Thesis for the Degree of Master of Fisheries Science

Integrating Biosecurity for a Successful Shift from Subsistence to Sustainable Aquaculture in Democratic Republic of Congo

by

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콩고공화국의 영세한 양식업을 지속 가능한 시스템으로 전환하기 위한 생물안전의 도입

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Abstract

Aquaculture has recently been recognized among the sectors to promote for poverty reduction and to ensure food security in DR Congo. This industry experienced fast growth in the mid-1980s worldwide, to become the animal production with the fastest growth. With the development of aquaculture, diseases issues came along, having serious socio-economic and environmental impact. By developing aquaculture, DR Congo will certainly be exposed to this challenge other countries faced around the world. It is therefore important to prepare the necessary tools to prevent or mitigate the impact of diseases, learning from other countries' experience. A literature review on DR Congo's

aquaculture, biosecurity in aquaculture and experiences of some countries, coupled with a survey to investigate awareness of Congolese aquaculture officers and farmers on diseases issues and biosecurity were conducted. The lack of provisions on aquatic life health management and the weakness of general support services to aquaculture represented the lapses identified at managerial side while general farming practices and farm management represented the biosecurity lapses from the farmers' side. This study, through identification of some measures to take at both the national level and the farm level, proposes guidelines for integration of biosecurity to guide the development of an economically viable, sustainable aquaculture sector in Democratic Republic of Congo.

Chapter 1. Introduction

1.1. Introduction

1.1.1. Background

Fisheries and aquaculture sector provide for livelihoods and economic opportunities and are an important source of nutrients. They will certainly play a major role in addressing one of the world's greatest challenge: provide food of good quality in enough quantity for a population set to rise to 9.6 billion people in 2050 (FAO, 2014). Since the share of aquaculture products in the total production has significantly increase past decades, and wild capture tends to decrease, aquaculture is considered as the logical choice in the near future to meet the demand for fish products in this context where the demand for fish continues to increase with the growth of the world population.

In developing countries, fish farming is contributing to local food security, access to cheap food of high nutritional quality in the rural areas and is source of incomes for the farmers. In Africa, where those challenges are obvious, aquaculture has recently been introduced mainly to improve rural remote areas livelihoods and nutrition through low productivity, familial type farms. Efforts of organizations such as FAO to promote

aquaculture practice are progressively bearing fruits: countries such as Nigeria or Uganda have successfully promoted aquaculture at commercial level, with noticeable production increase. Following this wave, Democratic Republic of Congo is currently at the step of construction of an institutional and legal framework to favour this transformation.

1.1.2. Concept of biosecurity in aquaculture

Global aquaculture production increased significantly around 1985 with a growth of about 10% per year. This fast growth is the result of intensification, trade, and introduction of new species of better performance as major factors that boosted the development of this sector. Those factors also exposed the industry to challenges of diseases outbreaks that caused severe financial losses. These losses are the result of deceased production of farmed species or increased production costs; diseases occurrence also showed an important harmful potential to the environment (Murray & Peeler, 2004). A disease outbreak is generally the result of conjugated favourable conditions: presence of pathogen and a host which can be infected by that pathogen; the pathogen's viability (which depends on their number and time they can survive in the environment); and viable infection route. These factors are essential for a disease to occur or emerge and spread (Melba G. Bondad-Reantaso, 2005). Avoiding disease emergence and outbreak is possible by mastering the cultured animal, the pathogens and the environment; by understanding of those factors, the right measures can be adopted to safeguard the

industry in all levels. Here lies the importance of biosecurity, which involves the practices, procedures and policies constituting the tools helping to prevent the introduction and spread not only of pathogens but also of aquatic invasive species (Dvorak, 2009). Diseases outbreaks around the world and particularly in Asia (the leading continent in terms of aquaculture production) constrained countries to adopt rules, tools and practices to secure the industry, with countries awareness on the necessity of biosecurity to secure the aquaculture industry at the local, regional and international level, keeping all the chain of production clean and considering the sanitary status of other countries for international trade.

Africa is not spared by this issue of diseases outbreaks; biosecurity is now of concern in emerging African commercial aquaculture which begins to experience scenarios of diseases emergence and outbreak or faces high standards of developed countries for food produced for human consumption. Authors such as Bagumire et al. (2010) and Isebaiddu (2016) pulled the alarm bell for Uganda's aquaculture, as they observed the lapses identified at farm and national level, representing a threat not just to aquaculture industry but also to the environment and the society. Nigeria, the leading Sub Saharan country in aquaculture, also faces diseases problems and biosecurity issues on this industry (Adetemo, 2013; Obosi at al., 2015).

1.1.3. Aquaculture in Democratic Republic of Congo

Aquaculture was introduced in DR Congo in the early 1950s' by the Belgian colonists as a family fish farming model to support self-food production, raising mainly tilapia. After the independence in 1960, the aquaculture collapsed with the Belgian knowledgeable human resource return to Belgium. From this time, the aquaculture which showed promises of good success declined; and the different programs of donors such as USAID (United States Agency for International Development) or BTC (Belgian Technical Cooperation) in the 1970s and 1980s had negligible impact.

Aquaculture has long been considered as a secondary activity for poor households to get cheap source of protein to complete their diet (SARNISSA, 2010). This idea was strengthened by the donor institutions' policy with their focus on the subsistence fish farming (Micha, 2013). It is just recently that the idea of profit-making commercial aquaculture has arisen, resulting in a rise of private semi-intensive tilapia farms in the periphery of big cities (SARNISSA, 2010). The farmed fish that were once exclusively produced for self-consumption are now entering the local markets.

Since aquaculture is largely expected to overtake captures in fish supply for direct human consumption in the world (Rohana Subashinge, 2009) and given the better performance of fish culture compared to warm blood animal farming, the logical choice for DR Congo should be to increase the production of farmed fish to fill the gap between fish supply and

demand and increase animal protein intake in general in its way to ensure food security. Having understood that, the government has being preparing policies and plans to develop aquaculture, recognizing it among the sectors of priority in the Document of Strategy for Poverty Reduction (MINAGRI, 2010). The new institutional context seems favourable, according to Micha (2013), for aquaculture to awake from the lethargic state it fell into and develop into a promising industry.

1.2. Statement of the problem

Aquaculture was for long time seen like a marginal activity for the underprivileged households. The shift in consideration of aquaculture in DR Congo, coupled to the natural potentialities of the country, and the current shifting in institutional and legal environment to provide opportunities in this sector (Micha, 2013) will certainly lead to aquaculture's development in the decades, if not the years to come as it has been the case for some Sub Saharan African countries. Furthermore, from the development trajectory of Uganda or Ghana's aquaculture (Fig. 1), we learn that this industry can grow exponentially in a short period of time (FAO, 2016); and lessons from various countries show that the industry faced challenges of economic, public health and environmental concern due to diseases outbreaks. It is therefore important that a government, which is planning to develop its aquaculture sector, prepares the necessary tools to guide this

development in a sustainable way for economy but also for environment and public and animal health preservation.

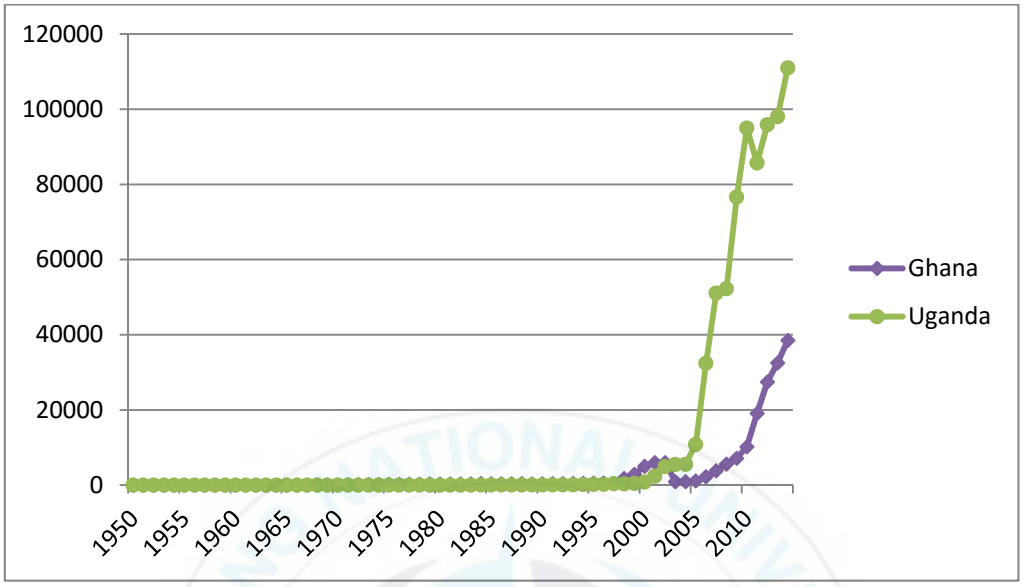

Fig. 1. Uganda and Ghana aquaculture production (www.fao.org)

Biosecurity institutional and legal framework, measures and practices should accompany any aquaculture development policy to ensure the construction of a sustainable industry. Taking all this into consideration, DR Congo can reduce the probability to face major problems and ensure a higher level of impact mitigation (as a result of upstream work and preparedness) by developing customized biosecurity framework adapted to the specificities of the country and the ambitions of the government concerning aquaculture development. This biosecurity framework would be gradually applied in alignment with the different steps of gradual development of the industry.

1.3. Objectives

1.3.1. Main objective

Propose guidelines for establishment of a biosecurity model adapted to DR Congo realities

1.3.2. Specific objectives

- To assess the farming practices to determine the weak points causing fish health loss
- To assess the policies, regulations and action plans in regard of fish health management
- To identify measures and practices which were successful in other countries to adopt or adapt to DR Congo's aquaculture.

Chapter 2. Research Methods

For the purpose of this study fifty-two documents have been reviewed and provided for valuable information; some examples are listed in the table below (Table 1). Reports from the Ministry of Agriculture and Rural Development (MINAGRI), and organizations such as FAO or SARNISSA (Sustainable Aquaculture Research Networks in Sub-Saharan Africa), websites (MINAGRI, INERA, etc.), legislative and regulatory instruments (MINAGRI, Ministry of Environment and Sustainable Development, WTO, OIE, FAO, etc.) and articles published in journals such as Aquaculture or Veterinary Parasitology, constituted the major sources of information on the state of DR Congo's aquaculture, threats of diseases issues on aquaculture development and introduction biosecurity in aquaculture to address the problem, etc.

We investigated awareness of Congolese aquaculture stakeholders on biosecurity, the need of good husbandry practices and roles authority plays in keeping a "clean aquaculture sector" through questionnaires. Two different questionnaires, Form A and Form B, were developed for farmers and officers respectively. Questions focused on areas presented as critical for biosecurity in aquaculture from the papers reviewed.

Table 1 examples of documents reviewed

Documents reviewed	Informations extracted
• Etude Diagnostique de l'aquaculture en République Démocratique du Congo ; Province Orientale (Ulyel, 2008) • Rapport sur l'Inventaire et Bilan Critique des Politiques et Programmes Nationaux de Développement de l'Aquaculture en République Démocratique du Congo (SARNISSA, 2010) • Etat de la pisciculture périurbaine dans la Ville Province de Kinshasa dans le Contexte Post-conflit Armé (SARNISSAb, 2010) • Fish Farming in the Congo Basin: Past, Present and Future (Micha, 2013)	DR Congo's aquaculture situation and future prospects
• International and National Biosecurity Strategies in Aquatic Animal Health (Oidtman B.C., 2011) • Biosecurity in Aquaculture part1: An Overview (Roy P. E. Yanong, 2012) • Biosecurity in Aquaculture part 3: Ponds (Yanong, 2013)	Biosecurity concept applied in aquaculture
• The WTO Agreements Series: Sanitary and Phytosanitary Measures (WTO, 2010) • Aquatic animal health code (OIE, Aquatic Animal Health Code, 2013) • Code of conduct for responsible fisheries (FAO, Code of Conduct for Responsible Fisheries, 1995) • Understanding the Codex Alimentarius (FAO, 2006)	International ruling for aquaculture biosecurity
• Disease and Health Management in Asian Aquaculture (Melba G. Bondad-Reantaso, 2005) • Thailand's current Quarantine Status on Aquatic Animal Diseases. (Kanchanakhan, 2001)	Biosecurity measures applied in example countries

Form A

QUESTIONNAIRE ON BIOSECURITY

Name:

Gender:

Education level:

Name of the farm:

1. For how many years has your farm being operating?

○ less than 5 years ○ between 5 and 10 years ○ more than 10 years

2. Number of ponds [ ] covered area (ha) [ ]

3. Water source for filling ponds

☐ river/stream ☐ irrigation water ☐ runoff ☐ underground/spring

☐ other sources, please specify [ ]

4. How do you drain your ponds? [ ]

Do you treat you effluent? ○ yes ○ no

5. How do you control the weeds in your farm?

☐ agrochemicals ☐ manual removing ☐ biological means (using herbivorus)

11. Have you ever experienced cases of disease in your farm?

○ yes ○ no

12. What do you do with the diseased fish?

☐ treat on specialist advice ☐ treat without specialist advice

☐ remove (how?)

13. Do you keep records on disease cases?

○ yes ○ no

14. Have you ever heard about biosecurity in aquaculture?

○ yes ○ no

15. From which source?

16. Does your staff wear protective clothing?

○ yes ○ no

17. Do you have qualified staff in your farm?

○ yes ○ no

18. Do they have knowledge on biosecurity measures?

○ yes ○ no

19. How often does a field officer visit your farm?

Form B

QUESTIONNAIRE FOR THE FISHERIES OFFICERS

Name :

Grade :

Position title :

1. How often do you visit farmers?
2. What services do you offer to farmers?
3. Are there any cases of fish diseases affecting tilapia fish farmers in your jurisdiction and what are they?
4. What has to be done to stop diseases from emerging at fish farms?
5. What is important for you to do in order to support farmers in fish health management?
6. What do you know about biosecurity?
7. What are the parameters which can be taken into consideration for biosecurity in aquaculture farms?
8. Do the farmers in your jurisdiction have good aquaculture practices related to biosecurity?
9. Do you support farmers to practice biosecurity?
10. What can be done to improve the practice of biosecurity at fish farms?

Chapter 3. Results and Discussion

3.1. Aquaculture in DR Congo

The democratic Republic of Congo is a central African country bordered by 9 neighbor countries; it is the second largest country in Africa (2,345,000 km²). DR Congo is crossed by the Equator with a hot and humid climate in the region of the Congo basin and a dryer and cool climate in the South; there are two seasons: rainy and dry season, but in the equatorial zone the precipitations are relatively constant throughout the year. The hydrographic system is rich, with the Congo River (second rank in the world, after Amazon, by discharge) and its tributaries, streams, great lakes and others of smaller size.

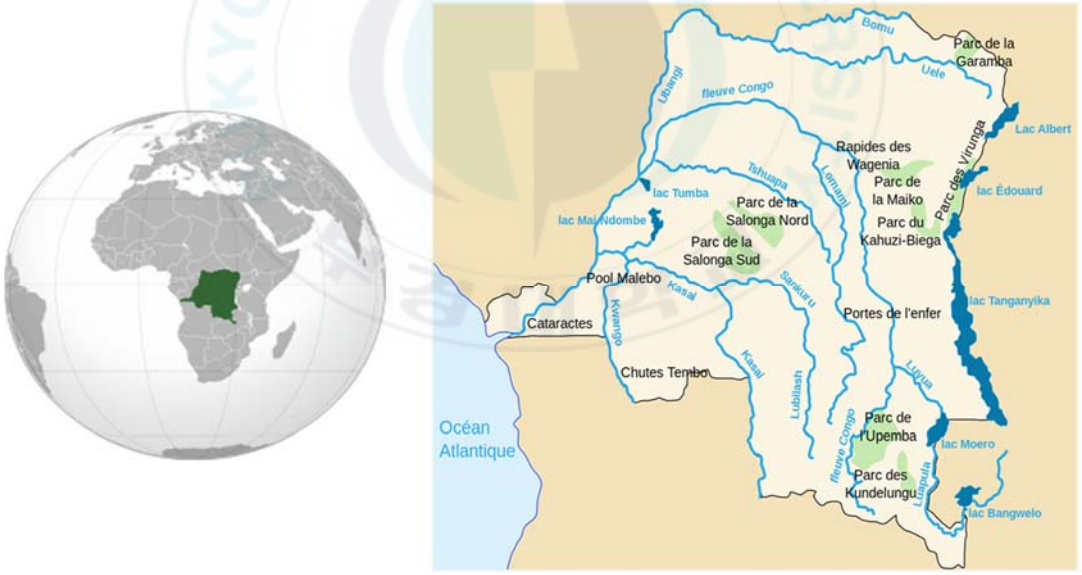

Fig. 2. DR Congo map

3.1.1. Aquaculture history and general overview

Aquaculture was introduced in DR Congo in the early 1950s' by the Belgian colonists as family fish farming model to support self-food production. The first trials were run in the Provinces of Katanga and Kasaï Oriental, and then expanded to the other provinces.

The results were encouraging with 120 000 ponds built (total surface area of 4 000 ha) and a production of over 6 000 tons a year (FAO/BAD, 1990).

Twenty five primary and secondary hatchery centers were created to offer support to fish farmers. The public hatcheries technicians ensured the supervision of fish farmers. In addition to this, on-farm aquaculture research was conducted by the "Institut National pour l'Etude Agronomique du Congo" (INEAC- Belgium) (FAO, 2016).

After the independence the aquaculture collapsed, with farms run by operators who do not have knowledge on ponds construction technics, stocking methods, feeding requirement and procedures, water quality control and even on when and how to harvest (Ulyel, 2008); nowadays, aquaculture suffers from the problems affecting most of the sectors in DR Congo: infrastructures destroyed during the conflicts; low definition of roles between central and local level; low capacity of planning, coordinating and integration of actions; lack of statistics; no harmonization in the implementation of programs and projects (MINAGRI, 2010). The agricultural feeder road network is in disrepair; 10% of the 87000 km been available (FAD, 2011); as a result, most of the production areas are isolated. The effect of these combined factors on aquaculture is a

low production level in contradiction with the great aquaculture potential of the country.

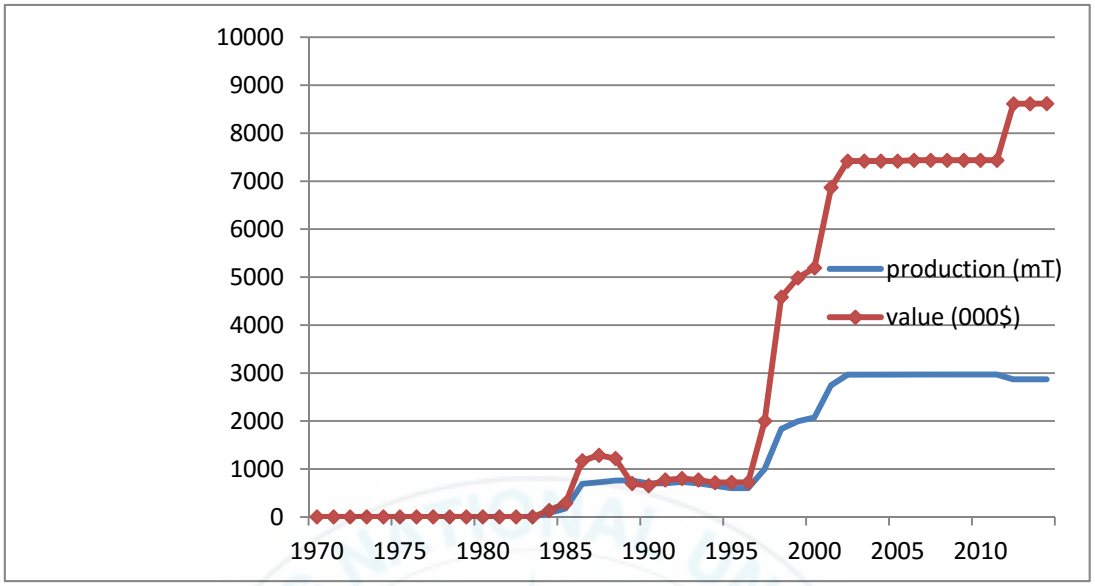

Fig. 3. DR Congo's aquaculture production (www.fao.org)

3.1.2. Farming systems distribution and characteristics

Aquaculture in DR Congo is largely practiced in ponds, most common and cost-effective form of aquaculture production system world-wide. The ponds are built in valleys and in other wetlands. Two types of farms can be distinguished:

• Extensive familial type: Organic wastes are used to fertilize the ponds (organic fertilization). The production is mostly for self-consumption. The contribution to the market is small, due to the low productivity.

• Semi intensive type: organic wastes are used to fertilize the ponds and in addition, by-products of some factories like beer factories are used to feed the fish. Some aquaculture

techniques like sex separation, artificial reproduction are used. The production is mostly destined to the market. (SARNISSA, 2010).

Aquaculture is practiced in all the provinces of the Democratic Republic of Congo.

3.1.3. Aquaculture governance

3.1.3.1. Policy framework and national regulation

Aquaculture has been ruled by an archaic and non-adapted law, the “Law on Fisheries and Hunting”, which was promulgated in 1937. A new law, the “Code of Fisheries and Aquaculture”, has received the government agreement and is currently discussed at the parliament. Aquaculture development strategy and plan have been proposed to provide guidelines to develop this sector sustainably (Micha, 2013).

The National Aquaculture Development Plan contains the directives for the future of aquaculture with the shift to commercial level and introduction of culture systems such as tanks, raceways and cages but keeping ponds as the major system in term of number and contribution to production.

3.1.3.2. Institutional landscape

The ordinance No.07/018 of May 16, 2007 placed the fisheries sector which includes fisheries and aquaculture under the authority of the Ministry of Agriculture, Fisheries and livestock; the Ministry of Environment, Nature Conservation and Tourism; and the Ministry of Rural Development. Since then, the Ministry of Agriculture, Fisheries and livestock and the Ministry of Rural Development have been fused in one ministry: the

Ministry of Agriculture and Rural Development (Fig. 4. Aquaculture institutional framework. Under this ministry, the Directorate of Fisheries and Aquaculture and a specialized service: the SENAQUA (Service National d'Aquaculture) are in charge of aquaculture.

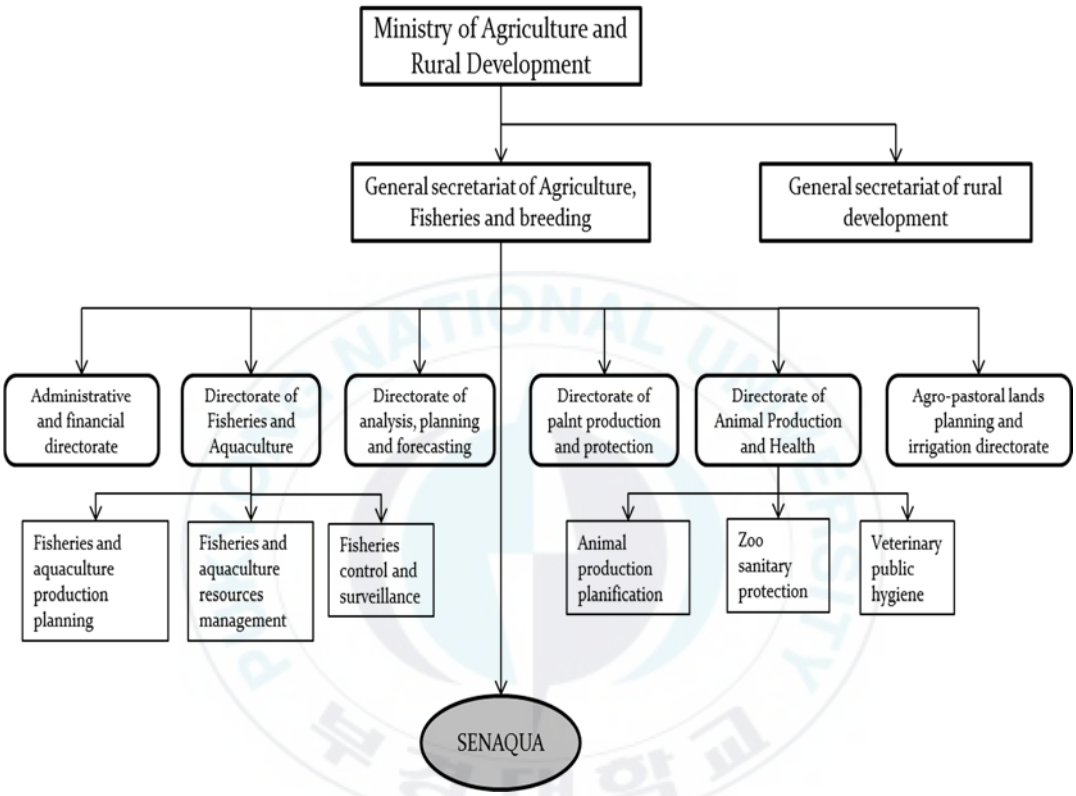

Fig. 4. Aquaculture institutional framework (www.agriculture-rdc.net)

SENAQUA's missions are as follow:

• Management of the primary and secondary hatchery centres.

• Organization of aquaculture coordination in the administrative areas of the country.

• Evaluation of resources, ways to revive aquaculture, and to prioritize actions.

• Re-establishment of the national register of the Ministry's policy for aquaculture.

• Coordination of actions initiated by national projects and programmes as well as bilateral or multilateral ones.

• Launching applied research in aquaculture.

3.1.4. Animal health management

Structures under the authority of the Ministry of Agriculture are in charge of animal health and disease management: the Directorate of Animal Production and Health; the Animal and Vegetal Quarantine Service; and Veterinary Reference Laboratories the LABOVET in Kinshasa and Lubumbashi.

The Directorate of Animal Production and Health deals with national policies and strategies in this area and make sure that the government decisions are applied. The Directorate reports to OIE (Office Internationale des Epizooties) and UA-BIRA (Union Africaine – Bureau International des Ressources Animales) the major animal epidemics and epizooties.

The Animal and Vegetal Quarantine Service operates inside of the country, in custom houses agencies and border posts. The service is in charge, inter alia, of zoo sanitary surveillance and animal quarantine. It controls the entry and exit flow of animals and

animal derivatives to prevent introduction, dissemination and spread of diseases and/or harmful pathogens to human and animals; it also controls veterinary drugs quality and can decree the seizure, quarantine or treatment, and disposal if necessary of animals, food, drugs if they are recognized out-of-date, contaminated, infected or harmful to human and animals.

The Veterinary Laboratories are a technical support in animal production and disease control for the human health protection. They diagnose animal diseases by investigations through routine handlings and help in their control and eradication. They participate to the research.

3.2. Biosecurity concept in aquaculture

The aquaculture sector is the animal production with the highest development trend. From the mid-1980s, intensification, trade, and introduction of new species of better performance boosted the development of this sector. They also exposed the industry to challenges of diseases outbreaks that caused severe financial losses worldwide. The growing aquaculture sector began to represent a serious threat to environment and public health. The economic losses have been expressed in various ways; here are some examples (Melba G. Bondad-Reantaso, 2005) :

- Thailand 1992: yellow head disease (YHD) with losses estimated to 30.6 million US$;

- China RP 1993: shrimp diseases associated to losses estimated to 420 million US$ and a decline in production from 210.000 to 87.000 tonnes;
- Honduras 1995: 31% decline of production of shrimp due to Taura Syndrome Virus (TSV);
- Philippines 1997: shrimp exports decrease from 30.462 to 10.000 tonnes;
- Ecuador 1999: White Spot Syndrome causes losses evaluated to 280.5 million US$ (63,000 tonnes); closing of hatchery operations; 13% jobs loss (26,000 people); 68% less sales and production in feed companies and packing plants.

Concerns about safety of farmed animal products in general led to the introduction of biosecurity in agricultural animal production systems; among those, the poultry industry successfully integrated this concept. This industry, which fully developed and finely tuned biosecurity procedures, has been used as a benchmark for application of biosecurity in a suitable way for the aquaculture industry context (Pruder, 2004). It was in the late 1990s that ideas of biosecurity concept introduction in aquaculture arose. We can define biosecurity in aquaculture as the sum of practices that minimize the risk of introducing an infectious disease, its spread in the facility and also to other sites and other susceptible species (Roy P. E. Yanong, 2012).

To ensure the “safe” status of aquaculture products, biosecurity has to be considered at national and farm level (Oidtman B.C., 2011). . At the national level, biosecurity policies and regulations are being implemented and enforced by Competent Authority and official

services. At this level, the concern is to avoid the spread of diseases from countries to countries through trade of living aquatic organisms or their products (Fish Vet Group, 2014), while at the farm level, biosecurity is achieved by the safeguard of animal health, the exclusion of the pathogen and maintenance of good environment through good husbandry practices, better management practices and so on (Melba G. Bondad-Reantaso, 2005).

3.3. Identified biosecurity issues in DR Congo's aquaculture

The review of aquaculture sector in DR Congo revealed weak points at all the levels that make the practice of this activity vulnerable. The lack of provisions on aquatic animal health management in laws and policies, the weak capacity of the services responsible for aquaculture, the poor data collection and information availability and sharing, the absence of aquaculture curricula in universities and colleges, and the poor consideration of aquaculture in agricultural subjects for research programmes represent a serious biosecurity gap at national level (SARNISSA, 2010). At the farm level, the situation is not much better (SARNISSAb, 2010); farmers, generally, have no knowledge on aquaculture practices and, as result, the ponds are poorly constructed, they use untreated surface water of unknown quality status, and the seed health status is unknown, since they come from uncertified hatcheries or are collected from the wild. Once they stock the fish in ponds, poor husbandry practices are applied and there is no checking for diseases from the farmers, who are not even aware on biosecurity issues (Ulyel, 2008).

It would be dangerous for DR Congo to promote aquaculture development without taking correctives measures to solve the problems here above and favour a receptive environment where biosecurity measures and practices would be easier to apply.

3.4. Integrating biosecurity in DR Congo's aquaculture

In the actual international aquaculture environment, integrating biosecurity in aquaculture is imperative. DR Congo's aquaculture is for now at an infant stage and this can constitute an advantage, since biosecurity can be included in the planning phase (aquaculture industry organization, farm construction, national and farm contingency plans, etc.), instead of being used as a corrective tool hard to implement when the industry is already set up and because of the various additional cost imposed by the changes that would be needed to upgrade it. Through biosecurity, the introduction of an infectious disease can be minimized and its spread within the facility or to other sites and other susceptible species can also be prevented (Roy P. E. Yanong, 2012). This concept and everything about it must be understood in order to be useful. Practices, procedures and policies help preventing the introduction of a pathogen and its spread, when it has been detected in the farm (Oidtman B.C., 2011); they have to be developed ahead of time to ensure good pro-active and reactive actions as a result of good preparedness.

The present work reviewed some general tools and specific examples of other countries to adopt or adapt in DR Congo with some improvements and/or modifications to build a strong aquaculture industry in the future.

3.4.1. National aquaculture biosecurity

An appropriate legislative structure with laws and, acts enforced by established competent authority and official services is fundamental for an effective biosecurity framework at the national level (Oidtman B.C., 2011). Governments are encouraged to reflect the international instruments on fish health management in their national laws to promote homogeneity between countries and facilitate implementation of international recommendations at national level.

3.4.1.1. Aquaculture biosecurity policy and regulations

Appropriated and strong national laws and regulations on aquatic animal diseases are the pillar of biosecurity. These tools should designate and empower a Competent Authority and official services responsible for its enforcement. All activities of the aquaculture sector subject to control by the official services must be regulated by these laws and regulations (e.g.: “Aquatic life disease control act” of South Korea which sets a comprehensive control system to prevent outbreaks or the spread of aquatic organisms’ diseases).

Preparing a legal framework in aquatic life diseases should be the first step in building DR Congo’s biosecurity framework.

In DR Congo, the veterinary authority, the Directorate of Animal Production and Health can fully play the role of competent authority for aquatic health management, designated and empowered by the legal instruments in aquatic life disease management to implement its different provisions. Official services work on the field on behalf of the competent authority.

3.4.1.2. Monitoring and surveillance

Surveillance activities include collection, compilation and systematic data analysis with a timely dissemination of information to the authorities for them to take appropriated measures (Hasten, 1997).

According to the approach or the nature or origin of data used, financial, logistical and technical constraints can be encountered for the surveillance implementation. The authorities have to choose the suitable surveillance approach (passive disease reporting system, structured surveys, participatory surveillance, etc.). The origin of data will help classify the surveillance as active (the primary purpose of data collection is surveillance) or passive (data are collected for different primary purpose such as production records for farm management and can be secondarily used for surveillance) (Dvorak, 2009).

There is no surveillance or monitoring program for aquatic animal diseases in DR Congo. The poor data collection, evidenced by the lack of statistics on aquaculture in the Ministry of Agriculture and Rural Development Statistics report (SNSA, 2012), shows that even

passive surveillance is not practiced. Farmers hardly get in contact with extension officers, making diseases reporting, in case they occur, difficult.

Veterinary laboratories are essential in surveillance programs for disease diagnostic. The "LABOVET" of Kinshasa and Lubumbashi are the two reference veterinary laboratories of the country. In order for them to play their role in aquatic animal disease diagnosis, they will need equipment upgrade and personnel capacity building.

Surveillance programs are necessary because they will facilitate generation of national fish disease list. Once the disease list is established, targeted surveillance programs can be established to monitor pathogens of significant importance, since all pathogen are not of equal concern (Roy P. E. Yanong, 2012).

Surveillance can also help in zoning and compartmentalization, which are important if a pathogen is present in a country to define where and determine if there are areas free of diseases (Fish Vet Group, 2014). Allocation of efforts will therefore be more specific. Surveillance is an important step to collect information essential for control and eradication measures; it provides information useful to run risk assessment or set up contingency plans. Programs can be established for aquatic animal health and diseases management. The challenging side of surveillance will be its cost: the socio-economic level and technical development of the country, the complexity of the aquatic environment, the nature of containment (pond, raceway, cages, pens, etc.), the intensity of practice, culture system (monoculture/poly-culture/integrated) and the variety of diseases will constitute difficulties to institute a reasonable surveillance and reporting system.

There is a need to weigh the economic benefits of these programs against the aquaculture development stage, with the aim to establish practical and cost-effective programs implementable with the existing resources and technical capacities.

The Animal and Vegetal Quarantine Service operates in borders areas as well as inside the country to control animal movements; capacity building for the aquatic animal diseases surveillance will be needed to help this service to play its role in surveillance programmes.

3.4.1.3. Aquaculture biosecurity research

Research is necessary for biosecurity in aquaculture. Research will provide information to use in decision making (e.g. import risk analysis), to improve the farm practices and reduce the risk of disease emergence and outbreaks, etc. Research cannot be run without researchers and appropriated facilities and equipment.

The INERA (National Institute for Agronomic Study and Research) is in charge of research in the agronomic sector in DR Congo. As it the case in the agronomic fields in DR Congo, more efforts are put in agriculture and breeding compared to aquaculture. Nevertheless because of its representativeness in the country (at least one station per province), INERA can be equipped and its researchers trained to give each province a designated research station to focus on their needs.

Fig. 5. INERA stations (www.inera-rdc.org)

3.4.1.4. Education, training and information sharing

Disease occurrence depends on the pathogen and on the fish of concern. The immunity of the fish which can be weaken when the fish is stressed is an important factor of disease outbreak. To avoid stress, farmers have to meet the fish requirements (water quality, temperature, nutrients requirements, etc.) which can differ according to the fish species cultured or the life stage. From the general husbandry practices for fish, specific practices can be required. This shows how important specific knowledge on aquaculture is.

The actual educational system in DR Congo does not provide an aquaculture curriculum to students. The three major universities of the country, UNIKIN (Kinshasa), UNILU (Lubumbashi) and UNIKIS (Kisangani) host a department of agronomic sciences and can

be good candidates to develop a curriculum of aquaculture, with the possibility to add among the specializations a specialization in fish disease. At the end of their curriculum, those professionals of aquaculture and specialist in fish disease would reinforce the workforce of aquaculture officers, of specialist working as consultants with farmers, or of knowledgeable staff in aquaculture farms.

Extension, advisory services and vulgarization have been a duty of the twenty-five principal and secondary hatchery centers since the colonial period of the country with demonstrations, farmers and instructors training, production of selected strains and fry distribution (SARNISSA, 2010). With the reform of aquaculture sector and creation of the SENAQUA in 1992, the hatcheries centers are managed by the SENAQUA's local authority at provincial level. On the field SENAQUA's officers have the help of some NGOs supervisors who offer extension and advisory services. They are dynamic in the capital city area but in the countryside, deteriorated areas with lack of basic infrastructures and weak institutional and management capacity (MINAGRI, 2010), farmers hardly have access to those services. There are also staff limitations in number and quality and lake or antiquated infrastructures (SARNISSAb, 2010).

Some farmers organizations have been created, one example is the GAPK (Groupement Agro-Piscicole de Kinsahsa) created to exchange experiences, improve the practices, perform the production and sell fish fry, fingerlings as well as consumable fish (Micha, 2013). Promoting this type of associations, gathering farmers according to the species

cultured, the production system and intensity, can help reaching more farmers to spread teachings on adapted farming practices. Government structures such as SENAQUA, SENADEP (Figure 3), can see their task lightened when associations are created to reach more farmers through them. They also benefit from the help of NGOs such as BDD and APILAFF (Oriental Province) which play the role of advisors to farmers (Ulyel, 2008) and some farms such as CADIM, CEDA or Ma Crevette, in the capital city area, which have the double mission of fish production and other farmers' education (SARNISSAb, 2010). All these players should be considered for capacity building programs.

The professionals of the sector are technical engineers (level A1: from superior institutes, the ISEAs or ISDRs) or engineers (level A0: from universities, such as UNIKIN, UNILU or UNIKIS) graduated in agronomic sciences. Agricultural and Veterinary Technical Schools provide high-school level technical courses and ERAIFT provides for post university courses (Master and PhD). The curriculum is general and once they graduate, the number of student choosing to work in aquaculture rather than agriculture or breeding is low (SARNISSA, 2010).

3.4.1.5. Multi-sectorial collaboration

Safe aquaculture product for human consumption requires mastering of activities going beyond the farm practice of aquaculture. Trade (import-export) and post-harvest sectors (transport, processing, sale, etc.) control, environmental monitoring, aquaculture research and curricula insertion in universities and other education institutions, public health

among others, are areas that the Ministry of Agriculture and Rural Development cannot supervise alone. Multi-sectorial linkages with other ministries are essential for biosecurity in aquaculture. The ministries which can be important are:

- the Ministry of Trade,
- the Ministry of Environment and Sustainable Development,
- the Ministry of Health,
- the Ministry of Scientific Research
- the Ministries in charge of Elementary and High school Education and in charge of High and University Education.

3.4.1.6. Import risk analysis (IRA)

Trade is a route of pathogen spread; exotic diseases have been introduced into countries through importation of aquaculture products. Through import of these commodities the countries expose themselves to introduction of pathogens. To minimize the risk, an import risk analysis (IRA) can be a useful tool for decision making (Risk identification→ Risk assessment→ Risk management →Risk communication) There is a need to develop a national legislation on import, export or transit of live aquatic animals and their products to support the work that will be done on the field and to designate the different structures which will be involved. Quarantine services find their importance in import/export of live aquatic animals with quarantine measures including, in the case of Thailand, pre-importation (preparation of the facility accepted as quarantine facility),

arrival at the entry port (verification of certificate of origin and health) and post-importation (quarantine with observation and tests for listed diseases) of the stocks (Kanchanakhan, 2001). For DR Congo, the SQAV (Animal and Vegetal Quarantine Service) will need capacity building to play this important role. Support of other services such as OCC (Congolese Office of Control) which work at the custom houses and border posts can be negotiated.

3.4.1.7. International agreements, codes and standards

Trade and productive exotic species introduction have been source of aquaculture development. They also opened the door to diseases spread and emergence of new diseases in countries. Governments are now willing to safeguard their aquaculture industry, and this can't be achieved without cooperation at the international level. Rules and mechanisms of trade are developed to prevent contaminated shipments of aquatic products and minimize the illegal transboundary movement of stocks. The sanitary status of neighbouring countries is an important aspect to take into consideration for any exchange of aquaculture commodities. The illegal transboundary movement of stocks can represent a serious issue for DR Congo, vast country bordered by nine countries.

At the international level, agreements have been made to regulate trade of living aquatic animals and their products in order to protect countries from exotic diseases but also to prevent countries from protectionist trade barriers erection under cover of sanitary and phyto-sanitary measures (Oidtman B.C., 2011).

- The Sanitary and Phyto-sanitary Measures Agreements (WTO, 1995)

It is the highest level of international agreement in the sector. It sets the basic rules on food safety and animal health standards and applies to all sanitary and phyto-sanitary measures that may have a direct or indirect impact on international trade (WTO, 2010).

DR Congo participated to a survey conducted 2012 on international support measures specific to the Least Developed Countries (LDCs) related to the WTO Provisions and Preferential Market Access. The report shows that the country doesn't participate to Sanitary and Phyto-Sanitary Agreement meetings for financial reasons. They also noted that the requirements set by the European Union, based on international standards were too high; the country has been unable to export agricultural products. Presumably, aquaculture products will face the same problem. A better participation of the country and efforts to meet the standards required will be necessary if DR Congo plans to export its aquaculture products in the future. This will be possible through review of the sanitary measures and practices, reflecting international standards. Testing, inspection, certification, pre-export quarantine, packing and proper labeling will be required. It is clear that the challenges will differ according to the level of development of nations; developed countries are therefore encouraged to assist developing countries in meeting the international standards given that a weak link weakens the all chain of global aquaculture industry.

- OIE (World Organization for Animal Health) Standards

The World Organization for Animal Health (OIE) is the intergovernmental organization responsible for improving animal health worldwide (Barry Bousfield, 2011). The OIE Aquatic Animal Health Code and the OIE Manual of Diagnostic Tests for Aquatic Animals contain the standards for cultured aquatic animals set by the OIE (Hill, 2009). The Code and the Manual provide lists of diseases of different aquatic animals groups (OIE, 2013), (OIE, 2003).

The Directorate of Animal Production and Health is the competent authority for animal health management and is in charge of animal diseases report to OIE in DR Congo. Collaboration between this directorate and the SENAQUA is important to insert aquatic animal diseases in surveillance programs and produce the national aquatic animal diseases list, drawing on the example of the NACA (Network of Aquaculture Centers in Asia-Pacific) which developed a list of 32 diseases, and including many of the OIE-listed diseases and diseases of importance in their region (Bondad-Reantaso, 2005).

- The Code of Conduct for responsible Fisheries

It is a voluntary instrument adopted by more than 170 members of FAO in 1995, seeing the need to conserve and manage the world's fisheries for future generations (FAO, 2001). This non-binding instrument can be useful for DR Congo in the process of building a robust biosecurity framework for the country's aquaculture industry, especially when considering the six technical guidelines for responsible fisheries devoted to aquaculture development with subjects such as "health management for responsible movement of live aquatic animals" (suppl.2) or "ecosystem approach to aquaculture" (suppl.4).

- Codex Alimentarius Commission (FAO/WHO/1999)

The Codex Alimentarius is the international organism responsible of definition of harmonized food standards for consumers' protection (Consumers International, 2010). (FAO, 2006). The DR Congo is part of the two international organisms (FAO and WHO) but doesn't participate in Codex Alimentarius assemblies.

3.4.2. Farm level of biosecurity

Farmers' aim should be to get healthy fish and keep their healthy status throughout the culture process in the farm and preserve the environment. To maintain health status in a farm, biosecurity measures must focus on three targets: the animal management through good husbandry practices to optimize health and immunity; the pathogen management by prevention, reduction and elimination; and the people management by education of staff and visitors. All the parameters of production will be secured since the ease of a pathogen entrance and spread depends on the cultured fish, the environmental factors, the characteristics of the pathogen and the workers compliance with biosecurity protocols (Roy P. E. Yanong, 2012)

Ponds are the principal aquaculture system in DR Congo and authorities' vision for the future commercial aquaculture is to keep this system at the top of the production systems (MINAGRI, 2008). The advantage of aquaculture in ponds is also the origin of its biosecurity challenges: interactions with nature (Yanong, 2013). Those challenges are the differences in geology and topography, water resources, prepared and live food, species

and density (oxygen limitation, metabolic waste accumulation (Randall E.Brummett, 2008)), exposure to pest, predators and other animals, disinfection options and limitations, and more complex disease management. For biosecurity at farm level, number of parameters will thus require special attentions

3.4.2.1. Farm siting and design

In the absence of appropriated regulation in aquaculture and given the weak support of extension and advisory services to Congolese farmers, farms are implanted without prior study for site selection, and ponds poorly constructed. Farm siting is a crucial step through which a number of hazardous parameters can be mastered: quality of water sources, presence of pathogens of interest for the cultured fish (if a national disease list exists), and contaminations from other human activities (industries, crop fields where agro chemicals are applied, etc.). On this well selected site, it is import to have the right facility design and to manage the farm properly. The design and management of the facility can help to exclude pathogens or limit its spread by physical isolation of different groups of fish. Different life stages of fish differ in their susceptibility to diseases. Younger life stages will be more susceptible to diseases than older life stages; there is a need to separate them in different systems. In the semi-extensive aquaculture in DR Congo, farms generally have several ponds for sex separation mainly, the age-class separation is possible and can be easier to promote; in the extensive type on the other hand, there will be need to build additional ponds, since in general a single pond is used

with partial harvests and stockings, favouring mix of different batches of fish. The existence of more ponds is better because they can also serve to separate animals of different diseases status: healthy, diseased or infected and fish of unknown disease status. The farm design and pond construction should also help in the drainage, important in case of disease outbreak not just to clean the facility but also to safeguard other surrounding farms by preventing contaminations through effluents. The revival of the public hatchery centres, one of whose role is to help farmers in ponds construction, is hence important. One of the ways to ensure proper site selection for farm establishment is through farm licensing system and authorization, by requirement of report of study from specialists.

3.4.2.2. Input utilization, control and management

New stock of fish, water intake or the farm environment can bring pathogen in an aquaculture system; pathogens can also be introduced via other organisms, in commercial or live and frozen food. It is therefore important to control all this parameters.

To ensure a supply of safe seed to farmers, rehabilitation of the public hatchery centers across the country and establishment a system of certification of private hatcheries is necessary. The availability of seed will help reduce the disadvantageous practice of seed collection from the wild which usual results in mixed age, classes and species stocked ponds. After getting seeds from a reliable provider, it is advised to observe them in a quarantine area for a period of time before stocking the ponds (Dvorak, 2009). The monitoring should continue throughout the production through routine observations.

Aquaculture inputs (feed, pond fertilization, use of chemicals and drugs, etc.) are of biosecurity concern because of the threat they can represent when mastered improperly.

Congolese farmers generally combine pond fertilization and feeding. Both the chemical fertilization and the biological one are used. Compost or poultry, cow, and pig manure are used to fertilize the ponds; they are used in a row form, without any treatment. They feed the fish with farm-made fish meal or commercial feed based on some industries by-products (maize bran, palm kernel, breweries by-products, rice bran, and soy). Most of those feed are made with no consideration of specific species and ages nutritional requirements. Local commercial pelleted feed production promotion; farmers training on how to safely use biological fertilization (animal manure) and how to prepare farm-made feed (formulation, hygiene and drying) are the way to reduce the biosecurity risks from feed. Regardless of the source of the feed, proper storage and use before expiration prevent from pests, microbial and fungal contamination.

Herbicides and general pesticides are commonly used in agriculture; the “Plan of Pest and Pesticides Control” shows major loopholes in the control and management of the use of those substances in agriculture: use of out-of-date products or use of some products forbidden by certain countries or associations because of their proven toxicity. This constitutes a threat to aquaculture with the shared water resources or in the cases of integrated aquaculture with agriculture (mostly association tilapia-rice). Because of the nature of the system used (earthen ponds), some farmers use herbicides to control the weeds growth to avoid predators or nuisance animal that can find a good environment in

the growing weeds. Up to now, the law No. 11/022 on Basic Principles on Agriculture is the only national text which globally takes in charge conditions of pesticides management in all the levels of the chain (import, storage, transport, utilisation, container disposal, etc.); this law is not efficient because of its low diffusion, widespread ignorance and the lack of implementing legislation (FAD, 2011).

In the current situation of DR Congo's aquaculture, there is no evidence of wide use of drugs and medicines, probably because of the extensive state of production. In projection of the future intensification planned to increase the production, drugs and veterinary products acquisition and use in aquaculture should be regulated. The SENIVEL (National Service of Veterinary and Breeding Inputs), in charge of drug use control for animal productions, should be tasked for farmers education on proper use of veterinary drugs and investigate the compliance to the regulations on veterinary drugs in aquaculture in both farms and certified drugs and chemicals dealers. Drugs and chemical acquisition can be liberal (the farmer buys freely from certified dealers) or on prescription of a fish health specialist after diagnosis.

The quality of the influent water is critical for fish health, since water is one of the way through which pathogens can be introduced in farms. Congolese farmers mainly use unprotected surface water; ponds are filled with this water without treating it. Farms are hence exposed to pathogens. While proper site selection can help mitigate the risk from water source, treatment can eliminate pathogens if they are present. Various methods can be used to treat water from the use of ozone or ultraviolet, to chemical treatment.

Parameters such as pH, and temperature or dissolved oxygen are to be taken into account during production cycles since inappropriate water parameters will increase fish stress and lower their immunity, leaving them more susceptible to infections by pathogens.

3.4.2.3. Ponds maintenance and effluent management

Ponds are the common system used in aquaculture in DR Congo, whether in extensive or semi-intensive farms. The origin of biosecurity challenges in this system is interaction with nature. The nature of the soil, the water source, the choice in nutrition method, species and density, the exposure to other animals and limited disinfection options and efficiency, make the disease management more complex (Yanong, 2013). Selecting the site when planning to establish a farm is a critical point where some of the biosecurity challenges can be avoided.

To eliminate the pathogens, farmers should use sanitation (cleaning) and disinfection (using chemical disinfectants) of ponds and equipment; disinfection can be used as routine practice or sanitary measure to avoid contamination of other farms when a disease outbreak event occurred (OIE, 2009). The pond systems should be designed to allow periodical drainage to reduce risk of pathogens proliferation with organic build up resulting from feeding, pond fertilization or dead fish carcass decay, and allow periodic cleaning. To maintain a pond in good sanitary conditions, the challenges will differ according to the size of the pond. Disinfection options for ponds are limited compared to systems such as concrete tanks or raceways. In ponds hydrated lime can be applied as a sterilant, causing rapid rise of pH above ten (lethal to parasites and bacteria) and aid to

eliminate ammonia; quicklime can also be used, with a recommended period of 10-14 days before starting another production cycle (Francis-Floyd, 2001). Recommended dosage of these disinfectants and the way to use them in ponds can be taught to the farmers by extension agents.

To control weeds around ponds, farmers generally use cows or goats which will graze the weeds. Interactions between fish and these animals can be source of hazard. A good alternative can be the mechanical removal of weeds. Weeds control helps in reducing predators and other feral animals (potential predators); pond nets (for small ponds), noise canon or visual deterrent help in keeping birds away from the ponds.

Aquaculture generates big quantities of wastewater charged with compounds such as suspended solids, nitrogen and phosphorus. As a human activity with environmental impact, aquaculture is subject to the law on basic Principles relating Environment Protection (Ministry of Environment and Sustainable Development). Any effluent which can represent a threat to the environment has to be treated before discharge. Sedimentation, sand or mechanical filtration, constructed wetlands technology, and biofiltering plants (aquatic polyculture or the more advanced system integrated multi-trophic aquaculture) (Turcios, 2014) can be used as a successful and cost effective method for aquaculture effluent treatment. According to Claude E. Boyd (2003), application of best management practices (BMPs) can be a reasonable and affordable solution to the problem of effluent management through improvement of water quality and reduction of the volume of effluents. The national text which will regulate aquatic

animal health should emphasize the importance of effluent treatment, which would limit spread in case of a disease outbreak in a farm. It should specify effluent standards to prevent negative impacts on the receiving waters, with the collaboration of the Ministry of Environment and Sustainable Development, the guarantor of environment protection, in alignment with its “Basic Law on Fundamental Principles Relating to the Environment Protection” (Cabinet du Président de la République, 2011).

3.4.2.4. Personnel and farm site traffic management

As mentioned previously, pathogens can enter in a facility through new fish stock, water for system, other animals or can be present in the farm environment. Another non negligible factor is the human factor; people can carry pathogens on their clothes, skin, shoes, etc. and play the role of vector. It is extremely true for employees who have to go from pond to pond when completing their duty. Managers, staff and visitors must understand and follow the necessary practices. The staff is advised to work from different areas, based on age, species and disease status of the fish. it is important to disinfect the equipment used from a pond to another, while it is better for each pond to have its own equipment.

Lack of knowledge on basic aquaculture practices can seriously expose a farm to losses. In DR Congo, the familial type of aquaculture uses non-professional labour generally constituted of family members who ignore the requirements for each step of production from stocking to harvesting. The original show on the picture below reflects unawareness of the risks of bringing pathogens into the pond but also on how they expose themselves,

entering ponds without personal protections; enteric bacteria (Escherichia coli, Staphylococcus aureus, Salmonella spp, etc.) can be found in ponds in tropical areas and handling fish without protection can represent a certain risk (Jensen, 1997)

Fig. 6. Scene of community harvesting a pond (Sarnissa, 2010)

In commercial aquaculture, where the production is more structured and hired labour is used, personnel traffic has to be regulated. The perfect scenario would be to have enough staff so that they are assigned to specific life stages and disease status area, but in most of the cases the number of employee cannot allow this kind of arrangement. It is therefore necessary to prepare a work plan in the form of a daily check list of consecutive activities for the staff to arrange their work from the most susceptible animals first to the less susceptible and from the “cleanest” animals to the “dirtiest” (Roy P. E. Yanong, 2012).

Disinfection stations for the staff and equipment must be available from one area to the other to avoid contaminations. The rules are establish to protect both humans working on farm and the fish from zoonotic infections and ensure safety in work concerning other sources of health problems such as disinfectants, drugs, and other chemicals used on farm.

3.4.2.5. Farm level biosecurity plans and standard operating procedures (SOPs)

In the fight against disease appearance, establishment and spread, understanding the biology of the pathogen and the factors that permit them to survive in reservoirs (non-living or living reservoirs) and the methods that can be used to kill them is crucial. A farmer who understands general biosecurity principles, and knows which disease causing organisms may affect the cultured animal can determine the acceptable risk and worst scenarios; customised protocols to adopt can be designed for each scenario.

A biosecurity plan is based on a number of factors: cultured species, pathogen of concern, water source, production scheme, system and building configuration, and other facility specific biosecurity concerns (Yanong, 2012). It is important that the farmers receive the help of knowledgeable professionals.

Once a biosecurity plan has been established in a facility, it should be translated to Standard Operating Procedures (SOPs) written out, easy to understand and accessible to help employees in their duties achievement. Since the employees are the ones who implement the Standard Operating Procedures through their daily tasks, formal education on the importance of biosecurity, the SOPs in the facility and compliance must be held on a regular basis.

3.4.2.6. Integrating HACCP

Aquaculture products are meant for human consumption, the final product must be safe. The use of antibiotics, the risks of chemicals contamination from other human activities or foodborne diseases from human pathogen contamination in ponds, etc. compromise the safety of the product. Even though there is no data available on the quality of aquaculture products in DR Congo, because of the biosecurity issues identified in the study, we can consider that aquaculture products are potentially exposed to contaminations. When there is a clear understanding of the animal health status, environmental conditions and presence of pathogens favours diseases outbreaks, it can be possible to choose targeted points of control. Authors such as Reily & Kaferstein (1997) and Serfling (2015) suggest the integration of Hazard Critical Control Points (HACCP) principles in aquaculture, using it as a risk management tool. It would be advantageous to integrate this practice into DR Congo's aquaculture because it can raise the public trust in aquaculture products and why not be used as marketing element to win international market share. HACCP can be applied to the production area but also, post-harvest, in the processing facilities (Jensen, 1997).

3.4.2.7. Records keeping

Farmers in DR Congo hardly keep general production records even though they are critical for all areas of production, system and health management. The records of general production can be used as indirect source of surveillance; they are primarily made for farm management but anomalies in the data observations constitute a sign of problems in

the production chain and disease can be one of this problems. Other specific records on biosecurity management and health-disease management can allow farmers to audit the plan, the measures applied and evaluate their efficiency.

3.4.3. Summary

The plinth of aquaculture biosecurity is a clear and strong national biosecurity framework composed of biosecurity policies and laws, reflecting the international tools in aquatic animal health, that empower a Competent Authority which enforces them through official services. This national biosecurity framework gives the guidelines for a uniform and effective practice of aquaculture in a sustainable way, preserving the farmed animal, the environment and the health of the human who is the targeted customer.

All the points that have been discussed in this study are important and thus should be introduced to DR Congo. However, it would be hard to implement them all at the same time. Given the fact that some of them require an existing aquaculture industry to be applied because of the cost they require, a proposed model (Fig. 7) gives a time line of actions to be taken from the short to the long term. Lists suggested here can be taken at the national level and which will have a beneficial effect on the farm level, leading to certified sustainable aquaculture in the country. Product from this recognized certified (or even labelled) industry would represent a good and safe animal protein source for the local population which faces food insecurity and would be easily accepted for export, earning foreign exchanges to the country.

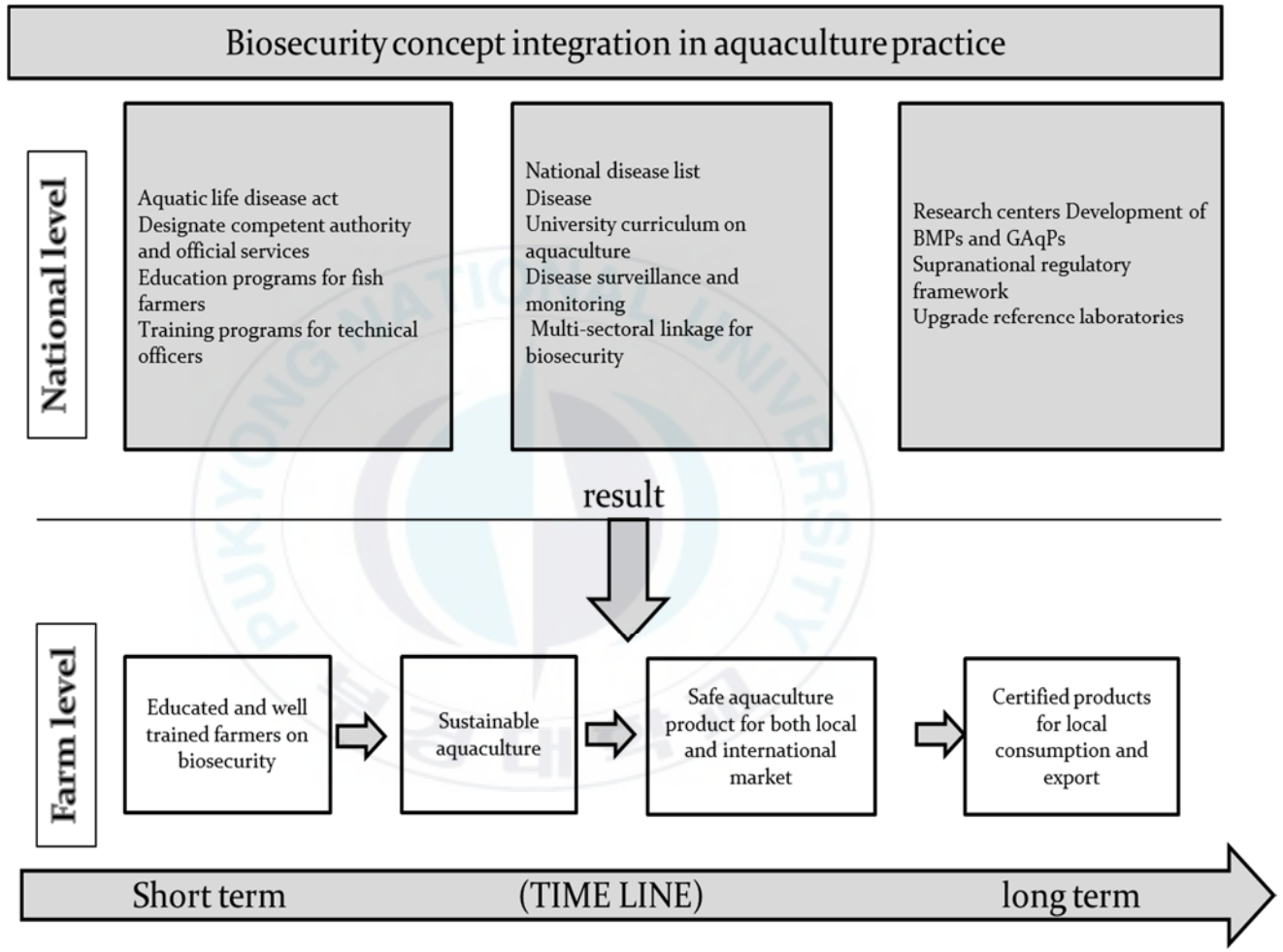

Fig. 7. Proposed model for building a sustainable aquaculture in DR Congo

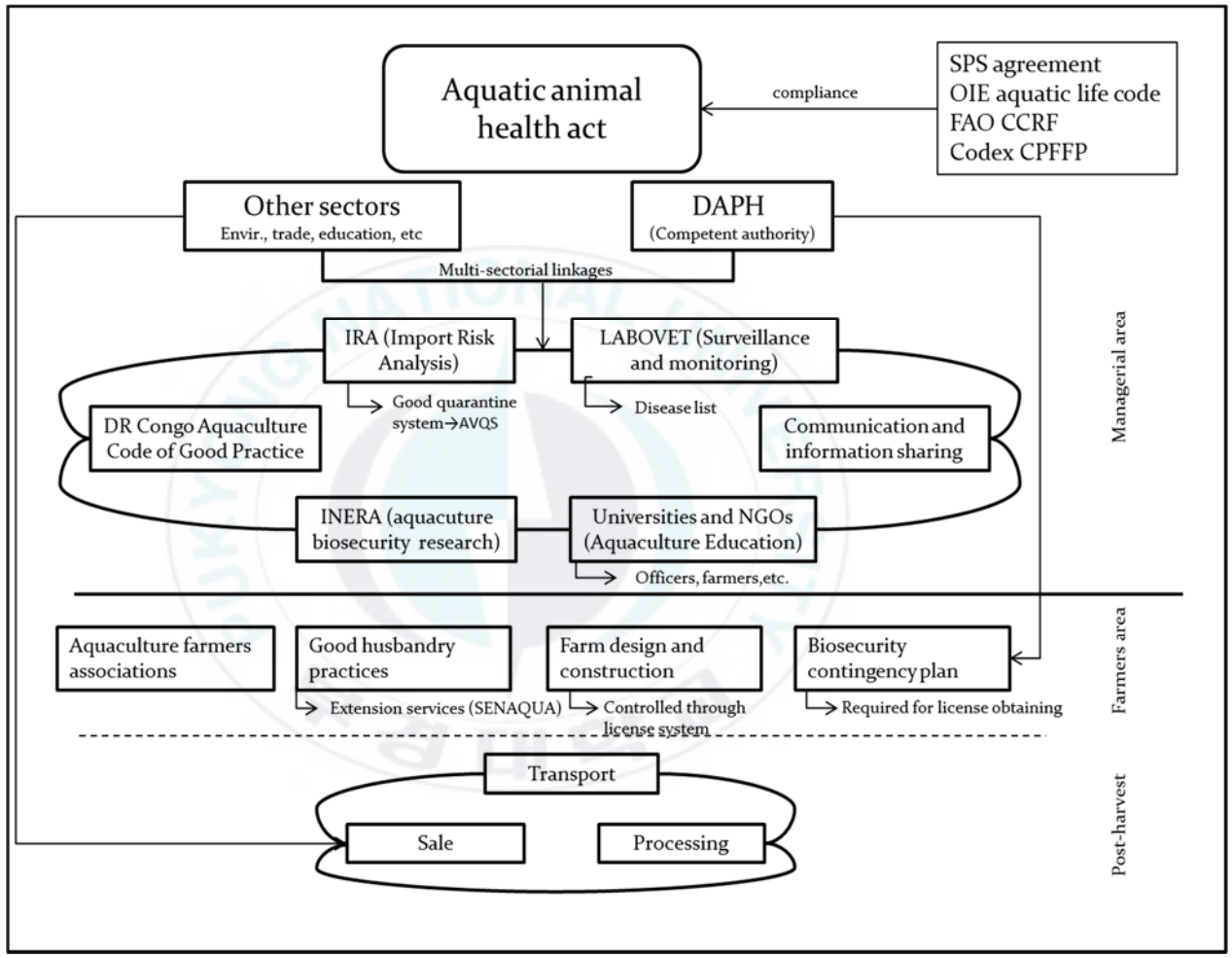

Fig. 8. Summarized biosecurity framework for DR Congo's aquaculture

3.5. Limitations of the study

Biosecurity is a broad subject. This study is a general introduction to biosecurity for aquaculture in DR Congo, proposing guidelines for establishment of an aquaculture biosecurity framework for the country. Aquaculture in DR Congo is at the moment at an infant stage and thus, there is a lack of related paper and it is poorly documented. Therefore, there were clear limitations in reviewing articles and documents about aquaculture, disease occurrence, and biosecurity, and more importantly, introduction of biosecurity may be too early for DR Congo in terms of infrastructures, knowledge level of farmers, etc.. From lessons of other developing countries however, consideration of biosecurity concept should be done even in this very early stage. Studies on assessment of famers' practices, hatcheries management; assessment of aquaculture regulations, programs in regard of aquatic animal health management; and other areas of importance for biosecurity in aquaculture are needed to propose more elaborated and specific biosecurity framework to safeguard the sector.

Chapter 4. Conclusion and recommendations

4.1. Conclusion

Biosecurity touches all the bases: environment integrity, animal welfare, food safety and economic gain. Mastering the farm level of aquaculture practice by the institutional arrangement and legal bases can allow a country to achieve this equilibrium.

DR Congo will embark in commercial aquaculture in a context where the diseases are serious issues internationally. At the international level, the demand for improved biosecurity will increase, as a result of the need to protect the resources, to provide enough food of good quality to the raising world population; the intensification of exchanges between nations through trade of aquaculture products; the preferential choice of consumers for high quality and safe products; the need to secure the aquaculture sector economically through maintenance of profitability; and, of course the threats of emergence of new health problems (Melba G. Bondad-Reantaso, 2005).

The fact that DR Congo's aquaculture is in the embryonic stage is opportunity for the country to build a strong industry highly linked to biosecurity, with an opportunity for very effective biosecurity to be implemented at the design stage and planning phase.

Addressing health questions must be a mix of pro-active and reactive programmes supported by adapted institutional and a legal framework, with an emphasis on prevention through better management practices, involving all the stakeholders. All this must be

supported by scientific informations resulting from the research programs run by experts in aquatic animal diseases science. Biosecurity requires investments; but the returns of the investment will be various: a save in money by preventing production losses, production cost increase or low production levels allowing aquaculture to play its economic role in the society as a revenue generating activity, an increased food quality for human consumption and a safeguarded environment.

4.2. Recommendations

4.2.1. Short term recommendations

- ❖ Prepare a law for aquatic life disease control reflecting the international agreements signed by the country
- ❖ Designate a competent authority and official services for aquatic life disease control
- ❖ Strengthen the capacity of the extension agents
- ❖ Vulgarize good husbandry practices, on farm feed formulation, and inform and raise awareness of farmers on diseases issues and biosecurity
- ❖ Insert a curriculum of aquaculture in the three national universities
- ❖ Capacity building of local extension officers, voluntary extension persons from NGOs and SENAQUA staff.

All this recommendations would be hard to implement simultaneously. Education could be, at the moment, given the highest priority level, with the training of farmers for application of good husbandry practices and general farm management and the capacity building of official services agents to help them play their role through advising and extension services.

4.2.2. Mid-term and Long term recommendation

- ❖ Equip the research centres and train experts to work in fish disease research field
- ❖ Designate and upgrade designated diagnostic laboratories
- ❖ Set up surveillance programs
- ❖ Prepare a disease list for DR Congo on basis of results from research and surveillance
- ❖ Promote local industrial formulated fish feed production

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