

Biosecurity Practices Applied in Aquacultural Farms in Northern Senegal, West Africa

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Abstract

This study was conducted in northern Senegal, covering the regions of Saint-Louis, Louga and Matam, from June 2016 to December 2016. Surveys were carried out at all farms in this area where fish, shrimp, and molluscs farming or grow-out activities are conducted. The sampling method used is the survey determined by respondents which is a variation of snowball sampling. This method allowed us to administer a questionnaire to the fifty-nine farms in activity in northern Senegal. The overall objective of this paper is to contribute to the improvement of knowledge on aquaculture biosecurity in the study areas through the application of biosecurity measures. This study highlighted the interconnections between the different farms, identified biosecurity measures for infrastructure, livestock and food, and assessed the different biosecurity measures applied to staff. The results revealed that biosecurity measures are poorly implemented. 74.6% of the people surveyed are also unaware of the mechanisms by which aquatic animal diseases appear and spread out, while 86.4% of them have no knowledge of biosecurity in

aquaculture. Our recommendations focus on the need to encourage aquaculture professionals to apply biosecurity measures at all production stages. There is also the need for training or capacity building for aquaculture farmers on biosecurity measures.

Keywords: Aquaculture, Biosecurity Measures, Northern Zone, Senegal

Introduction

World aquaculture production has been increasing steadily at an impressive annual rate of about 11% since 1980 (Lee, 2005). In aquaculture, pathogens tend to cause infections when a host/pathogen imbalance occurs. This leads to a deterioration of the aquatic environment to such an extent that the natural resistance of farmed aquatic animals is compromised and the infection progresses to disease. Good management practices can help maintain this host/pathogen balance, thus minimizing disease occurrence (Plumb, 2002). Viral infections of shrimp farming epidemics have caused billions of dollars in lost income (Lightner, 2003). The best way to control disease outbreaks in aquaculture is through prevention, and this requires the application of biosecurity measures. Biosecurity in aquaculture can be defined as a set of practices, procedures, policies, and regulations used to prevent the introduction and spread of pathogenic organisms (bacteria, viruses, fungi, parasites) and many aquatic invasive species (zebra mussels, rusty crayfish) (Dvorak, 2009). Undeniably, one of the most effective and affordable ways to minimize the introduction of pathogens or invasive species on a farm is to implement a biosecurity program (FIAC, 2010). This means that biosecurity is applied at different levels. At the international level, the practice of biosecurity is mainly based on the application of national or international regulations (Codes and Standards of the World Organisation for Animal Health, the World Trade Organisation, the Codex Alimentarius). In the Aquatic Animal Health Code, clear regulatory provisions are in place to avoid the transfer of animal or human pathogens, while avoiding unjustified health barriers. Biosecurity also applies at the farm level, and the implementation of an effective biosecurity plan is essential to reduce the risk of disease introduction or spread. In aquaculture, it is better to avoid health problems than to have to deal with them. This is because economic losses are often high and is within a very short time frame. In addition, it is widely accepted that the prevention of fish diseases is less costly than their treatment (CEFAS, 2009). Despite the importance of biosecurity in livestock production and in particular in aquaculture, biosecurity plans and measures are often non-existent or used in a reactive manner. The annual cost invested in measures to prevent outbreaks of infectious pancreatic necrosis in fish that have affected the Norwegian aquaculture industry has been estimated at about 60 million

dollars, and this has limited the spread of the diseases in the country (FRS, 2013). It is therefore important to implement and apply good biosecurity practices in order to ensure not only productivity, but also product quality. To limit the spread of diseases in aquaculture, measures must be applied to all stakeholders, infrastructure, and the ingredients used to conduct the activity at all levels of production. Transboundary aquatic animal diseases (TADs) are caused by highly contagious pathogens that can spread very quickly, regardless of national borders, and have serious socio-economic consequences. Domestic and international trade is an important route of transmission of these diseases. Trade development, if not controlled, can lead to the emergence of new mechanisms for the introduction and spread of pathogens and diseases in new regions as their hosts move (FAO, 2010). In addition to these diseases caused by the action of microorganisms, there is a whole range of non-infectious problems caused by non-living factors (environmental, nutritional, etc.). The management of these problems require the application of strict biosecurity measures. In Senegal, aquaculture is a relatively young and undeveloped activity. However, it is a part of all economic development programs, particularly the National Strategy for Economic and Social Development (NSES). This activity has great potential in the northern Senegal, including the regions of Saint Louis, Louga and Matam, where it is expanding rapidly with the presence of the northern branch of the National Aquaculture Agency. The open design of aquaculture sites and their water supply is a potential risk of introduction and spread out of pathogens. However, biosecurity measures can be used to reduce this risk to an acceptable level. In Senegal, aquaculture is very promising but mainly practiced in an extensive or semi-intensive level. Production yields are still low and do not yet exceed 1300 tons (FAO, 2015). This low production may be related to different parameters, including the lack of biosecurity practices. Thus, what is the level of application of biosecurity rules in aquaculture operations in northern Senegal? At farm level in the study area, biosecurity measures appear to be non-existent or insufficiently enforced. This is why we proposed to carry out this study, which focuses on the "State of implementation of biosecurity measures in aquaculture farms in the northern aquaculture zone of Senegal". The overall objective of this paper is to contribute to the improvement of knowledge on aquaculture biosecurity in northern Senegal (Saint Louis, Louga and Matam region) through the application of biosecurity measures. The specific objectives are to determine the interconnections between different farms, to identify biosecurity measures for infrastructure, livestock and food, and to evaluate the different biosecurity measures applied for by staff.

Material And Methods

Presentation of the Study Area

This study was carried out in northern Senegal, covering the regions of Saint Louis, Louga and Matam, from June 2016 to December 2016. Surveys were carried out at all farms in the area where fish, shrimp, and molluscs farming or grow-out activities are conducted. Figure 1 is an illustration of the study area with the location of the different sites surveyed.

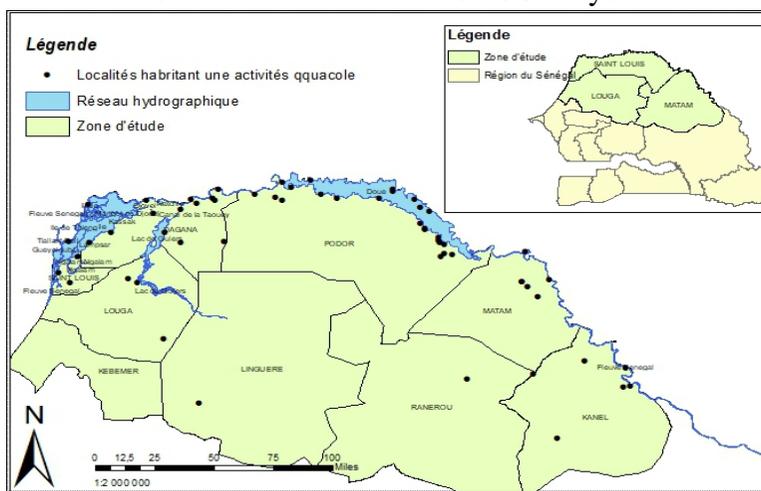


Figure 1. Geographic location of surveyed sites

Material

The material used to carry out this study consists of survey sheets that have been used to collect information on the geographical location of aquaculture farms, the relationships and interconnections between them, and the biosecurity practices applied on different aquaculture production systems.

Sampling Methodology

The sampling method used during this study is the survey determined by respondents. This method, which is a variation of snowball sampling, consists of selecting a farm first at random and recording all biosecurity practices. From this farm, the other farms are visited by indication of the first farm which is surveyed. Therefore, this method allowed us to administer the questionnaires to the fifty-nine farms in activity in northern Senegal.

Analysis and Interpretation of the Results

The data collection was carried out on survey forms, and the data entry was made immediately after the administration of the questionnaire. Data entry, structuring, and quality control were carried out using the Sphinx software. The data were analyzed by the R software once all farms were

surveyed. The geographical location of aquaculture farms were carried out by the ArcGIS10.2.2.2 software.

Results

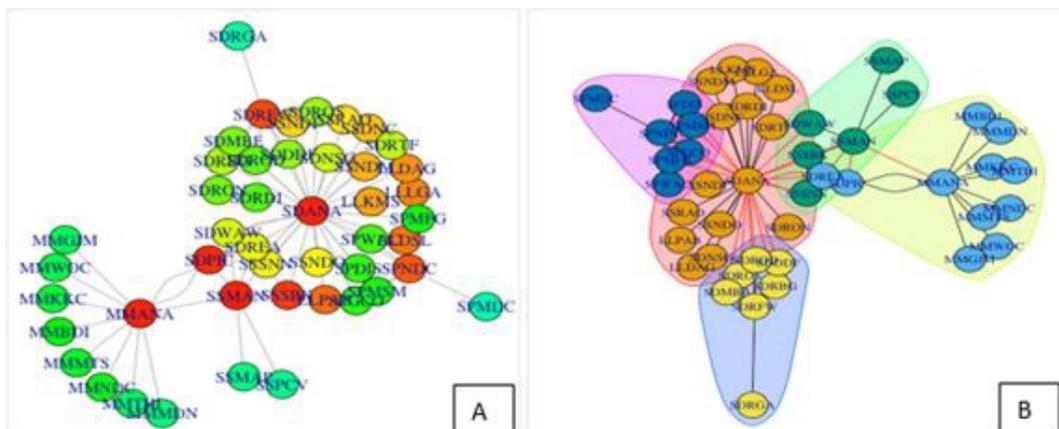
Interconnections and Factors Favoring Contact Between the Farms in the Study

Table 1 describes the different factors that motivate inter-farm contact. It shows that 74.6% [0.61;0.83] of farms have contacts with their neighbors. 83% [0.71;0.91] of farms in the same locality use the same water supply source, the Senegal river. 93.2% [0.83;0.98] of the fish farmed in the study area come from the Aquaculture National Agency (ANA) fish farm based in Richard-Toll. The same trend is observed for the feed with a percentage of 94.9% [0.75; 0.93] coming from ANA. Also, ANA technicians make follow-up visits throughout the zone. In addition, there is the presence of fish-eating birds observed at 78% [0.65; 0.87] of farms, which is an indirect factor of the risk of contact between farms.

Table 5. Factors motivating inter-farm contacts

Modality	Number of citations	Frequency of the modality (%)	Confidence interval
Contacts with other farms	44	74,6	[0.61;0.83]
Using the same water source (Sénégal River)	44	74,6	[0.61;0.83]
Supply of fish from ANA	55	93,2	[0.83;0.98]
Supply of fish feed from ANA	49	83.0	[0.71;0.91]
ANA technicians follow-up visits	51	94,9	[0.75; 0.93]
Presence of piscivorous birds	46	78.0	[0.65; 0.87]

Consequently, the data analysis revealed an existing network (Figure 2 A) illustrating the contacts that exist between farms in northern Senegal. It can be seen that the convergence point of all the farms is either the ANA Richard Toll's fish farm or the ANA Matam's fish farm. To a lesser extent is the Maraye's fish farm of the National Agency for Agricultural Integration and Development. The grouping of farms into clusters (Figure 2 B), based on existing relationships between farms, highlighted five (5) majors groups with different biosecurity practices levels.



LLPAB=Ahmet Biteye Farm; LLDSL=Dierlerlou Syll Farm; LLLGA=Leona Louga Farm; LLDAG=Dagadj Farm; LLKMS=Keur Momar Sarr Farm ; SSMAN=ANIDA farm; SSNDM=Abdoulaye Mbojji Ndiarème farm ; SSDNC=Dior Ndiaye Colonats farm; SSNDI=Ndialakhar farm ;SSBK=Balla KANE farm ; SSPCV= Shrimp Project farm ;SSRAO=RAO farm ; SSSNN=Souleye Ndiaye farm ; SSNDO=Ndombo farm ;SMAP=Maraye Private pond farm ; SDANA=Richard Toll Aquaculture national Agency farm ; SDREA=Aquaculture national Agency's hatchery; SDPIC=PIC farm ; SDWAW=Wass Walo farm ;SDNSG=Saer Gueye farm ; SDRBG=Baye Gay Rosso farm ; SDRos=Rosso farm ; SDDDF=Bonax Diack Son farm ; SOWF=Fawade Wélé farm ; SDRFW=Baye Gaye Rosso farm ; SDBME=Mbengue farm , SDRON=Ronkh farm ; SDRod=Ousmane Diop farm ; SDRGA=Gae farm ; SDRDI=Diameguene Richard Toll farm ; SPMDc=Woury Medina Diathibé farm; SPNDc=Ndiandane farm; SPWAL=Walade Marigot;SPWAc= Walade's Cage culture farm ; SPDIS=Diabo Soubalo farm; SPGCO=Gourel Comi farm; SPMSM=Soubalo Mboumba farm; SPMFG= Fondé Gandé farm; MMBDI=Belly Diallo's farm; MMANA=Matam's Aquaculture national agency farm; MMNDc=Ndouloumadji's farm; MMMTS=Thierno Samassa's farm; MMKKc=Kobilo farm; MMWOC=Woury farm; MMGJM=GIE Jeune Matam farm; MMTHI=Thiadé farm; MMDN=NDIAYE Family's farm;

Figure 2. Network and cluster of aquaculture farms in northern Senegal

Biosecurity Measures Applied to Livestock Infrastructure

Biosecurity measures applied to infrastructures are illustrated in Figure 3. It revealed that 86.4% [0.47; 0.69] of infrastructures are arranged in a row while only 10.2% [0.25; 0.86] applies forward walking. 33.9% [0.40; 0.75] of farms are fenced, resulting to the presence of domestic animals in aquacultures farm at a frequency of 69.5% [0.46; 0.70]. It should also be noted that more than half of farms do not have bird protection, although there are fish-eating birds in the area. Disinfection of the equipments after use is respected by only 3.4% [0.08;0.97] of the farmers, while 50.8% [0.44; 0.72] of them reported exchanging their equipments. The results also shows that the post-harvest dewatering of the pondis applied by only 15.3% [0.47; 0.69] and 27.1% [0.38; 0.77] perform physico-chemical analysis of the water.

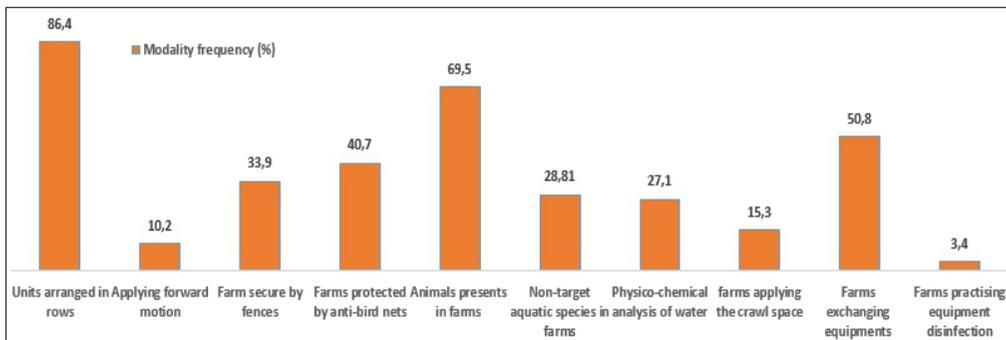


Figure 3. Biosecurity practices applied to aquaculture infrastructures

Biosecurity Measures Applied to Farmed Animals

Biosecurity measures applied to farmed animals as indicated in Figure 4 show that only 8.5% [0.22;0.88] of operators keeps in quarantine aquatic animals coming from other farms. In terms of mortality management, 69.5% [0.56;0.80] of aquaculturists leave dead animals in the rearing infrastructure, while 5.1% [0.14;0.94] removes and buries them. In aquaculture farms in the northern Senegal, 91.5% [0.81;0.97] do not carry out any health treatment on farmed animals. Also, mortality rates are frequent and lesions are often observed on farmed animals. None of the farms perform microbiological analysis, only a few (6.8% [0.19;0.91]) perform parasitological analysis and 96.6% [0.88;0.99] do not apply any biosafety instructions. Veterinary visits are received only for 15.2% [0.31;0.82] of aquaculturists and 74.6% [0.46;0.70] of respondents have no knowledge on aquatic animal diseases.

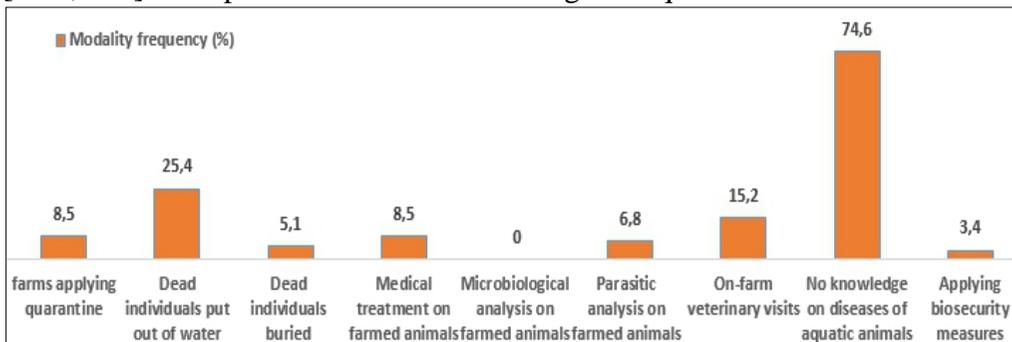


Figure 4. Biological safety measures applied to farmed animals

Biosecurity Measures Applied to the Food

The biosecurity measures applied to food are illustrated in Table 2. The result shows that 83.1% [0.47;0.69] of farms use local food without any analysis either on the food or on the local ingredients used for its preparation. With regard to storage, it is noted that 20.3% [0.35;0.80] of farmers store their

feed in warehouses with storage pallets, while 79.7% [0.4;0.69] of producers have their feed stored in poor conditions.

Table 2. Biosecurity measures applied to the food

Biosecurity aspects	Modality	Citation number	Frequency (%)	Confidence interval
Food type	Local	49	83,1	[0.47 ;0.69]
	Industrial	3	5,1	[0.14 ;0.94]
	No feed	4	6,8	[0.19 ;0.91]
Local food ingredients analysis	No Analysis	100	100	[0.96 ;1.00]
	Analysed ingredients	0	0	[0.00 ;1.00]
Local food analysis	No Analysis	100	100	[0.96 ;1.00]
	Analysed ingredients	0	0	[0.00 ;1.00]
Food storage	storage pallets	12	20,3	[0.35 ;0.80]
	Inadequate storage	47	79,7	[0.47 ;0.69]

Biosecurity Measures Applied by Staff and Visitors

Figure 5 shows the frequency of application of biosecurity measures related to staff and visitors in northern Senegal fish farms. These results shows that 5.1% [0.14;0.94] of the staff have work clothes, while a low percentage (1.7%) [0.01;0.99] of them pass medical examinations. It should also be noted that 61% [0.45;0.71] of the farms have no cloakroom or toilets and in none of these farms was any rotoluva or foot bath found. 98.3% [0.91;0.99] of farms in this area receive visitors, while only 11.9% [0.28;0.85] of farms have developed visitor areas. In addition, 74.6% [0.47;0.70] of visitors have access to water used for aquaculture, while 15.0 % [0.32;0.83] of them have contact with species being raised. It should also be noted that 74.6 % [0.47; 0.70] of the people surveyed are unaware of aquatic animal diseases, while 86.4% [0.75; 0.94] of them have no knowledge of preventive measures applied to prevent occurrence of diseases.

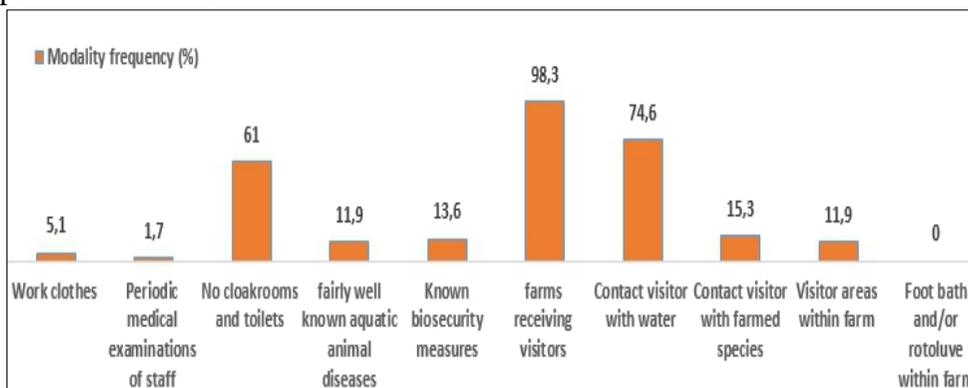


Figure 5. Application of biosecurity measures by staff and visitors

Discussion

Discussion Of The Methodology

The sampling method determined by the respondents and used in this study consisted of the distribution of questionnaires to everyone involved in aquaculture activity in the Saint-Louis, Louga, and Matam regions. This technique allowed us to review all the aquaculture activities that are identified in northern Senegal. This method is recommended by Marpsat *et al.* (2010) who indicated that each time a person answers the questionnaire, they are asked to indicate one to three other people they know and who have a similar activity. Limiting the indicated persons to three has limited the biases that occur in conventional snowball sampling (Johnston *et al.*, 2010). This method is very well suited for studies where the target population is "difficult", low, and where there is little information. Moreover, it is a very simple method to implement when starting a new activity because such a population prevents any traditional sampling procedure, which requires databases as described by Wilhelm (2014). This situation reflects the current situation in Senegal where there is little data on aquaculture. Furthermore, the existing situation is constantly changing as new aquaculture activities are established each year throughout the country.

Interconnections and Factors Favoring Farm-to-Farm Contacts in the Study

Contacts between neighboring farms are quite frequent. Analysis of farms network and livestock clusters in the northern aquaculture zone of Senegal shows a convergence towards the fish farms of Richard-Toll and Matam and sometimes towards the farm of Maraye. These are all state-owned aquaculture management and extension structures. These farms have very strong links with others and are intermediaries between all farms. These exchanges create biosecurity gaps. Indeed, the level of biosecurity is different depending on the clusters. On one hand, some have a relatively acceptable level of biosecurity which is the case for supervisory structures. On the other hand, others have a lower level and should be reduced to an acceptable one. When appropriate biosecurity measures are not applied, these interactions expose all operators to the risk of the emergence and spread of health problems. However, the relationship analysis of farms shows that if such a problem occurs, it will be sufficient if adequate measures are taken at the points of convergence for solution. Contacts between farms consist of good neighborly contacts and exchanges of equipments, most of which are not disinfected. In a study carried out by Koné *et al.* (2012), it was found that disinfection is practiced by 25.0 % of the farms surveyed. This percentage of application is low, but it is better than that obtained from our study. These practices are contrary to FAO's (2012) biosecurity recommendations. Sharing

water source without prior analysis of physical, chemical, and microbiological quality are risk factors for the spread of pathogens on farms in the study area. This risk is cross-cutting because it concerns biosecurity measures that could be applied to equipment, fish, infrastructure, and workers. Vågsholm *et al.* (1994) concluded in a study in Norway that the spread of salmon infectious anaemia was associated with proximity to farms that were in contact with the pathogen and at which biosecurity was poorly applied.

Biosecurity Measures Applied to Equipments

Infrastructure arrangement is necessary when considering the separation of sectors. It must be followed by the application of forward movement, which is poorly practiced in farms visited. Securing farms with fence is also important. The rarity of farm-level fencing is indeed linked to the fact that the majority of farms are located near the Senegal River. The presence of bird protection as suggested by Lotz (1979) has only been observed in a few farms that are mostly state-owned. This is also important because it prevents non-target species from gaining access to the farm. Animal bans or restrictions are measures that any fish farmer should take to prevent the emergence of possible pathogens. This is because mammals are intermediate hosts for many diseases, especially parasitic diseases to which aquatic animals are susceptible. Boutin (2001) recommended disinfecting the equipment and not exchanging it with neighbouring farms. The application of these recommendations is not observed by aquaculturists based in the northern Senegal. These practices are very similar to the study carried out by Koné *et al.* (2012) in Côte d'Ivoire. This study shows that 96.6% of farmers do not disinfect farm equipment after use, while more than half of farmers exchanged equipment with their neighbours. Disinfection releases material from potential pathogens (Blanco *et al.*, 2001). This practice with a crawl space, only applied by 15.3 % of farms, is described by Ricou (2006) as a primary prophylactic measure recommended in the management of fish farming. Studies carried out by the FRS (2005) and Raynard *et al.* (2007) showed that poor biosecurity enforcement poses a risk of increased occurrence and spread of pathogens and pests between farms and between farms and wild fish.

Biosecurity Measures Applied to Aquatic Animals

One of the biosecurity measures recommended in the Aquatic Animal Health Code (2017) of the OIE is the quarantine of all animals that have just arrived on a farm. This is done to assess if they are not potential vectors of pathogens, as they may be in incubation upon arrival. The practices of quarantining freshly arrived animals on the farm and the proper management of mortalities are unknown to most aquaculturists, even though they pose a risk to aquatic animals. According to Bores (2002), leaving dead aquatic

animals in rearing infrastructure is a risk to public health and contributes to the spread of pathogens in environment. Preventive or curative treatments on farmed aquatic animals are exclusively noted for supervisory structure. This is because they are the only ones to undertake microbiological or parasitological analysis. Apart from the supervisory structures such as the National Aquaculture Agency and the National Agency for Integration and Agricultural Development, the majority of stakeholders have no knowledge of aquatic animal diseases and do not apply any biosecurity measures. As far as veterinary visits are concerned, they are received only in 15.2% [0.07; 0.26] of farms.

Biosecurity Measures Applied to Aquatic Animals Food

The farms surveyed use local food obtained at the management structures, while no analysis is carried out on either the food or the local inputs used for its formulation. These practices do not permit to determine the exact composition of the food, particularly in terms of essential amino acids, essential fatty acids, non-essential fatty acids, minerals, and vitamins. According to Tacon (1995), in extensive and semi-extensive farming, fish can partially meet their nutritional needs in their environment. However, when activity increases, subjects entirely depend on the complete diet provided to them throughout their farming cycle. When the formulation of the food gives an incomplete or unbalanced diet, nutritional disorders are quite frequent. The storage conditions of food are also important because they offer stability and durability. The practices noted in this study do not guarantee the quality of the food, which is most often denatured. In ingredients used to formulate fish feed, there are food products rich in polyunsaturated fatty acids (PUFAs) that are particularly affected by lipid oxidation (rancidity by oxidation). These products which include fish oils, fish meal, rice products, and oilseed meal obtained by continuous pressure have low natural antioxidant activity. In the absence of adequate antioxidant protection, lipids rich in PUFAs, including Essential Fatty Acids (EFAs), are highly exposed to auto-oxidation when in contact with atmospheric oxygen. Under these conditions, the nutritional benefit of EFAs becomes harmful to fish health (Tacon, 1995).

Biosecurity Measures Applied by Staff

One of the most common observations made is that staff at aquaculture sites, in the Saint Louis, Louga or Matam regions, rarely have work clothes. Work clothing was exclusively noted for persons in service at the supervisory structures. In addition, a large proportion of the farms surveyed do not have changing rooms, although this is very important. Some workers do not hesitate to relieve themselves in the bushes, which also exposes farms to contamination due to runoff. It is recommended that aquaculture farms should have well

located and ready usage sanitary facilities. They must include toilet and hand washing facilities. The installation of foot baths is strongly recommended in biosecurity, especially when farms receive visitors. Visitors should not have any contact with either the farm water used for aquaculture or the animals being raised. This is because these contacts constitute a risk of the spread of zoonotic diseases. However, this is the case of Mycobacteria which are responsible for diseases in both fish and humans with *Mycobacterium marinum* involved in skin infections at the extremities (Richez et al., 2007). This is also the case for some vibriosis, including *Vibrio parahaemolyticus*, *V. cholerae*, *V. vulnificus*, and *V. mimicus*, which are responsible for bacterial diseases in fish but isolated from wounds, sepsis or septic arthritis in fish farmers. Contamination occurs either by ingestion or by super infected traumatic injury (Umland et al., 2000). It is also possible to note the case of several parasitic diseases where humans can be either an intermediate host with nematodes like *Anisakiasis* or a definitive host with parasites like *Diphyllobothrium spp* (Roberts et al., 2012). Practices such as wearing appropriate work clothes, prohibiting all contact between people from outside the farm and aquatics animals, and switching to footbaths or rotoluva helps to limit contamination from outside. These measures recommended by Craig et al. (2006) therefore limit the spread out of pathogens in all aquaculture operations. The application of good biosecurity practices in aquaculture promotes animal welfare and productivity while ensuring better product quality and the profitability of activities.

Conclusion

This study showed that the recommendations on aquaculture biosecurity are poorly implemented in the northern Senegal (Saint-Louis, Matam and Louga). Simple practices such as quarantine, disinfection of equipments after use, storage of food in good conditions, use of work clothes for staff, management of access to the farm with a fence, visitor register, foot baths and/or a patella, and the management of injured or sick aquatics animals are poorly noted. Practices such as use of the same water source without prior physico-chemical, microbiological or parasitic analysis, exchange of equipment, and visitors' access to water and animals should be prohibited. Our recommendations highlight the need to encourage aquaculture professionals to apply biosecurity measures at all stages of production. There is also the need to train or build capacity of biosecurity aquaculture farmers.

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