases, it was owned by the farmer; in 58.1% percent of cases, it was used exclusively for loading in one farm; in 90.3% of cases, it was cleaned before loading; and in 77.4% of cases, it was also disinfected (Table 4).

Table 4. List of questions in the checklist regarding "Fishing and fish load", with their percentage of affirmative responses.

Description	Percentage
Dead fish are removed before fishing.	95.2
Applying of the all-full/all-empty methodology.	32.3
Equipment is easily washed and kept clean.	98.4
Fish sold live are loaded using the same water in which they were housed.	66.1
The truck is owned by the farmer.	72.6
The truck is used exclusively by a single company for loading.	58.1
Truck cleaning before loading.	90.3
Truck disinfection before loading.	77.4

3.2.6. Registrations

A total of 37.1% of the premises had a visitor registration system in place. An up-to-date loading/unloading register was available in 98.4% of cases. A rodent control plan was present in 62.9% of the premises, while most of the farms (88.7%) used specialized firms to dispose of animal by-products (ABPs) (Table 5).

Table 5. List of questions in the checklist regarding "Registrations", with their percentage of affirmative responses.

Description	Percentage
Presence of a logbook for visitors.	37.1
Recording of movements and keeping the loading/unloading register up-to-date.	98.4
Presence of a rodent control plan.	62.9
Animal by-products (ABP) are disposed of by specialized and authorized companies.	88.7

3.2.7. Employees Training

In 43.5% of cases, staff had followed training workshops over the last three years. In 71% of the farms, transport workers turned out to have been adequately trained for their task.

3.3. *Expert Elicitation and Farms Ranking*

Through the elicitation exercises conducted with the experts, it was possible to obtain a value of importance for each of the biosecurity aspects considered. Table 6 shows the final list of items presented to the experts and used during the expert elicitation, including their average score.

From combining the checklists answers with the importance of the biosecurity aspects defined by the experts, a score for each farm was obtained. The possible range of values was from 0.00 (worst case) to 291.41 (best case), while farms' checklist scores ranged from 102.82 to 253.74. Farms were ranked in five classes: low [0, 58.282], medium-low [58.282, 116.564], medium [116.564, 174.846], medium-high [174.846, 233.128], and high [233.128, 291.410] (Figure 3). No farms were included in the "low" level class but fell under the "medium-low" (1 farm, 1.6%), "medium" (24.2%), "medium-high" (55.8%), and "high" (19.4%) classes.

Table 6. List of the items evaluated by the experts, ordered by their average score, which defines the importance of biosecurity aspects. The 40 selected items matched with the questions present in the checklist.

Aspect	Description	Average Score
Disease prevention	Dead fish are collected, stored, and regularly disposed in well identified containers.	8.79
Fishing and fish load	Cleaning and disinfecting the truck before loading.	8.71
Biosecurity	Dedicated equipment used for the different areas of the plant.	8.50
Biosecurity	Equipment (waders, tanks, etc.) cleaned and disinfected.	8.40
Registrations	Recording of movements and keeping the loading/unloading register up-to-date.	8.30
Biosecurity	Checking of transport vehicles and their disinfection before entering and leaving the company.	8.29
Structural features of the farm	Protection of farms from fish-eating birds by anti-bird nets.	8.26
Disease prevention	Mortality is regularly recorded.	8.17
Fishing and fish load	Equipment is easily washed and kept clean.	8.13
Feed and medicines	Presence of a treatment logbook.	8.02
Structural features of the farm	Presence of a fence and controlled access to the breeding areas.	8.00
Structural features of the farm	Presence of dedicated areas for loading dead fish outside the rearing area.	7.97
Registrations	Animal by-products (ABP) are disposed of by specialized and authorized companies.	7.96
Structural features of the farm	Presence of dedicated areas for disinfecting vehicles outside the breeding area.	7.93
Disease prevention	Eggs are disinfected according to a protocol.	7.93
Structural features of the farm	Presence of a physical separation of the different facilities within the farm (e.g., hatchery, fattening, breeding stock).	7.86
Disease prevention	Presence of traceability of the clinical/laboratory diagnosis made by the breeder/health professional.	7.85
Fishing and fish load	Appling of the all-full/all-empty methodology.	7.72
Biosecurity	Disinfection of footwear before entering the hatchery or fish pre-growing.	7.71
Structural features of the farm	Presence of a fish processing plant.	7.70
Structural features of the farm	Presence of barriers to prevent the upwelling of wild fish and escape.	7.66
Biosecurity	Disposable footwear and/or gowns used by visitors.	7.65
Employees training	Transport personnel have been adequately trained.	7.53
Fishing and fish load	The truck is used exclusively by a single company for loading.	7.10
Structural features of the farm	Presence of a filter area/changing rooms and separate toilets.	7.03
Employees training	Farm personnel have attended some refresher courses over the last three years on the topics mentioned in the notes.	6.98
Disease prevention	Documentation of the execution of the health surveillance programme provided for in Article 11 of Legislative Decree No. 148/2008.	6.90
Biosecurity	Compliance with a good hygiene practice manual.	6.88
Registrations	Presence of a rodent control plan.	6.74
Feed and medicines	Bags of feed are stored in a dry place and separated from disinfectants or other chemicals.	6.43
Fishing and fish load	Dead fishes are removed before fishing.	6.42
Fishing and fish load	The truck is owned by the farmer.	6.36
Structural features of the farm	Presence of a dedicated and separate area for storing equipment, feed, medicines, and disinfectants.	6.34
Fishing and fish load	Fish sold live are loaded using the same water in which they were housed.	6.06
Disease prevention	Operators work exclusively on a farm.	6.02
Structural features of the farm	Direct sales area separated from the breeding area.	5.80
Structural features of the farm	Unloading of feed takes place outside the breeding area.	5.66
Biosecurity aspects	The water entering the hatchery is sanitized.	5.26
Biosecurity aspects	Presence of signage with operational instructions.	5.23
Registrations	Presence of a logbook for visitors.	5.16

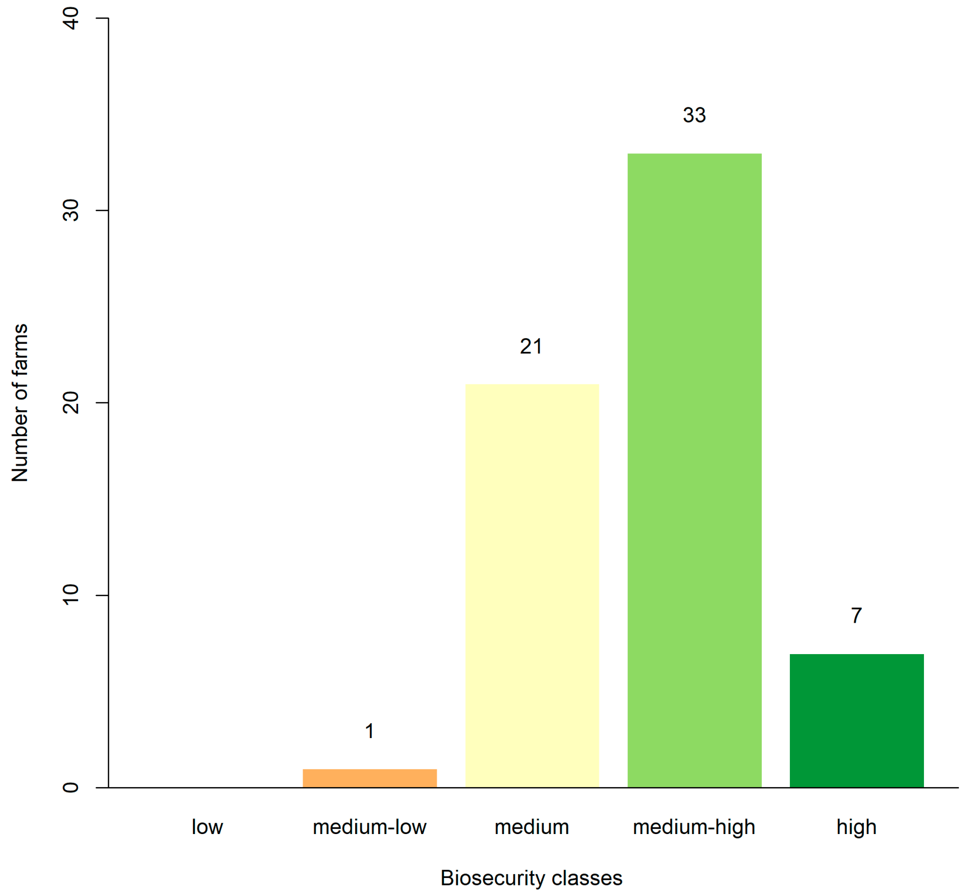

Figure 3. Checklist results classified in five descriptive classes of biosecurity from "low" to "high". No farms ranked in the "low" category.

Using the open source object-relational DBMS PostgreSQL, the spatial dataset of farms is published through the IZSVe Spatial Data Infrastructure (SDI) that offers the possibility of producing quick maps with information on the level of biosecurity. An example is presented in Figure 4.

From the geographic point of view, selected farms are mainly present along the Chiese River (Trentino South Tyrol). "High", "medium-high", and "medium" biosecurity levels are evenly distributed across the farms, and no clusters or spatial patterns were identified. The unique "medium-low" case is situated in the northeastern part of the study area, but upstream and downstream farms present a good biosecurity level.

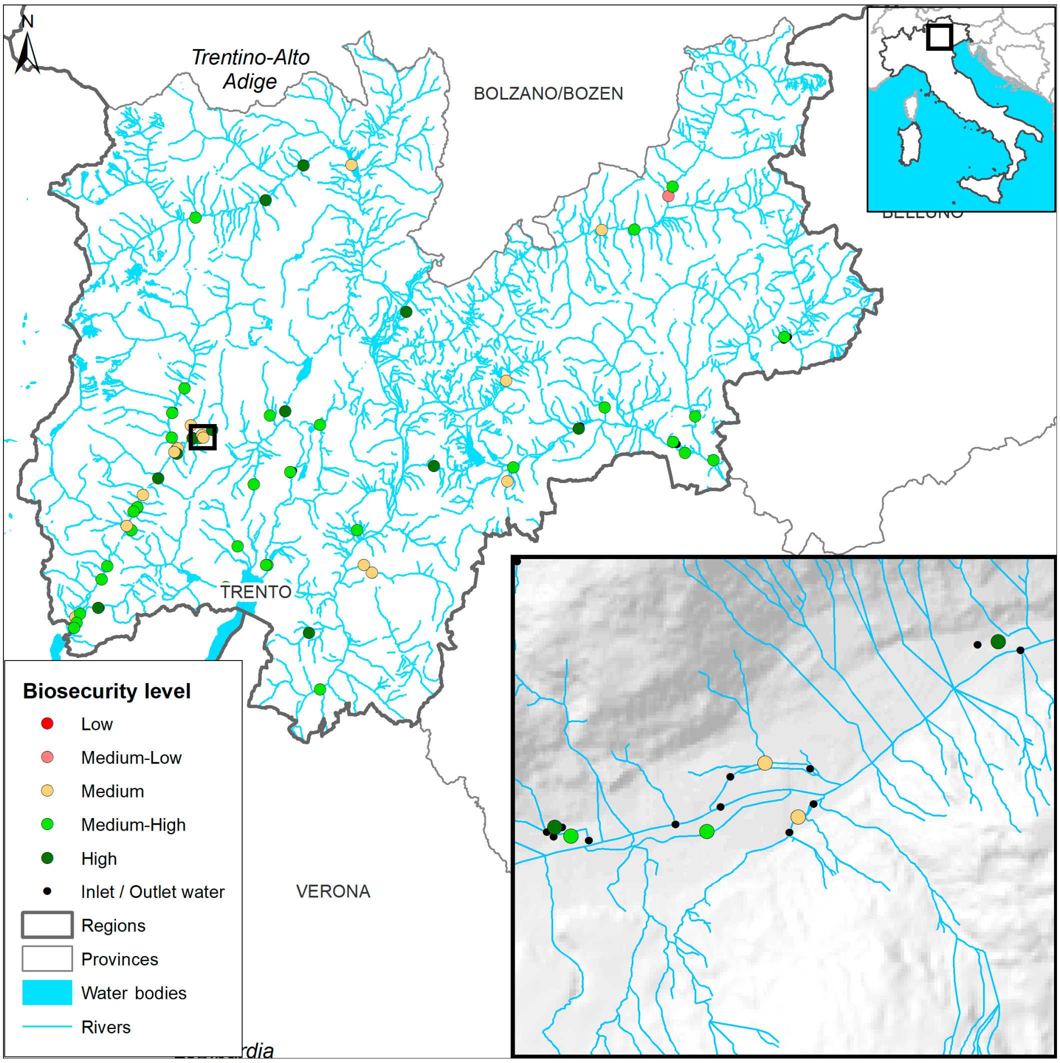

Figure 4. Example of map with farms symbolized by biosecurity level presented in Figure 3. Farms are connected to the rivers (hydrological graph) through inlet/outlet water junctions.

4. Discussion

From the data collected through the checklists, it was possible to obtain a picture of the current and actual situation of the trout farming sector in the APT. Farms were very different in terms of structural and management complexity. This caused some difficulties in the preliminary phases of the study, especially for data collection and processing, which partially limited the analyses. The characterization of the territory where the farms are located may have an influence on the presence or absence of certain facilities. For example, the presence of areas outside the farm for unloading feed, for dead fish loading, or for the disinfection of vehicles is not always traceable in small realities; similarly, water treatment is practically never undertaken if the source is a well; and again, the usefulness of anti-bird nets depends greatly on the area where the farm is built.

In general, some of the elements or aspects considered in this study are basically always, or in most cases, present. The highly represented structural elements are fencing, areas inside the farm for storage of equipment, feed, medicines and disinfectants, and downstream barrages. Equipment management seems to be performed adequately in a good number of farms, where (i) equipment is cleaned and disinfected; (ii) the different areas of the farm have dedicated equipment; and (iii) equipment for fishing and fish loading are easily washed and disinfected. On the other hand, signage is not highly adopted in the farms included in the study, and similarly, the visitor's logbook is present in only

23 farms. The probable reason for these two low values lies in the tradition of animal farming in the area. Operators are accustomed to working alone; farms are small, often family-run, and the importance of indicating to others the operations that need to be carried out is poorly understood—very likely, there is a verbal teaching of procedures. Second, they do not identify "visitors" as health personnel or outside operators who come in for routine or extraordinary visits or for deliveries/returns, and this results in the lack of a complete logbook.

Several other aspects related to legal obligations were applied regularly in the majority of the farms: mortality registration; documentation of the surveillance program; deaths collected, stored, and disposed of regularly; ABPs managed by specialized companies; the presence of a loading/unloading register.

Involving experts in the field to obtain a weighting of the detected elements or aspects of the checklists made it possible to identify those critical factors on which to pay special attention, both in emergency situations (e.g., infectious disease outbreak) and from a peacetime planning perspective on improved interventions.

From the analyses performed on the values obtained from the expert elicitation, the factors found to be of greatest importance in determining the level of biosecurity in a trout farm are as follows:

1. Sanitation and disinfection of the loading truck;
2. Regular collection, storage, and disposal of the dead fish;
3. Farm protection from ichthyophagous birds by bird nets;
4. Use of dedicated equipment for different areas of the plant;
5. Presence of dedicated areas for loading dead fish outside the rearing area.

In the literature, several studies explore and analyze the risk factors for disease introduction in freshwater fish farms [19–23], which can be defined by theme groups such as live fish and egg movements, exposure/spread via water, processing plant on site, geographical factors, and mechanical transmission. Some authors found that live fish and egg movements and water are the most important transmission routes of pathogen introduction, followed by the other factors [21,23], while other authors placed proximity to other farms in the first place, along with water [19].

When analyzing the biosecurity actions taken to control the possible pathogen introduction routes into the farm, all the elements from this study (disinfection of transport vehicles, management of dead animals through dedicated loading areas, presence of anti-bird nets, and presence of dedicated equipment) turned out to be in line with the literature. These measures should be included in a standard biosecurity plan as they reveal pathogen introduction routes and present key elements for preventing the spread of disease [24,25]. On the contrary, other features considered less important by the expert elicitation (e.g., storage of feed in a dry place and separated from other chemicals, presence of signs with operational indications, presence of a visitors' logbook) were probably classified as such because they are important only if applied correctly and not so much because of their presence.

Thanks to the expert elicitation exercise, it was possible to provide a critical approach to the topics addressed by the checklist. In light of the entry into force of the new Animal Health Law (AHL) Regulation (Reg. UE 2016/429 and its delegated and implementing acts), the data collection form used will need to be updated for a more appropriate use by the LCA carrying out farm visits. The new AHL emphasizes the importance of implementing biosecurity measures to prevent the introduction of disease-causing pathogens into farms, a key concept for the EU that drafted the legislation [26]. The results of this study might be taken into account to develop a new checklist, emphasizing the factors found to be more important and reducing the consideration of the less-relevant ones. This could also contribute to making the system more efficient, focusing only on important factors and thus reducing paperwork and eventually bureaucracy. The original checklist was the result of an extensive discussion process among experts in the field, with proposals and feedback, but it contained repetitive and, at times, irrelevant aspects that made its filling time consuming. The new one will be drafted in the same way but, taking advantage of this work, it will hopefully be simpler and more precise. Similarly, the farm assessment for risk level assignment will also be revisited and updated.

One of the in-site application/practical implications of this project was to obtain a ranking of trout farms by combining the biosecurity characteristics that emerged from the checklists with the values obtained from expert elicitation.

From this combination, most of the farms ranged from the medium to the medium-high class. This can be justified by the long tradition and experience of salmonid farming in the APT and because they mostly belong to category 1 (free from VHS and IHN). Moreover, most farms have been in business for years and have constantly invested to improve their condition, reaching a higher level of productivity and becoming more competitive. It should also be emphasized that in the specific study area, the LCA has always been actively present, applying constant control and support to the farmers with a clear positive influence on the productive sector.

The data collected through the checklists provide a snapshot of the situation at the time of the visit; it could be that some situations have improved over time due to interventions carried out on the farms to implement biosecurity measures. An interesting follow-up might be to update the data on biosecurity measures in order to assess any changes and consequently rearrange the farms ranking after the implementation of Reg. 2016/429.

In addition, this study provides a useful dataset that can be fundamental in case of animal health emergencies such as disease outbreak or environmental threats. Using a geographical information system (GIS), data can be integrated with spatial information to produce an overview of the biosecurity situation of farms through thematic maps. GIS can also combine biosecurity data with other territorial or environmental aspects to provide new insights to decision makers.

The framework presented in this study should be used on a regular basis in order to keep the data up-to-date to allow for further analysis of a situation or for action undertaken as close as possible to the actual situation.

5. Conclusions

This study can be considered as a pilot project which aims to integrate different aspects related to aquaculture; thanks to the expert elicitation technique, it was possible to identify the most- and least-important biosecurity measures for salmonid farms in the APT. The ranking of the farms made it possible to highlight those mostly exposed to potential health problems and to provide feedback to the farmers in the study area so that they could implement appropriate biosecurity measures. The study provides a picture that shows an overall satisfying condition of the trout production sector in APT in terms of biosecurity level. An annual update of the presented data and a complete collection of data from all the fish farms present in the territory will provide a clear picture of the situation in case of an emergency.

All data were computerized and stored so that they could be updated annually and, if necessary, extended to other establishments (initially excluded from the study). The resulting picture would be an excellent tool with which to quickly identify the farms most exposed to a possible pathogen in an emergency setting. By integrating the data with GIS technology, which allows for the combination of spatial data (e.g., oriented hydrological graph, geolocation of farms) with biosecurity data and other elements of interest to aquaculture, such a tool could be even more effective in supporting decision-makers. Such a tool could also be adopted in other territories where aquaculture is an important economic and livestock reality.

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