HOW DO THIRD-PARTY CERTIFICATIONS CONTROL THE USE OF ANTIBIOTICS IN GLOBAL SALMON AQUACULTURE?

by

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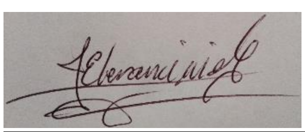

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Table of Contents

List of Figures

List of Tables

Abstract

Since 1980 farmed salmon has become a vital food source and world commodity; however, the resulting increase in the use of antibiotics by the global aquaculture industry has raised health and environmental concerns, as well as the need for proper regulation. As a market-based solution, 3rd party certification schemes have gradually become an important player for the regulation of antibiotics used by salmon farms. Consequently, this study examined the three most common certification schemes adopted by salmon farms worldwide: Aquaculture Stewardship Council (ASC), Best Aquaculture Practice (BAP) and Global Good Agricultural Practices (GLOBALG.A. P.). The study centered in identifying their relevant standards, evaluating their approach in controlling the use of antibiotics, and subsequently revealing related weaknesses to mitigate the risks resulting from the use of antibiotics. Based on the literature, a set of 11 indicators was defined to grade the performance of each certification scheme. The analysis indicates that all schemes perform similarly within a 60.6% to 66.6% range. Identified weaknesses across schemes relate to standards covering the choice of antibiotics application method, monitoring of antibiotic residues in sediments, as well as bacterial/microorganism biodiversity. By improving these standards, schemes could buttress the regulation of antibiotics while continue to apply the precautionary principle to minimize the risks identified.

KEYWORDS: aquaculture, salmon farming, certification scheme, standards, antibiotics, antibiotic resistance bacteria, therapeutic treatment, environmental and health impacts

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1 Introduction

1.1 Statement of the Problem

Aquaculture has become an important food source to meet the rising demand of a growing global population, resulting in increased food security (Aly & Albutti, 2014; Tidwell & Allan, 2001). In 2015, cultured salmon contributed 13.20% to the total value of world fish aquaculture (Figure 2), becoming one of the highest-value species and fastest food production system (McLaren, 2011; Food and Agriculture Organization [FAO], 2016). Consequently, this study focusses on salmon aquaculture. Biodiversity can also be enhanced through aquaculture by slowing the depletion of wild stocks (Diana, 2009). However, the fast and worldwide development of aquaculture has caused the growth of certain bacterial diseases, increasing the need for antibiotics at a global scale for the application of therapeutic treatments to diseased fish (Defoirdt, Boon, Sorgeloos, & Bossier, 2007; Defoirdt, Sorgeloos, & Bossier, 2011).

Besides therapeutic treatments, antibacterial drugs are also administered to fish in smaller amounts for prophylactic treatments, which is a precautionary treatment to prevent the onset of diseases in healthy fish (Cabello, 2006). Depending on fish species, culture systems and aquaculture region, many classes of antibiotics are used in a wide quantity range to control fish diseases (Park, Hwang, Hong, & Kwon, 2012; Burridge, Weis, Cabello, Pizarro, & Bostick, 2010). The main concern of the potential misuse of antibiotics in aquaculture is that some of them are also important drugs used in human medicine, thus increasing the chances of transferring antibiotic resistance traits to human pathogens, hence lowering the effectiveness of antibiotics used for the treatment of human infections (Done, Venkatesan, & Halden, 2015; Kathleen et al., 2016). In fact, the World Health Organization (WHO, 2007) identified a list of critically important antibiotics for the sole use of human medicine, forbidding its use in all types of animal husbandry (Done, Venkatesan, & Halden, 2015). In addition, the persistence of antibiotics residues and compounds in sediments and the water column contributes to the potential development and spread of antibiotic resistance among bacteria, altering the composition of the existing marine bacterial flora (Burridge, Weis, Cabello, Pizarro, & Bostick, 2010; Nash, Burbridge, & Volkman, 2005). Therefore, new resistance bacteria could also emerge due to the misuse of antibiotics posing health risks to humans, farmed fish and non-targeted marine species (Ashbolt et al., 2013; Cabello, 2006).

Aquaculture certification addresses the misuse of antibiotics by requiring salmon farms to comply with related certification standards. A third-party certification is defined as "an entity independent from both supplier and consumer organizations [that] conducts the auditing and issues certificates stating that a product or process complies with a specific set of criteria or standards" (FAO, 2007, p. 2). Since farmed salmon is sold in global markets as a commodity, third party certifications are usually global in scope. However, salmon farms are operated and regulated locally, provincially or state wise creating many local and national regulations (FAO, 2017a). Thus, market-based tools like voluntary certification can enable the harmonization of these fragmented regulations into more coherent control instruments for the benefits and protection of consumers worldwide (Steering Committee of the State-of-Knowledge Assessment of Standards and Certification, 2012). Certification also serves the needs of consumers for more information about the quality of the fish produced as per accepted health, environmental and social standards. Standards can also enable the adoption of best practices and the long-term sustainability of salmon aquaculture at local, regional and global scales

(Volpe, Gee, Beck, & Ethier, 2011). Since antibiotics usage in global aquaculture has become a major public concern, certification schemes and their associated standards could address the need to restrict the use of antibiotics by salmon farms (Best Aquaculture Practices [BAP], 2016).

1.2 Purpose of the Study/Objectives

This study investigates the role of third party certifications in controlling the use of antibiotics in salmon aquaculture by comparing the three most popular certifications used in the global commercialization of farmed salmon. The third-party certifications selected are: Aquaculture Stewardship Council (ASC), Best Aquaculture Practices (BAP), and Global Good Agricultural Practices (GLOBALG.A. P.). The main goal of the study is divided into two specific objectives:

1. Identifying the relevant standards of each certification scheme.
2. Selecting the most effective scheme controlling the use of antibiotics in salmon farms by evaluating their standards.
3. Identifying weaknesses that could be addressed in certification schemes to mitigate the negative effects of the use of antibiotics

1.3 Limitations

This study focusses on salmon aquaculture and the use of antibiotics as therapeutants during the fish grow-out phase only, thus excluding the smolts production phase. Also, it does not cover the implications of using antibiotics as growth promoters or for disease prevention (prophylactic uses), which are prohibited in Europe as well as by most certification schemes (Center for Disease Dynamics, Economics & Policy, 2016; Reda, Ibrahim, El-Nobi, & El-Bouhy, 2013). As well, the study will not cover factors concerning disease transmission or the implications of standards on fish health and welfare that could in turn impact antibiotic usage levels. Likewise, national legislation and related regulations are not covered in this study, but compliance to them by aquaculture industry players is recognized by most certification schemes.

1.4 Significance of the Study

Aquaculture issues involve human, fish and ecosystem health that could be negatively impacted by the misuse of antibiotics. Therefore, this study investigates the role of third party certifications in regulating the use of antibiotics in salmon farms. Also, this study focuses on streamlining the most relevant standards that could support local policy formulation, salmon farm management and consumer education.

2 Literature Review

Over the last four decades the fast growth of aquaculture has met the higher food needs of a growing global population while improving food security in poor countries (The World Bank, 2013). This growth has been driven partly by the depletion of wild fish stocks and the increasing demand for aquaculture products (Tidwell & Allan, 2001). Production and value of cultured fish has steadily increased in the last four decades (Figure 1).

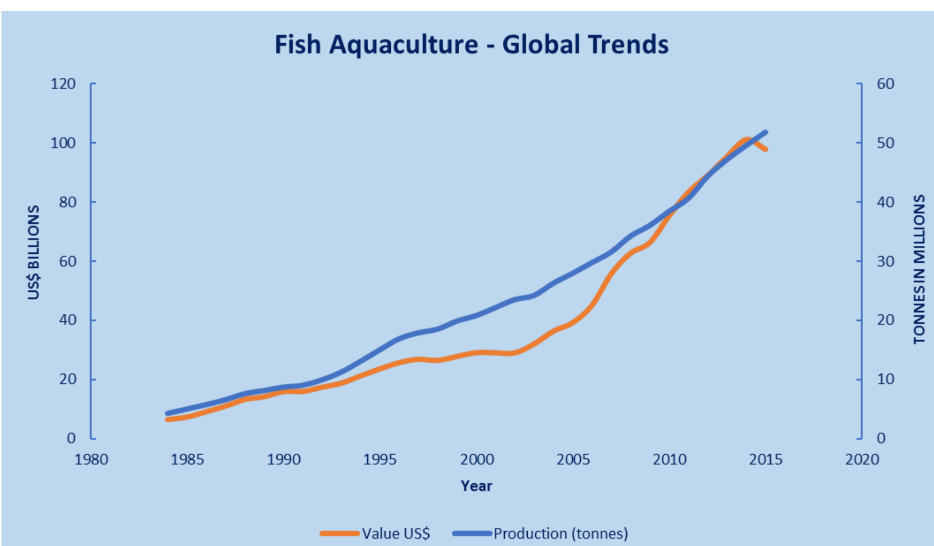

Figure 1: Global production and value of cultured fish for the period 1984-2015 (FAO, 2015a)

In 2014, fish harvested from aquaculture yielded 73.8 million tonnes, whereas fish from captured fisheries produced 93.4 million tonnes (FAO, 2016). The World Bank (2013) projected that by 2030 aquaculture will supply over 60% of fish for human consumption, while global production of captured fisheries will probably remain at around 93 million tons. In 2015, cultured salmon contributed 4.95% to the total fish cultured in terms of biomass and 13.20% in terms of value (Figure 2).

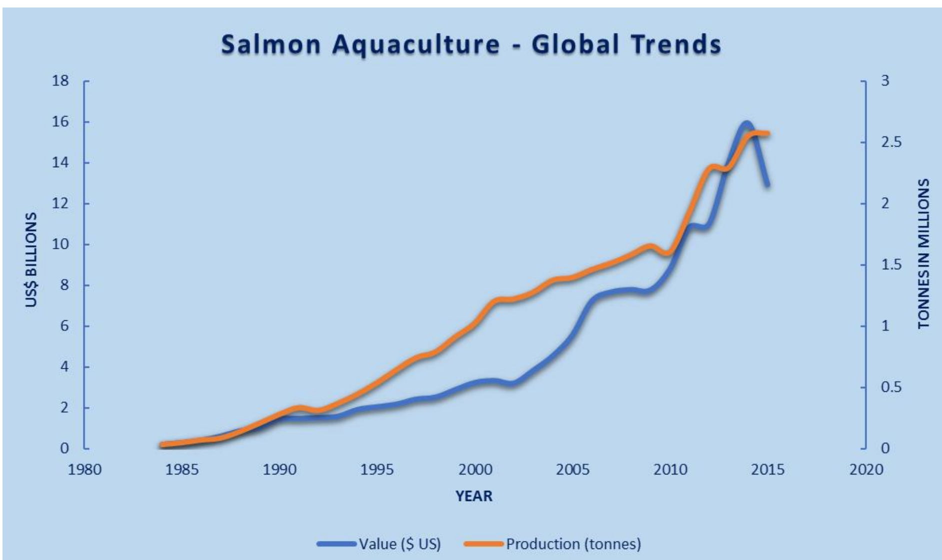

Figure 2: Global production and value of cultured salmon for the period 1984-2015. (FAO, 2015b)

The development of aquaculture has led to a more intensive and concentrated industry creating larger farms (Romero, Feijoo & Navarrete, 2012). However, this global industry has been impacted by the emergence of fish diseases requiring increasing amounts of antibiotics used in fish therapeutic treatments (Done, Venkatesan, & Halden, 2015). Antibiotics are important to curtail fish diseases and maintain farmed salmon production but their excessive use poses risks to human, fish and ecosystem health (Mortazavi, 2014). These risks have raised public health concerns, involving the spread of disease-causing bacteria revealing strong resistance to many classes of antibiotics used in human and veterinary medicine (Hollis & Ahmed, 2013). Consequently, aquaculture certification schemes require salmon farms to conform to standards addressing the use of antibiotics. Therefore, the goal of this study is to investigate the role of third party certifications in restricting the use of antibiotics in salmon aquaculture by means of applicable standards and requirements.

2.1 Salmon Aquaculture Systems

The main culture systems used in salmon aquaculture are cages and net-pens. Although the design of these structures could be slightly different, they are functionally identical (R. Filgueira, personal communication, March 23, 2017). Consequently, for clarity, the term net pen will be used in this study and defined as a "moored, floating, square, hexagonal or circular unit with a closed net hanging down below it" (FAO, 2017b, para. 30) (Figure 3).

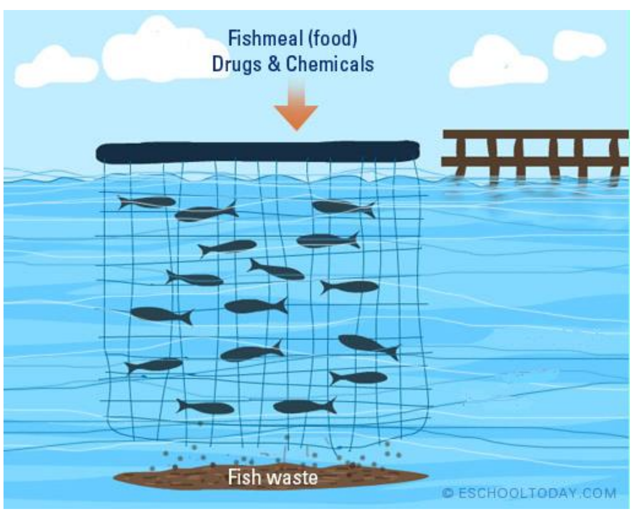

Figure 3: Fish aquaculture net pen, adapted from eSchoolToday (n.d.).

2.2 Chemicals Used in Aquaculture

Aquaculture systems use a variety of chemical compounds including antibiotics, pesticides (or parasiticides), antifoulants, disinfectants (e.g. hydrogen peroxide and malachite green), anaesthetics, hormones, pigments, vitamins and minerals (Bjornsdottir, Oddsson, Thorarinsdottir, & Unnthorsson, 2016; Burridge, Weis, Cabello, Pizarro, & Bostick, 2010; Rodgers & Furones, 2009; Romero, Feijoo & Navarrete, 2012). Their consumption levels vary, depending on the type of aquaculture operation (i.e. fish farms, shellfish farms), and the country and location (Rodgers & Furones, 2009). Antimicrobials are a class of chemicals used to control diseases, external parasites, and fungus outbreaks. They are also used to maintain water quality, disinfect eggs and equipment, as well as reducing aquatic weeds and free-living molluscs (Table 1) (Rodgers & Furones, 2009).

Table 1: Types of antimicrobials agents, target use and application method (adapted from Rodgers & Furones, 2009)

Agent type	Usage	Application method
Therapeutant (e.g. antibiotics)	Treatment of bacterial fish diseases	Oral –medicated feed; injection; topical; bath
Parasiticides	Control of sea lice on salmon; treatment of parasites in ornamental fish ponds; control of protozoa and trematodes on finfish	Oral –medicated feed; bath; dip; flush
Biocides, algicides and herbicides	Reduce plant growth in pond systems; antifouling treatment for fish farm cage netting	Direct; flush

As a type of antimicrobial, antibiotics are therapeutic agents used for the treatment and control of bacterial diseases. This study focuses on antibiotics and does not cover the use of other chemical compounds used in aquaculture.

2.3 Antibiotics

Since their discovery, antibiotics have improved human health, extending life expectancy plausibly by two to ten years (Hollis & Ahmed, 2013). Antibiotics have also supported the production of feed animals (i.e. fish, poultry, cattle), resulting in better animal health, in turn increasing the productivity of animal husbandry industries like aquaculture (Hollis & Ahmed, 2013). However, the excessive and widespread use of antibiotics worldwide poses risks to human health and the environment through many pathways (Done, Venkatesan, & Halden, 2015; Berkner, Konradi, & Schönfeld, 2014). Antibiotics are used in aquaculture as therapeutic agents to control infections and prevent bacterial diseases (Done, Venkatesan, & Halden, 2015). They are also used as prophylactic agents and administered at predetermined levels to prevent the onset of disease (Cabello, 2006; Hollis & Ahmed, 2013). Antibiotics usage varies significantly depending on farm location and class of antibiotics. Unfortunately, worldwide usage statistics are not reported regularly (Done, Venkatesan, & Halden, 2015). The main data sources for the use of antibiotics in aquaculture come from non-academic literature published by the FAO, and survey reports indicating the most common classes of antibiotics used in aquaculture (Done, Venkatesan, & Halden, 2015). Sales of antibiotics are used as a rough estimate of their use. For instance, in 2003 the Norwegian salmon industry consumed around 1.61 grams of antibiotics per tonne of produced salmon, while the Chilean salmon industry used 477 grams of antibiotics per tonne of produced salmon (Burridge, Weis, Cabello, Pizarro, & Bostick, 2010). While in 2014, Chile consumed 590 grams of antibiotics per tonne of farmed salmon (Departamento de Salud Animal - Sernapesca - Subdirección de Acuicultura, 2016), and Norway's ratio was approximately 39 grams per tonne of farmed salmon (Aqua, 2016). However, this information is difficult to obtain and in some cases not even reported (Done, Venkatesan, & Halden, 2015).

2.3.1 Approved antibiotics used in aquaculture.

Antibiotics used in aquaculture are subject to approval by national regulatory agencies on a regular basis. Consequently, antibiotics approved in one country are not necessarily approved in another country (Stickney, 2017). Since the number of approved antibiotics changes frequently, the USA, Canada and the European Union (EU) periodically provide information about permitted aquaculture drugs via the Internet. Approved antibiotics commonly used in aquaculture are: Amoxicillin, Florfenicol, Oxytetracycline and Tribrissen. These antibiotics are used for the treatment of bacterial infections. Oxytetracycline and Tribrissen are also used against vibrio infections (e.g. *Vibrio anguillarum*) (Burridge, Weis, Cabello, Pizarro, & Bostick, 2010).

2.3.2 Antibiotics – application methods.

In net pen systems, antibiotics are administered to fish through feed additives (medicated feed) or bath treatments (water medication) (Park, Hwang, Hong, & Kwon, 2012). In-feed treatments are carried out by milling the active ingredient directly into the fish diet (Igboeli, Burka, & Fast, 2014). The dosage is calculated as per the feed consumption rate of the salmon (Burridge, Weis, Cabello, Pizarro, & Bostick, 2010). Bath treatment includes skirting and tarping methods as well as the use of well-boats. Skirting entails hanging a skirt around the cage to a depth higher than the depth of the enclosed salmon, thus reducing the water exchange with the surrounding environment, and consequently the amount of antibiotics required for the treatment (R. Filgueira, personal communication, March 23, 2017). Compared to skirting methods, the amount of antibiotics required for tarping treatments is reduced by lowering the volume of water to be treated in the cage. This is performed by reducing the depth of the net in the cage and surrounding the cage by a waterproof tarpaulin. After the skirt or tarpaulin is in place, the antibiotics are added to the water as per the recommended treatment concentration. The fish are treated for a pre-determined period (30-60 minutes), then the treatment water is released into the ocean water by removing the skirt or tarpaulin (Burridge, 2013). Alternatively, well-boats are equipped with wells receiving the fish to be treated. Once the fish settles in the wells, antibiotics are added as per the specified concentration. Lastly, the wells are flushed with seawater and then the fish is returned to the cages (Burridge, 2013). In summary, once all types of bath treatments are completed, effluents are diluted into the surrounding water potentially affecting non-target organisms (Igboeli, Burka and Fast, 2014). Since well-boat treatments require lower volumes of water, they use less therapeutants in comparison to skirt or tarp bath treatments (Burridge, 2013). Bath treatments have the advantage of exposing all the fish to the same drug concentration (Burridge, 2013). In comparison to tarp treatments, well boats procedures also facilitate the treatment of effluents. In contrast, in-feed treatments are not applied evenly because sick or weak fish eat less than healthy or stronger fish (Igboeli, Burka and Fast, 2014). Unlike bath treatments, the in-feed method is less disturbing to the fish and safer to farmer personnel (Colquhoun, Nordmo, Ramstad, Sutherland, & Simmons, 2002). In-feed treatments could also be applied independently of weather conditions and concurrently to all cages on a farm site, lowering the possibility of cross-infection occurring in bath treatments (Stone, Sutherland, Sommerville, Richards, & Varma, 1999). In-feed treatments are the most common method used for the delivery of antibiotics to fish (Romero, Feijoo & Navarrete, 2012).

2.3.3 Antibiotics usage risks.

The indiscriminate and excessive use of antibiotics in global aquaculture is a permanent environmental concern since salmon farms are usually located in relatively pristine marine ecosystems, like natural bays or sea inlets where net pens are installed (Burridge, Weis, Cabello, Pizarro, & Bostick, 2010). Consequently, salmon farms can potentially release effluents and fish feed containing traces of antibiotics, contaminating ocean waters that then could harm non-target organisms like vertebrates, invertebrates, algae and bacteria (Burridge, Weis, Cabello, Pizarro, & Bostick, 2010; Buschmann et al., 2012; Park, Hwang, Hong, & Kwon, 2012). Many antibiotics administered through feed are also not fully assimilated by the fish and turn out unchanged in their feces, ending up on the ocean floor along with uneaten medicated food (Science for Environment Policy, 2015; Park, Hwang, Hong, & Kwon, 2012). Grigorakis and Rigos (2011) state that up to 75% of an antibiotic dose can end up in the surrounding environment. Although some of the antibiotics contained in faeces and feed pellets can be recaptured, their complete recovery from the marine environment is impossible (Park, Hwang, Hong, & Kwon, 2012). Water containing antibiotics used in bath treatments is also released into ocean waters. A worrisome health concern is the persistence of certain compounds of antibiotics in sediments and the water column, contributing to the potential transmission of antibiotic resistance to non-target bacteria, including human and animal pathogens (Buschmann et al., 2012; Burridge, Weis, Cabello, Pizarro, & Bostick, 2010; Larsson, 2014).

A global concern is that disease-causing bacteria or pathogens could potentially develop antibiotic resistance following exposure to fish antibiotics that are also used to treat human diseases (Done, Venkatesan, & Halden, 2015). Therefore, resistant infections become harder to treat with current antibiotics (Finley et al. 2013). It is estimated "that by 2050, 10 million lives a year and a cumulative 100 trillion USD of economic output are at risk due to the rise of drug-resistant infections…" (Review on Antimicrobial Resistance, 2016). As well, antibiotics used in humans and animals usually share the same classes (Finley et al. 2013). Approximately, 76% of antibiotics used in agriculture and aquaculture are also used in human medicine (Done, Venkatesan, & Halden, 2015). Accordingly, the WHO has identified a list of "critically important" antibiotics to ensure their prudent application in people and animals. This list categorizes 260 antimicrobials agents (e.g. antibiotics) to save crucial drugs for the exclusive use of human medicine, as well as to control the development and propagation of antimicrobial resistance (WHO, 2007; Done, Venkatesan, & Halden, 2015).

Other concerns relate to the potential accumulation of antibiotic residues in farmed fish products that could be harmful to the health of consumers (Plumb & Hanson, 2011). Antibiotic residues can temporarily remain in their original form or as metabolites in fish tissues (Park, Hwang, Hong, & Kwon, 2012). Consequently, after therapeutic treatments are completed the fish requires a withdrawal period before it is ready for consumption, which is determined by the type of antibiotics, fish species and the environmental temperature (Park, Hwang, Hong, & Kwon, 2012). The withdrawal period is highly linked "to the maximum residue limit (MRL) of the antibiotic drug or its metabolite" (Park, Hwang, Hong, & Kwon, 2012). However, safety levels of MRL are independently determined by the regulations of individual countries (Park, et al., 2012). Internationally, the Hazard Analysis Critical Control Point (HACCP) system is recognized as a food safety management method, which can be used as a risk management tool to control antibiotic residues in aquaculture products (Jahncke, 2007). Another potential threat caused by antibiotics is that sediments and seawater contaminated with antibiotics could become reservoirs of dormant antibiotic-resistance bacteria that could harm bacterial biodiversity, microorganisms (e.g. microalgae), and animal and human health (Buschmann, et al., 2012; Nogales, Lanfranconi, Pina-Villalonga, & Bosch, 2010; Cesare et al., 2013). According to Gaw, Thomas and Hutchinson (2014), 41 antibiotic compounds have been detected in coastal waters "exceeding the European Medicines Agency threshold for predicted environmental concentrations for surface waters of 0.01 µg l^{-1}" (p. 3).

2.4 Aquaculture Standards and Certification Schemes

The International Standardization Organization (ISO) offers an established and general definition of standards as:

> *"[A] document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context" (ISO/IEC Guide 2, 2004, p. 12).*

This broad ISO definition enables different industries and organizations to develop their own standards according to their needs and circumstances (Bonsaksen, 2014). For instance, the Canadian Aquaculture Industry Alliance (CAIA) developed standards to reach consensus on common criteria to address the main environmental and socio-economic impacts of aquaculture operations; establish best management practices to minimize these impacts; set acceptable performance levels; and devise strategies to keep improving the aquaculture industry (CAIA, 2009). At a global scale, standards serve as industry benchmarks relaying information to customers worldwide about the technical specifications of a product, compliance with health and safety criteria, and related production processes (Nadvi, 2008). An economic incentive for the adoption of standards relates to their potential to lower transaction costs, through the codification of knowledge involving global value chains (GVC) or global production networks (Nadvi, 2008; Humphrey & Schmitz, 2001). Standards can also serve as market-based mechanisms to improve consumer benefits and reliance on the aquaculture industry, while reducing its potential negative effects (FAO, 2011). As part of regulatory reforms, national governments and international organizations (e.g. OECD) can initiate the adoption of diverse standards formulated by national and international organizations, covering a variety of concerns (e.g. sustainability, quality, food safety) (Organization for Economic Cooperation and Development [OECD], 2010; Nadvi, 2008). Main players engaged in setting standards include private industry, transnational companies, international NGOs (e.g. Worldwide Fund for Nature, WWF), and international non-profit organizations (e.g. Marine Stewardship Council, MSC) (Nadvi, 2008).

Certification is defined as “a procedure through which written or equivalent assurance states that a product, process or service conforms to specified requirements” (FAO, 2007, p.2). Consequently, the production process followed by an aquaculture farm and its output product(s) can be certified according to this definition (FAO, 2007). Certification requires auditing to assess the level of compliance achieved by the farm as per requirements specified by mandatory (e.g. government legislation) or voluntary standards (e.g. NGOs standards) (FAO, 2007). The auditing process can be performed by an auditing entity that usually provides a certificate of compliance, in effect also acting as the certification entity (FAO, 2007). Certification schemes comprise certification standards and applicable certification processes. Specific components of certification schemes include: standards, a defined scope (e.g. objectives), and a certification system (i.e. process, auditing requirements) (FAO, 2007). Developers of standards and certification schemes can follow a diversity of guidelines relevant to aquaculture provided by national, regional and international organizations (e.g. FAO,). For example, the *FAO Technical Guidelines on Aquaculture Certification* provide guidelines for accreditation procedures needed to implement certification schemes according to global rules and principles set out and monitored by FAO (FAO, 2011). Another organization providing guidelines of interest to aquaculture is the Global Food Safety Initiative (GFSI), whose mandate is to improve food management systems worldwide (GFSI, n.d.). In addition, aquaculture players can conform to the FAO/WHO Codex Alimentarius, addressing food standards to protect human health (FAO, 2016a); and the World Organization for Animal Health (OIE) - Aquatic Animal Health Code, addressing fish health standards (OIE, 2010). Industry good practices indirectly support the prudent use of antibiotics by improving the handling of antibiotics, the storage and disposal of expired lots, as well as the maintenance of water quality.

In addition to codes of conduct and guides of good practices, several studies and initiatives have been carried out by academic, industry and NGOs institutions to improve the sustainability of aquaculture, covering its economic, environmental, social and institutional aspects (Volpe, Beck, Ethier, Gee, & Wilson, 2010; Global Sustainable Seafood Initiative, 2015).

For example, a study sponsored by the University of Victoria created the Global Aquaculture Performance Index (GAPI), consisting of indicators to monitor and evaluate the environmental performance of global aquaculture. Its ANTI indicator considers the amount of antibiotics used per tonne of fish produced, as well as the risks posed by antibiotics based on ratings provided by the WHO and OIE organizations (Volpe, Beck, Ethier, Gee, & Wilson, 2010). Another initiative is the Global Sustainable Seafood Initiative (GSSI), which is a global platform and partnership of experts, seafood companies, NGOs, government and inter-government agencies promoting sustainable seafood (GSSI, n.d.). The GSSI provides a global benchmark tool to evaluate seafood certification schemes according to a set of indicators, including the usage of antibiotics.

The schemes selected for this study use a third-party certification process, requiring the participation of a standards provider (e.g. BAP), a buyer (e.g. farm), and a separate entity, the third party (e.g. GlobalTRUST). An audit is conducted by the third-party that issues a certificate of compliance, confirming that a product or process meets the specific standards and requirements followed by the buyer (FAO, 2007). Third party certification also requires an accreditation process, which is defined as “third party attestation related to a conformity assessment body conveying formal demonstration of the standard body’s competence to carry out specific conformity-assessment tasks (ISO/IEC 17000)” (Potts, Wilkings, Lynch, & McFatridge, 2016, p. 172). To obtain third-party certification, most standards providers follow the ISO-65 accreditation norm (CAIA, 2009), or comply with the International Social and Environmental Accreditation and Labelling Alliance (ISEAL) - Code of Good Practice for Setting Social and Environmental Standards (FAO, 2011). Therefore, third party certification requires an independent accreditation process, confirming that a third-party provider is qualified to issue compliance certificates (FAO, 2007).

2.5 Selected Certification Schemes

The selection of certification schemes is based on their global reach within the context of salmon aquaculture. Many types of certification schemes exist (e.g. public, private), but third-party certification is the most common type of certification used in salmon producing countries (e.g. Norway, Chile) (Potts, Wilkings, Lynch, & McFatridge, 2016, 2016). Consequently, this study will evaluate certification schemes that adopt a third-party implementation process: Aquaculture Stewardship Council (ASC) Salmon Standard, Best Aquaculture Practices (BAP), and GLOBALG.A.P.

2.5.1 Aquaculture Stewardship Council Salmon Standard.

The Aquaculture Stewardship Council (ASC) originated as an initiative of the World Wide Fund (WWF) NGO and the Sustainable Trade Initiative (IDH) (ASC, 2017b). The standards are organized according to a set of eight principles (Table 2), covering escapes, nutrient loading, carrying capacity, disease and parasites, and chemical inputs amongst other issues (Bonsaksen, 2014). Other areas covered by the standards include product traceability, which is certified according to the Marine Stewardship Council (MSC) - Chain of Custody system (ASC, 2017a). The ASC standards also fully comply with the FAO Aquaculture Certification Guidelines, ISEAL accreditation guidelines, and the ISO Guide 65 (ASC, 2017b; International Trade Centre [ITC], n.d.).

Table 2: ASC Standards – Principles (adapted from ASC Salmon Standard, 2017)

Principle	Description
1	Comply with all applicable national laws and local regulations
2	Conserve natural habitat, local biodiversity and ecosystem function
3	Protect the health and genetic integrity of wild populations
4	Use resources in an environmentally efficient and responsible manner
5	Manage disease and parasites in an environmentally responsible manner
6	Develop and operate farms in a socially responsible manner
7	Be a good neighbor and conscientious citizen
8	Standards for suppliers of smolt

2.5.2 Best Aquaculture Practices.

The Global Aquaculture Alliance (GAA) is an international NGO, addressing the needs of salmon farms through the development of its BAP standards, which covers animal welfare, food safety and traceability, as well as the environmental and social aspects of aquaculture (BAP, n.d.-a; Bonsaksen, 2014). BAP standards follow GAA nine guiding principles for responsible aquaculture (Table 3), (GAA, n.d.).

Table 3: GAA nine guiding principles (reprinted from Best Aquaculture Practices, 2016)

Principle	Description
1	Shall coordinate and collaborate with national, regional and local governments in the development and implementation of policies, regulations and procedures necessary and practicable to achieve environmental, economic and social sustainability of aquaculture operations.
2	Shall utilize only those sites for aquaculture facilities whose characteristics are compatible with long-term sustainable operation with acceptable ecological effects, particularly avoiding unnecessary destruction of mangroves and other environmentally significant flora and fauna.
3	Shall design and operate aquaculture facilities in a manner that conserves water resources, including underground sources of fresh water.
4	Shall design and operate aquaculture facilities in a manner that minimizes the effects of effluents on surface and ground water quality and sustains ecological diversity.
5	Shall strive for continuing improvements in feed use and shall use therapeutic agents judiciously in accordance with appropriate regulations and only when needed based on common sense and best scientific judgment.
6	Shall take all reasonable measures necessary to avoid disease outbreaks among culture species, between local farm sites and across geographic areas.
7	Shall take all reasonable steps to ascertain that permissible introductions of exotic species are done in a responsible and acceptable manner and in accordance with appropriate regulations.
8	Shall cooperate with others in the industry in research and technological and educational activities intended to improve the environmental compatibility of aquaculture.
9	Shall strive to benefit local economies and community life through diversification of the local economy, promotion of employment, contributions to the tax base and infrastructure, and respect for artisanal fisheries, forestry and agriculture.

BAP standards are organized according to four pillars of responsible aquaculture: food safety, social welfare, environmental, and animal health and welfare (BAP n.d.-b). As a first step, BAP certification requires compliance with local regulations (BAP, 2016). BAP standards also comply with the FAO Technical Guidelines on Aquaculture Certification and GFSI food safety requirements (BAP, 2016; BAP, 2013). ISO-65 is the accreditation norm used by the BAP scheme (GAA, 2016). BAP salmon farm standards are grouped in five major categories (Table 4).

Table 4: BAP Salmon farm standards (adapted from Best Aquaculture Practices, 2016)

BAP salmon farm standards	
Community	1. Property rights and regulatory compliance 2. Community relations 3. Worker safety and employee relations
Environment	4. Sediment and water quality 5. Fishmeal and fish oil conservation 6. Control of escapes 7. Predator and wildlife interactions 8. Storage and disposal of farm supplies
Animal Health and Welfare	9. Health and welfare 10. Biosecurity and disease management
Food safety	11. Control of potential food safety hazards
Traceability	12. Record-keeping requirement

2.5.3 GLOBALG.A.P. Standards.

The GLOBALG.A.P. originated as an initiative of European retailers leading to the Good Agricultural Practice (G.A.P.) certification system, and then to its current name (GLOBALG.A.P., n.d.-b). GLOBALG.A.P. standards (Integrated Farm Assurance) are organized in modules oriented to processes instead of products (FAO, 2007). GLOBALG.A.P. certification scheme includes a general module, covering all farm activities related to agriculture and aquaculture (i.e. AFx). It includes a specific aquaculture module covering finfish, crustaceans and molluscs species and criteria applicable to the entire production cycle, which are grouped in 16 categories (i.e. ABx) (Table 5) (GLOBALG.A.P.; 2016a). GLOBALG.A.P. certification scheme also includes chain of custody up to the point of sale (GLOBALG.A.P., n.d.-a). Accreditation is implemented according to the ISO/IEC 17065 norm (GLOBALG.A.P., 2016b). And a guideline used by GLOBALG.A.P. is the FAO/WHO Codex Alimentarius (GLOBALG.A.P.; 2016a).

Table 5: GLOBALG.A.P. - Aquaculture module (adapted from GLOBALG.A.P., 2016)

GLOBALG.A.P. Aquaculture standards	
AB1	**Site management**
AB2	**Reproduction**
AB3	**Chemical compounds**
AB4	**Occupational health and safety**
AB5	**Fish welfare, management and husbandry (at all point of the production chain)**
AB6	**Sampling and testing**
AB7	**Feed management**
AB8	**Pest control**
AB9	**Environmental and biodiversity management**
AB10	**Water usage and disposal**
AB11	**Harvesting & post harvest - operations**
AB12	**Holding and crowding facilities**
AB13	**Slaughter activities**
AB14	**Depuration**
AB15	**Post harvest – mass balance and traceability**
AB16	**Social criteria**

3 Methodology

The literature review provides the framework to identify and compare certification schemes in the context of antibiotics usage by salmon farms worldwide. The three selected schemes are the most commonly adopted by salmon farms globally: ASC, BAP and GLOBALG.A.P. The ASC and BAP schemes are specifically developed for salmon aquaculture, while GLOBALG.A.P. is oriented to aquaculture in general. A selection and further comparison of the scheme standards will determine the most effective scheme restricting the use of antibiotics in salmon aquaculture. Therefore, the data to be analyzed constitutes the standards from each certification scheme directly or indirectly controlling the use of antibiotics. A hierarchy consisting of indicators and a set of criteria, covering the use of antibiotics serves to compare the standards from each scheme.

3.1 Methods Literature Sources

The appropriate method for this study encompasses a variation or combination of methods used by scientific studies and reports published by global organizations (FAO, 2007; Marschke & Wilkings, 2014), as well as theses that assess the standards and certification schemes most commonly used in the aquaculture industry (Bonsaksen, 2014; McLaren, 2011).

3.2 Identifying the Standards from each Certification Scheme

The first task of the study consists in identifying the relevant standards covering the use of antibiotics, which are organized in two categories. The first category includes standards that directly control the usage of antibiotics, such as requirements that are usually based on metrics and results, or the prohibition of certain uses. The second category includes standards that could indirectly control the use of antibiotics, for example requirements involving best practices (i.e. record keeping, disposal of expired drugs) or specific protocols to monitor fish health.

3.3 Comparing Certification Standards and Requirements

The second task consists in comparing the standards and requirements of each certification scheme. Based on the literature review, a set of criteria and indicators are defined to evaluate and compare the coverage and level of detail of each standard in the context of antibiotic usage (Table 6). A criterion is an impact area to focus on, for example *food safety*, while an indicator is a measure to assess the extent of the focussed area, for example *observance of withdrawals periods after antibiotic treatments*.

Table 6: Indicators for the evaluation of standards controlling the use of antibiotics

Criterion	No.	Indicator	Rationale for inclusion
Legal and regulatory frameworks	1	Compliance with local laws and international regulations.	As a baseline, certified farms must follow local laws and international regulations (1).
	2	Discontinuing the use of antibiotics banned in exporting and importing countries.	To use only antibiotics currently approved by the national regulatory agencies of trading countries and avoid contravening international regulations (2).
Data collection and availability	3	Data collection on the use of antibiotics, including their type and degree of effectiveness.	To understand the risks and benefits of antibiotics and support future research (3).
Fish health	4	Testing resistance to potential prescribed antibiotics.	To reduce resistance and minimize risks posed to human and animal health, as well as ecosystem integrity. This requires determining resistance to therapeutic treatments (4, 5). If feasible, this could also include formal treatment rotation (6).
	5	Using antibiotics only to treat fish bacterial diseases diagnosed by authorized fish health professional.	To minimize health and environmental risks, as per international, regional and national guidelines and regulations (7). This requires prohibiting the use of antibiotics for prophylactic treatments or as growth promoters (4, 8).
Application method	6	Choice of antibiotics application method.	To minimize risks posed to the environment and non-target organisms, as well as to protect human and fish health (9, 10, 11). The method to be applied (e.g. in-feed, bath treatment) requires and assessment of its effectiveness under local environmental conditions (9).
Environmental protection	7	Monitoring medicated feed and the accumulation of antibiotic residues in sediments and water near net pen areas.	To minimize the accumulation of antibacterial residues in sediments, contributing to the spread of antibiotic resistance to bacteria, including human and animal pathogens (11, 12). These residues can potentially inhibit microbial activity and disturb organic matter degradation (20).

Criterion	No.	Indicator	Rationale for inclusion
	8	Monitoring bacteria and microorganism biodiversity.	To protect bacteria and microorganism biodiversity, as well as ecosystem integrity (12, 13, 14). This will require monitoring sediments near and under net pens (15).
Human health	9	Forbidding the use of "critically important" antibiotics for the exclusive use of human medicine, as per the WHO list.	To control the development and propagation of antimicrobial resistance by avoiding their use in fish therapeutic treatments, threatening the effectiveness of human antibiotics (3).
	10	Monitoring the amount of antibiotics used and associated risks.	To minimize the release of antibiotics into the environment and prevent resistance leading to ineffective human antibiotics (7, 16). This requires adherence to the "critically important" list of antibiotics provided by the WHO organization. Compliance can include the use of metrics (e.g. ANTI) (17, 18).
Food safety	11	Compliance with withdrawals periods after antibiotic treatments, as well as antibiotics Maximum Residue Limits (MRL).	To eliminate antibiotic residues in fish and protect consumer health in domestic and international markets (9). This requires adherence to the regulations of trading countries and international trade agreements. Compliance can include the use of food safety systems (e.g. HACCP) (19).

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(15) Best Aquaculture Practices. (2015). Aquaculture Facility Certification: Salmon Farms: Best Aquaculture Practices, Certification Standards, Guidelines
(16) Best Aquaculture Practices (BAP). (2008). Comments on BAP Standards.
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(19) Joint Institute for Food Safety and Applied Nutrition (JIFSAN). (2007). Use of HACCP Principles to Control Antibiotic Residues in Aquaculture Products. University of Maryland.
(20) FAO. (1997). Towards safe and effective use of chemicals in coastal aquaculture. Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP).

3.3.1 Grading scale.

A grading scale (Table 7) is used to evaluate the breadth and depth of the selected certification standards against the listed indicators (Table 6).

Table 7: Grading scale for the evaluation of certification standards (adapted from Bonsaksen, 2014).

Level	Description	Score
Full	Standard fully covers the established indicator. The criterion is fully addressed by the certification scheme.	3
Medium	Standard does meet the defined indicator, but lacks some important details. The criterion is appropriately addressed by the certification scheme.	2
Low	Standard barely meets the established indicator and lacks essential regulations. The criterion is only addressed in general terms by the certification scheme.	1
None	Standard does not match the established indicator and associated criterion. The criterion is not regulated by the certification scheme.	0

4 Analysis and Results

The selected standards from each certification scheme address the main issues caused by antibiotics, affecting the ecosystem surrounding a farm site. The standards also cover a range of measures to minimize the impacts of antibiotics on fish health, therapeutic treatments, and bacterial resistance to treatments among others. A few standards and associated indicators, concerning fauna biodiversity, benthic and water quality are not selected because they target organic loading and dissolved nutrients and do not explicitly address the potential and negative impacts of using antibiotics as part of farm operations. Various GLOBALG.A.P. standards also include environmental and biodiversity management indicators, for instance involving waste management systems and biodiversity policies. However, these standards are not selected because their compliance requirements do not necessarily relate to antibiotics.

4.1 ASC Standards

Nine standards directly control the use of antibiotics (Table 8

Table 8), and nine standards related to best practices and supporting documentation indirectly mitigate the use of antibiotics (Table A 1).

Table 8: ASC standards directly controlling the use of antibiotics (reprinted from Aquaculture Stewardship Council, 2017)

Criterion	Indicator	Requirement
5.1 Survival and health of farmed fish	5.1.1 Evidence of a fish health management plan for the identification and monitoring of fish diseases and parasites and environmental conditions relevant for good fish health, including implementing corrective action when required.	Yes
5.2 Therapeutic treatments	5.2.2 Allowance for use of therapeutic treatments that include antibiotics or chemicals that are banned in any of the primary salmon producing or importing countries.	None
	5.2.4 Compliance with all withholding periods after treatments.	Yes
	5.2.7 Allowance for prophylactic use of antimicrobial treatments.	None
	5.2.8 Allowance for use of antibiotics listed as critically important for human medicine by the World Health Organization (WHO).	None
	5.2.9 Number of treatments of antibiotics over the most recent production cycle.	≤ 3
	5.2.10 If more than one antibiotic treatment is used in the most recent production cycle, demonstration that the antibiotic load is at least 15% less that of the average of the two previous production cycles.	Yes, within five years of the publication of the ASC Salmon Standard
5.3 Resistance of parasites, viruses and bacteria to medicinal treatments	5.3.1 Bio-assay analysis to determine resistance when two applications of a treatment have not produced the expected effect.	Yes
	5.3.2 When bio-assay tests determine resistance is forming, use of an alternative, permitted treatment, or an immediate harvest of all fish on the site.	Yes

4.2 BAP Standards

Four standards directly control the use of antibiotics in the areas of disease management and food safety (Table 9). Fourteen standards concerning local laws, fish health, food safety, water quality, and storage and disposal of farm supplies indirectly impact the use of antibiotics (Table A 2).

Table 9: BAP standards directly controlling the use of antibiotics (adapted from Best Aquaculture Practices, 2015)

Criterion	Indicator	Requirement
10. Animal Health and Welfare – Biosecurity and Disease Management	10.1: The applicant shall designate an accredited fish health professional to oversee the Fish Health Management Plan, direct the diagnosis and treatment of fish diseases and coordinate activities with neighboring farms under an Area Management Agreement, where such an agreement is in place (see Section 2). The fish health professional shall be available in person or by phone at audit to answer questions. The applicant shall notify the certifying body if the fish health professional changes. (section 2: Community - Community Relations)	Yes
	10.9: If used, drug treatments shall be based on authorizations by the fish health professional, who shall be guided by the FHMP and principles of best practice for the veterinary profession. The health professional shall prescribe medicines only to treat diagnosed diseases in accordance with instructions on product labels and national regulations. (See also Section 11.) FHMP: Fish Health Management Plan	Yes
11. Food safety	11.1: Antibiotics or chemicals that are proactively prohibited in the producing or importing country shall not be used in feeds or any treatment that could result in harmful residue in fish.	None
	11.5: Antibiotics shall only be used to treat diagnosed bacterial disease (see also Standard 10.9) and shall not be used as growth promoters.	Yes

4.3 GLOBALG.A.P. Standards

Eight GLOBALG.A.P. standards in the areas of food safety, fish health, therapeutic treatments and related records directly regulate the use of antibiotics (Table 10), while twenty-six standards indirectly affect the use of antibiotics (Table A 3). This last group of standards cover the following areas: local legislation, fish health, food safety, chemical compounds storage, empty containers and non-used chemicals, storage of aquaculture feeds, and therapeutic treatments and records.

Table 10: GLOBALG.A.P. standards directly controlling the use of antibiotics (adapted from GLOBALG.A.P., 2016)

Criterion	Indicator	Requirement
AB.5 Fish Welfare, Management and Husbandry (at all points of production) **AB. 5.3 Treatments**	AB. 5.3.1 Do producers only use medicines and treatments that are permitted by the relevant competent authority for use in aquaculture and for the named species? Is a list of all medicines and treatments that may be use available?	Major Must
	AB. 5.3.2 Do medicines and treatments applied exclude the banned compounds under the FAO/WHO CODEX ALIMENTARIUS including the following compounds? Nitrofurans (or its derivatives), Triarylmethane dyes (including, but not limited to Malachite green, Crystal violet and Brilliant green), Stilbenes (including, but not limited to Stilbene, Dienestrol, Diethylstibestrol, Hexoestrol), Chloramphenicol, Nitroimidazoles (including, but not limited to Dimetridazole, Ipronidazole, Metronidazole) or -agonist (including, but not limited to Clenbuterol).	Major Must
	AB. 5.3.3 Are medicines and treatments used at the farm authorized and/or prescribed by a veterinarian? Is the application according to the instructions in the VHP[1]?	Major Must
	AB. 5.3.5 Is the producer able to demonstrate compliance regarding Maximum Residue Limits (MRLs) in the market where the farmed products are intended to be traded (domestic or international)?	Major Must
	AB. 5.3.6 Are natural or synthetic hormones and antibiotics agents NOT used for the purpose of promoting growth?	Major Must
	AB. 5.3.8 Are antibiotic agents only applied following the diagnosis of an infectious bacterial disease?	Major Must
	AB. 5.3.9 Are fish residue analysis carried out based on food safety risk assessment to verify compliance with MRLs for approved medicines and to verify there are no residues of non-approved substances? Are the analyses performed by an independent, ISO 17025 – accredited (or equivalent standard) laboratory? National surveillance and control programs undertaken by the relevant competent authority may be used for documentation.	Major Must
AB 5.4 Treatment Records	AB 5.4.4 Are pre-harvest withdrawal periods for relevant treatments, and for relevant production units, known and strictly adhered to?	Major Must

[1] Veterinary Health Plan

4.4 Antibiotics Issues: Selected Criteria and Indicators

The selected standards from each scheme (Tables 8 to 10, and Tables A1 to A3) are analyzed and assessed according to the criteria and indicators listed on Table 6. The results of this analysis are listed on Table 11. Also, Table B1 in Appendix B shows the correspondence of the selected standards to each of the defined indicators.

Table 11: Comparison of aquaculture certification schemes

Criterion	No.	Indicator	ASC	BAP	GLOBALG.A.P.
Legal and regulatory frameworks	1	Compliance with local laws and international regulations.	3	3	3
	2	Discontinuing the use of antibiotics banned in exporting and importing countries.	3	3	1
Data collection and availability	3	Data collection on the use of antibiotics, including their type and their degree of effectiveness.	3	3	3
Fish health	4	Testing resistance to potential prescribed antibiotics.	3	2	2
	5	Using antibiotics only to treat fish bacterial diseases diagnosed by authorized fish health professional.	3	3	3
Application method	6	Choice of antibiotics application method.	1	1	1
Environmental protection	7	Monitoring medicated feed and accumulation of antibiotic residues in sediments and water near net pen areas.	1	1	1
	8	Monitoring bacteria and microorganism biodiversity.	1	1	1
Human health	9	Forbidding the use of "critically important" antibiotics for the exclusive use of human medicine, as per the WHO list.	2	0	2
	10	Monitoring the amount of antibiotics used and associated risks.	2	1	2
Food safety	11	Compliance with withdrawals periods after antibiotic treatments, as well as antibiotics Maximum Residue Limits (MRL).	0	2	3
		Total	**22**	**20**	**22**

<u>Legend</u>
Full: 3; Medium: 2; Low: 1; None: 0.

4.4.1 Compliance with local laws and international regulations.

As a baseline, all schemes require farms pursuing certification to follow local laws and international regulations. These laws and regulations usually pertain to the protection and use of land and water resources, as well as adherence to international agreements governing trade among exporting and importing countries. Consequently, all schemes receive the maximum score (3).

4.4.2 Discontinuing the use of antibiotics banned in producing and importing countries.

ASC strictly prohibits the use of antibiotics that are proactively banned by producing and importing countries.

BAP explicitly prevents the use of antibiotics in-feed or for therapeutic treatments, which are proactively prohibited in producing or importing countries.

GLOBALG.A.P. follows the list of chemicals banned by the FAO/WHO CODEX ALIMENTARIUS, including banned antibiotics. A list of all antibiotics and treatments that may be used at the farm shall be available and included in the required Veterinary Health Plan (VHP) (GLOBALG.A.P., 2016). However, GLOBALG.A.P. does not explicitly refer to antibiotics currently banned in producing and importing countries and receives the low score (1).

In conclusion, only ASC and BAP prohibit the use of antibiotics that are proactively banned in producing and exporting countries, justifying their maximum score (3).

4.4.3 Data collection on the use of antibiotics.

ASC requires farms to collect data on the use of antibiotics and to maintain accurate records of all applied treatments, which ensures that farms use the safe and correct dosage of antibiotics. It can also support the ASC organization in adjusting future metrics associated with standards and indicators (ASC, 2017).

BAP captures antibiotics usage data through detailed records of all application of drugs carried out by the farm. BAP also requires farms to keep records of disease outbreaks. As well, information on adopted measures to control disease shall be available for future GAA-sponsored research (BAP, 2015).

GLOBALG.A.P. addresses the need for data collection trough treatment records, including detailed information about medicines and treatments purchased and administered by the farm. This information also comprises trend analysis involving antibiotics usage and production levels, as well as the number and frequency of treatments (GLOBALG.A.P., 2016).

All schemes require that farms collect antibiotics usage data by keeping detailed and accurate records about antibiotics purchases, their administration and degree of effectiveness. Consequently, all schemes receive the maximum grade (3).

4.4.4 Testing resistance to potential prescribed antibiotics.

Four ASC standards precisely address resistance to antibiotic treatments. Two of them describe the number of treatments allowed during the latest production cycle, as well as the allowance of antibiotic load levels as a percentage of previous treatments. The remaining two standards refer to specific conditions to perform bio-assay analysis and measures taken in response to resistance to therapeutic treatments (ASC, 2017).

BAP requires farms to write a procedure for the diagnosis and treatment of fish disease that covers resistance, but this is not part of a distinct or separate standard. As part of this procedure, certain conditions need to be met to recommend the testing of resistance before repeating a treatment with the same antibiotic.

GLOBALG.A.P. refers to antibiotic resistance within compliance criteria related to the provision of the VHP standard. If appropriate, the VHP requires the availability of prevention plans, including the “monitoring of sensitivity and rotation of medicines” to prevent resistance (GLOBALG.A.P., 2016, p. 46).

In summary, all schemes aim to minimize the emergence or further development of antibiotic resistance. However, ASC is the only one including certain indicators and metrics to monitor and control antibiotic resistance. Accordingly, ASC receives the full score (3) while BAP and GLOBALG.A.P. receive the medium score (2) for this indicator.

4.4.5 Using antibiotics only to treat fish bacterial diseases diagnosed by authorized fish health professional.

ASC standards specify that all medication procedures shall be prescribed by a veterinarian only after confirming the existence of fish disease. ASC also explicitly forbids the prophylactic use of antibiotics but does not refer to the use of antibiotics as growth promoters.

BAP requires the designation of a licensed fish health professional, who shall follow legal procedures involving the testing and treatment of disease. The fish health professional shall prescribe antibiotics according to a Fish Health Management Plan (FHMP), only to treat diagnosed bacterial disease. The use of antibiotics as growth promoters is explicitly forbidden but the prophylactic use of antibiotics is not described (BAP, 2015).

GLOBALG.A.P. states that antibiotics and treatments must be prescribed by a veterinarian and according to VHP instructions. Antibiotics agents cannot be used for growth promotion and only applied after the diagnosis and confirmation of a bacterial disease. However, GLOBALG.A.P. does not address the use of antibiotics in prophylactic treatments.

All schemes restrict the use of antibiotics for the exclusive use of therapeutic treatments. As well, they stress that it is the responsibility of a designated fish health professional (e.g. veterinarian) to confirm the presence of disease, its diagnosis and treatment. The literature states that the use of antibiotics in prophylactic treatments is a common practice and must be prevented (FAO, 2005; Done, Venkatesan, & Halden, 2015; Cabello, 2006; Sapkota et al., 2008). Nevertheless, differentiating between prophylactic treatment and growth promotion use is challenging due to inherent feedback between the two uses (R. Filgueira, personal communication, August 21, 2017). As well, several types of antibiotics applications are generally based on ambiguous definitions that led to conflicting studies (Landers, et al., 2012; Reda, et al., 2013; Watts, Schreier, Lanska, & Hale (2017). Since the specifics about prophylactic and growth promotion uses are not evaluated, all schemes receive a maximum score (3).

4.4.6 Choice of antibiotics application method.

ASC provides guidance, standards and indicators for the application of parasiticides but no ASC standard or guidelines pertains specifically to the selection of appropriate or effective methods for the application of antibiotics. However, ASC requires a fish health management plan to support the monitoring of fish diseases and environmental conditions needed to maintain good fish health, which in turn could minimize the use of antibiotics. If antibiotics treatments are required, it is inferred from the relevant standards that it is the responsibility of the veterinarian or fish health manager to select the proper antibiotic application method, using as a guide the health management plan.

BAP does not provide a specific standard to inform the selection of an effective antibiotic application method. However, BAP requires a Fish Health Management Plan (FHMP) under the responsibility of a certified health professional, who is also responsible for the diagnosis and treatment of fish diseases. Therefore, the health professional is also responsible for the selection of the correct antibiotic treatment and its proper application method, as guided by the FHMP.

GLOBALG.A.P. refers to antibiotics application methods through standards related to treatments and associated records. Basically, these standards state that the application of antibiotics shall be directed by the fish health professional according to VHP instructions. Also, the farm shall provide records and current information about application methods performed as per the VHP. However, GLOBALG.A.P. standards do not explicitly address the selection of an effective method to apply antibiotics.

The schemes do not provide standards to direct the selection of a method for the application of antibiotics (e.g. in-feed or bath treatment), rather it is the responsibility of the fish health professional or veterinarian to determine the appropriate method based on an established health plan. Thus, schemes just rely on industry best practices followed and directed by the fish health professional. Therefore, all schemes receive a low score (1).

4.4.7 Monitoring medicated feed and accumulation of antibiotic residues in sediments and water near net pen areas.

ASC addresses the benthic impacts using indicators to monitor the chemical inputs and nutrient loading surrounding a farm. However, these indicators do not necessarily target the potential accumulation of antibiotic residues in sediments.

BAP minimizes the negative impacts on benthos and water quality through various standards. However, BAP does not specify indicators to target the potential accumulation of antibiotic residues in the surrounding environment of a farm.

GLOBALG.A.P. monitors the possible accumulation of chemical residues and its impacts on the benthos. However, GLOBALG.A.P. does not provide standards or recommendations to monitor antibiotic residues in sediments.

All schemes address the potential accumulation of chemicals in sediments under and near a farm, and in the water column to protect benthic biodiversity, but do not provide detailed information to monitor the potential accumulation of antibiotics residues in the surrounding environment. Therefore, all schemes receive a low score (1) because at least they address the accumulation of chemicals in sediments, tacitly including antibiotics residues in this group.

4.4.8 Monitoring bacteria and microorganism biodiversity.

ASC features standards to monitor and protect fauna and macrofaunal biodiversity in natural habitats from effects caused by chemical inputs and nutrient loading. ASC measurements consist of methodologies to calculate faunal index and macrofaunal taxa. However, these standards and measurements do not target bacterial biodiversity.

As part of a farm operating permit involving sediment and benthic protection, BAP indicates that the chemical properties of sediments are sometimes linked to the density of species used as an indication of diversity. BAP also addresses ecosystem biodiversity through their standards concerning predator and wildlife interactions. Although this information about sediment properties and ecosystem health is related to biodiversity, it does not mention the threats of antibiotics residues on bacterial biodiversity.

GLOBALG.A.P. includes many standards concerning the conservation of biodiversity under their “Environmental and Biodiversity Management” section. Specifically, GLOBALG.A.P.

requires farms to monitor their impacts on benthic biodiversity and recipient water body sediment, resulting from the possible accumulation of chemical residues through the provision of a sampling program. These chemical residues include antibiotic residues but the latter are not addressed as part of a standard or indicator.

In summary, all schemes monitor biodiversity levels of fauna and macrofauna to protect the population of non-target organisms. However, the diversity of the surrounding bacteria population is not specifically targeted. Consequently, all schemes receive a low score (1).

4.4.9 Forbidding the use of “critically important” antibiotics in the WHO list for the exclusive use of human medicine.

ASC certainly restricts the use of antibiotics used in human medicine that are listed as “critically important” by the WHO. As part of an Area Based Management (ABM) arrangement, ASC also describes the cumulative use and possible risks of using this type of antibiotics. As well, ASC stresses the assessment of risks to human health, resulting from the development of resistance in the environment. ASC still recommends the prescription of these “highly important” antibiotics as a last resort instead of a complete ban.

BAP does not refer at all to the WHO list of “critically important” antibiotics used in human medicine.

GLOBALG.A.P. includes the use of “critically important” antibiotics used in human health as part of a Veterinary Health Plan (VHP). This plan indicates that the use of these antibiotics shall not be used as a product of first-choice. They could be prescribed but each time their use must be justified in writing.

Therefore, ASC receives a medium score (2) because it provides relevant and detailed information to restrict the use of highly important antibiotics used in human medicine. Yet ASC still permits the use of exclusive human antibiotics as a last resort. GLOBALG.A.P. restricts the use of human antibiotics as part of a veterinary health plan but the information does not include the risks involved, consequently it receives a medium score (2). In contrast, BAP does not make any reference to the use of this type of antibiotics and receives the lowest score (0).

4.4.10 Monitoring the amount of antibiotics used and associated risks.

As part of required on-farm documentation, ASC monitors the amount of antibiotics used by referring to "a gram per ton of fish produced" metrics. ASC metrics though do not consider the risks of using "critically important" antibiotics used in human medicine.

BAP requires farms to keep records of antibiotics and drug usage, as part of its required traceability data. However, BAP does not correlate antibiotics usage levels with production levels, neither assesses the possible risks of using important antibiotics used in human medicine.

As part of compliance criteria, GLOBALG.A.P. requires a trend analysis of antibiotics usage versus harvest tonnage for each identified production batch. Nevertheless, this analysis does not include indicators or metrics related to the possible risks caused by using important human antibiotics.

In summary, ASC obtains a medium grade (2) since it includes an "antibiotics usage over fish produced" ratio, but lacks risks measurements concerning the type of antibiotics used. BAP only requires keeping records of antibiotics usage, then obtains the low score (1). GLOBALG.A.P. correlates antibiotics usage quantities to production levels but does not consider the risks involved in using human antibiotics, therefore receives a medium grade (2).

4.4.11 Compliance with withdrawals periods and antibiotics Maximum Residue Limits (MRL).

ASC requires farms to comply with all withholding periods after treatments, without providing further details. Also, ASC does not include any indicators concerning food safety in relation to the use of antibiotics.

To lower residues in the fish after the administration of antibiotics, BAP requires written procedures to record withdrawal times, along with detailed information (e.g. date, compound used, dose) about each treatment. BAP also requires access to documentation from feed manufacturers, stating that antibiotics are not present in non-medicated feed. These requirements also involve BAP traceability standards.

AS part of the VHP, GLOBALG.A.P. includes information about pre-harvest withdrawal periods. As well, GLOBALG.A.P. requires to assess risks of antibiotics residues concerning food safety and potential effects on non-targeted species. The VHP also includes information regarding an action plan for the harvest of fish when permitted MRL levels have been exceeded. In addition, this scheme provides a comprehensive indicator regarding analysis of residues grounded on food safety risks assessment and compliance verification.

Based on the previous information, ASC receives the minimum score (0); BAP a medium score (2); and GLOBALG.A.P. the maximum score (3).

5 Discussion

This study investigated the regulating role play by 3rd party certification schemes on the use of antibiotics in coastal salmon aquaculture. Based on the literature review, a set composed of 11 indicators was created comprising key aspects about the use of antibiotics. The indicators were grouped in seven categories: legal and regulatory frameworks, data collection and availability, application method, environmental protection, fish and human health, and food safety (Table 6). This set of indicators serves to compare the three most important 3rd party certification schemes used in worldwide salmon farming: ASC, BAP and GLOBALG.A.P.

To streamline the comparison among schemes, the relevant standards were categorized as having a direct or indirect impact on the use of antibiotics. Schemes include many standards that indirectly maintain fish health and mitigate the use of antibiotics (Appendix A), covering farming practices like: effluents, water quality, product traceability, storage/disposal of expired antibiotics, handling of non-organic waste, along with the coordinated management of fish health and biosecurity (e.g. antibiotic treatments linked to resistance) by farms in the area [2] (ASC, 2017). All these standards indirectly prevent disease transmission and/or mitigate the use of antibiotics, complementing the standards that directly control the use of antibiotics (Tables 8-10).

5.1 Comparing Schemes: Strengths and Weaknesses

As per the 11 devised indicators, the maximum score denoting excellence in regulating antibiotics corresponds to 33 (11 x 3), whereas the total score obtained by each scheme falls within a range of 20 to 22. Within the study scope, this narrow range means that the overall

[2] This management of biosecurity requires the implementation of an Area Based Management (ABM) plan.

usage of antibiotics is regulated similarly by the three schemes. However, for a few indicators significant score differences exist among the schemes (Table 11). For instance, GLOBALG.A.P. obtains the highest score for the food safety indicator (11)[3] while ASC receives a zero grade. This high score implies that GLOBALGA.P. is highly focussed on maintaining the safety of salmon products and the health of consumers. However, GLOBALG.A.P. scores 1 for the indicator about "the use of antibiotics banned by trading countries" (2), while the other two schemes receive the highest grade for this indicator, suggesting that GLOBALG.A.P. could be further scrutinized in international markets.

The study also shows that the three schemes fall short in three indicators, consistently reporting a highest score of 1 (Table 7), which corresponds to "choice of antibiotics application method" (6), "monitoring of antibiotic residues in sediments…" (7), and "microorganism and bacterial biodiversity" (8). The limited information from schemes about choices and methods for the application of antibiotics indicates a lack of relevant guidelines based on common best practices followed by farms worldwide, while considering local environmental conditions such as water currents and coastal physical connectivity (R. Filgueira, personal communication, August 21, 2017; Scottish Environment Protection Agency [SEPA], 2013; Bonsaksen, 2014, BAP, 2016). The environmental protection guidelines and standards provided by the three schemes lack specific information to monitor the possible accumulation of antibiotics residues in benthic sediments and water, as well as bacteria and microorganism biodiversity levels near the farm. This information could factor the protection of non-target organism and surrounding ecosystem, and possible consequences on fish and human health. Consequently, schemes

[3] Indicator number (Table 11)

should devise adequate and cost-effective sampling methods to monitor these sediments and type of biodiversity. BAP refers to benthic sediments and recommends the future development of a protocol to monitor them around fish farms, despite difficulties derived from environmental, biological and physical variabilities (BAP, 2016). Nevertheless, certification costs must be justified, for instance by securing access to new markets or expanding existing ones (i.e. cost benefits analysis) (FAO, 2007). In contrast, schemes need to persuade farms about the value of their standards without compromising compliance requirements (Jonell, Phillips, Rönnbäck, & Troell, 2013). Essentially, aquaculture standards aim to provide economic growth in tandem with sustainable development (Bonsaksen, 2014). Hypothetically, a farm could score 3 for each of the 11 indicators and obtain a total score of 33 (Table 11), but attaining this "level of excellence" is probably not achievable due to current economic and technical constraints. Nevertheless, technological advances are progressively lowering related costs, like recently the decreasing cost of genetic tests, suggesting their potential adoption in the near term (R. Filgueira, personal communication, September 14, 2017). Further research would likely contribute to the development of cost-effective indicators to better monitor the use of antibiotics in aquaculture farms (R. Filgueira, personal communication, September 16, 2017).

5.2 Connection to other Aquaculture Initiatives and Associated Tools

Within the context of aquaculture and sustainability, scientific researchers, international institutions, industry groups and NGOs have written many useful studies and reports to compare aquaculture certification schemes. For example, the Standards Systems Comparison Tool (ISEAL Alliance, n.d.), an analytical engine that allows the comparison of aquaculture schemes; including ASC, BAP and GLOBALG.A.P., as per preferred characteristics or choices (e.g.

product, scheme name). These studies usually provide a general comparison among certification schemes; instead this thesis delves deeper into the impacts of antibiotics.

A second tool is the Global Sustainable Seafood Initiative (GSSI), a global benchmarking tool for seafood certification based on the FAO Technical Guidelines on Aquaculture, among other FAO core documents (GSSI, 2015). This tool aims to reduce the confusion created by the numerous and diverse voluntary certification schemes using a set of criteria and indicators to evaluate the performance of seafood certification programs (GSSI, 2015). The GSSI benchmark framework comprises four modules, of which the “GSSI Requirements and GSSI Indicators for Aquaculture Certification Standards” module is of interest to this study, since it includes among others, some requirements and indicators to control the use of veterinary drugs. Specifically, one of the GSSI requirements covers the monitoring and identification of hazards caused by the release of antibiotics using suitable reference points, which if exceeded requires the application of corrective measures (e.g. contingency plans) (GSSI, 2015). Once reference points are determined, they could be used to enhance the indicators monitoring the accumulation of benthic antibiotic residues (7), and the monitoring of antimicrobial/bacterial biodiversity (8). Consequently, the GSSI tool could guide the development and implementation of new indicators controlling the use of antibiotics.

A third and important tool assessing the environmental performance of marine aquaculture is the Global Aquaculture Performance Index (GAPI) (Volpe,Beck, Ethier, Gee, & Wilson, 2010). The GAPI study stresses the need for a data-driven, performance based approach to environmental protection. GAPI comprises 10 indicators grouped in three categories: *inputs, discharges, and biological.* The “discharges” category includes the *Antibiotics*

(ANTI) indicator, which measures the “amount of antibiotics used, weighted by a measure of human and animal health risk” (Volpe, Beck, Ethier, Gee, & Wilson, 2010, p. 4). The risk components of the ANTI indicator could be used for the evaluation of schemes against the “prohibition to use ‘critically important’ antibiotics” indicator (9).

6 Conclusion

This study investigates the degree to which ASC, BAP and GLOBALG.A.P. certification schemes can effectively regulate the use of antibiotics in global salmon aquaculture, mainly to mitigate fish and human health risks, protect non-target organisms, as well as reduce the environmental proliferation and persistence of antibiotic resistance. For this purpose, a set of 11 indicators that target the regulation of antibiotics in salmon farming are defined. Using a grading scale from 0 to 33, the schemes are assigned total scores within a range of 20 to 22 (60.6 % to 66.6 %). These values indicate that all schemes perform similarly. Common weaknesses across certification schemes indicate that their performance could be improved by increasing the reliability of standards related to the antibiotics application method, monitoring of antibiotic residues in sediments, and monitoring of bacterial/microorganism biodiversity. Therefore, it is recommended that certification schemes continue to reinforce the prudent use of antibiotics in accordance to the precautionary principle to minimize the risks identified.

Glossary

Antibacterial: Drug that kills or inhibits the growth of bacteria (Harrison & Lederberg, 1998, p. 104).

Antibiotic: Class of substances that can kill or inhibit the growth of some groups of microorganisms. Originally antibiotics were derived from natural sources (e.g., penicillin from molds), but many currently used antibiotics are semisynthetic and modified with additions of man-made chemical components. See antimicrobials (Harrison & Lederberg, 1998, p. 104).

Antibiotic load: The sum of the total amount of active ingredient of antibiotics used (kg) (ASC, 2017, p. 47).

Antibiotic resistance: Property of bacteria that confers the capacity to inactivate or exclude antibiotics or a mechanism that blocks the inhibitory or killing effects of antibiotics (Choffnes, Relman, Olsen, Hutton, & Mack, 2012).

Antimicrobials: Class of substances that can destroy or inhibit the growth of bacteria. See antibiotics (Harrison & Lederberg, 1998, p. 104).

Bacteria: Microscopic, single-celled organisms that have some biochemical and structural features different from those of animal and plant cells (Harrison & Lederberg, 1998, p. 104).

Chain of custody: The procedures implemented by a fishery and subsequent entities handling fish and fish products to ensure that products from a certified fishery are not mixed with products from any other fishery and remain fully traceable during processing, storage, distribution and sale. Also known as 'CoC' (Marine Stewardship Council [MSC], 2015, p. 6).

Chemotherapeutants: …a drug or a pesticide depending on the use and method of application. (Burridge, Doe, & Ernst, 2011 p. 1).

Connectivity: the physical dispersion of particles which are passive or which interact with their environment (e.g., larvae corresponding to the pelagic phase during the life cycle of organisms) (Bacher, Filgueira, & Guyondet, 2016, p. 25).

Growth promoters: A class of substances, usually antibiotics, used at low doses to promote growth in food animals (Alliance for the Prudent Use of Antibiotics, n.d.).

Metabolites: Any intermediate or product resulting by metabolism or by a metabolic process (Motarjemi, Moy, Todd, 2014, p. 45).

Microbe: A microorganism or biologic agent that can replicate in humans (including bacteria, viruses, protozoa, fungi, and prions) (Choffnes, Olsen, & Wizemann, 2013).

Microorganism: Living organisms that are microscopic or submicroscopic: they cannot be seen with the human eye. They include bacteria, some fungi, and protozoa (Alliance for the Prudent Use of Antibiotics, n.d.).

Pathogen: A microorganism, virus, or other substance that causes disease in another organism, the host (Alliance for the Prudent Use of Antibiotics, n.d.).

Precautionary principle: [It] states that, in cases of serious or irreversible threats to the health of humans or ecosystems, acknowledged scientific uncertainty should not be used as a reason to postpone preventive measures. The principle originated as a tool to bridge uncertain scientific information and a political responsibility to act to prevent damage to human health and to ecosystems (Martuzzi & Tickner, 2004).

Prophylactics: Drugs used to prevent disease, before any symptoms of the disease have been observed (Alliance for the Prudent Use of Antibiotics, n.d.).

Requirement: The number and/or performance level that must be reached to determine if [an] impact is being minimized (ASC, 2017, p. 11).

Third party: Person or body that is recognized as being independent of the parties involved, as concerns the issue in question, and involves no conflict of interest (FAO, 2011, p. 4).

Traceability: The ability to follow the movement of a product of aquaculture or inputs such as feed and seed, through specified stage(s) of production, processing and distribution (Adapted from Codex) (Session of Committee on Fisheries, [COFI], 2011).

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Appendix A: Standards indirectly controlling the use of antibiotics

Table A 1: ASC standards indirectly controlling the use of antibiotics (reprinted from Aquaculture Stewardship Council, 2017)

Criterion	Indicator	Requirement
1.1 Compliance with all applicable local and national legal requirements and regulations	1.1.1 Presence of documents demonstrating compliance with local and national regulations and requirements on land and water use	Yes
	1.1.4 Presence of documents demonstrating compliance with regulations and permits concerning water quality impacts	Yes
2.1 Benthic biodiversity and benthic effects	2.1.2 Faunal index score indicating good to high ecological quality in sediment outside the AZE, following the sampling methodology outlined in Appendix I-1	AZTI Marine Biotic Index (AMBI 6) score ≤ 3.3, or Shannon-Wiener Index score > 3, or Benthic Quality Index (BQI) score ≥ 15, or Infaunal Trophic Index (ITI) score ≥ 25
	2.1.3 Number of macrofaunal taxa in the sediment within the AZE, following the sampling methodology outlined in Appendix I-1	≥ 2 highly abundant7 taxa that are not pollution indicator species
2.2 Water quality in and near the site of operation	2.2.6 Appropriate controls are in place that maintains good culture and hygienic conditions on the farm which extends to all chemicals, including veterinary drugs, thereby ensuring that adverse impacts on environmental quality are minimised.	Yes
5.1 Survival and health of farmed fish	5.1.2 Site visits by a designated veterinarian at least four times a year, and by a fish health manager at least once a month.	Yes
5.2 Therapeutic treatments	5.2.1 On-farm documentation that includes, at a minimum, detailed information on all chemicals and therapeutants used during the most recent production cycle, the amounts used (including grams per ton of fish produced), the dates used, which group of fish were treated and against which diseases, proof of proper dosing, and all disease and pathogens detected on the site.	Yes
	5.2.3 Percentage of medication events that are prescribed by a veterinarian.	100%
	5.2.11 Presence of documents demonstrating that the farm has provided buyers of its salmon a list of all therapeutants used in production.	Yes

Table A 2: BAP standards indirectly controlling the use of antibiotics (adapted from Best Aquaculture Practices, 2015)

Criterion	Indicator	Requirement
1. Community Property Rights and Regulatory Compliance	1.1: Current documents shall be available to prove legal land and water use by the applicant.	Yes
	1.3: Current documents shall be available to prove compliance with applicable environmental and other regulations for construction and operation.	Yes
8. Environment – Storage and Disposal of Farm Supplies	8.1: The applicant shall have a written Material Storage, Handling and Waste Disposal Plan [MSHWDP] that includes the BAP requirements for proper handling and disposal as outlined in the implementation requirements above and be able to demonstrate compliance with it.	Yes
	8.4: An inventory shall be kept of all hazardous materials or wastes (chemotherapeutants and materials that are hazardous to people) stored on or disposed of by the farm.	Yes
	8.6: Fuel, lubricants and chemicals shall be labeled, stored and disposed of in a safe and responsible manner and marked with warning signs.	Yes
	8.9: Garbage and other solid waste shall be disposed of in compliance with local regulations and shall avoid environmental contamination.	Yes
9. Animal Health and Welfare Health and Welfare	9.8: The applicant shall be able to demonstrate compliance with a written Water Quality Management Plan described in the implementation requirements above that includes provisions for water quality monitoring, staff training, mitigation measures for poor quality and procedures for the monitoring and control of dissolved oxygen during fish transport.	Yes
10. Animal Health and Welfare – Biosecurity Management	10.2: The applicant shall show that the designated fish health professional has the required licenses and accreditations to act in the farming region.	Yes
	10:4 The fish health professional shall ensure compliance with all legal requirements for disease testing, fish movements (including zoosanitary regulations of inbound and outbound transports), treatments for fish diseases and reporting of notifiable diseases.	Yes
	10.5: Written procedures for the diagnosis and treatment of disease in fish shall include monitoring for endemic parasitic, bacterial and viral infections.	Yes
	10.8: Observations by farm staff of disease indicators and resulting actions concerning disease diagnosis and treatment shall be recorded.	Yes
	10.10: Records shall be maintained for every application of drugs and other chemicals that include the date, compound used, reason(s) for use, dose, withdrawal time and harvest date. (See the Traceability requirement.)	Yes

Criterion	Indicator	Requirement
	10.11: The applicant shall record data on disease outbreaks and actions taken so this information can be made available to the BAP database for future GAA-sponsored research. (See Introduction.)	Yes
11. Food safety	11.3: Documents shall be available from feed manufacturers that state antibiotics or other drugs are not present in non-medicated feed, that provide details of drugs or antibiotics in medicated feeds and state that levels of heavy metals and PCBs/ dioxins in feed are below limits for those compounds set by the countries in which the plants operate.	Yes

Table A 3: GLOBALG.A.P. standards indirectly controlling the use of antibiotics (adapted from GLOBALG.A.P., 2016)

Criterion	Indicator	Requirement Level
AB. 1 Site Management AB.1.1 Legislative Framework	AB.1.1.1 Are farms operated in accordance with applicable legislation in relation to the GLOBALG.A.P. Standard?	Major Must
	AB. 1.1.2 Are farm management able to explain how they fulfill their legal obligation with respect to the Food Safety, Animal Welfare, Environmental and Workers Health & Safety Legislation applicable to their enterprise?	Major Must
AB. 3 Chemical Compounds AB. 3.1 Chemical Compounds Storage	AB. 3.1.1 Is a product inventory documented and readily available for all chemical compounds in store?	Major Must
	AB. 3.1.3 Are chemical compounds stored in accordance with the manufacturer instructions and legislation?	Major Must
	AB. 3.1.5 Is the chemical compounds store kept locked and access limited to workers with training (according to AF 4.2.2 and AB 4.1.1)?	Major Must
	AB. 3.1.6 Area all chemical compounds stored in their original packaging, which shall be kept in a suitable condition to allow label instructions to be clearly identified?	Major Must
	AB. 3.1.7 Is the chemical compound store able to retain spillage and are there emergency facilities to deal with accidental spillage?	Major Must
	AB. 3.1.8 Are there facilities and equipment suitable for measuring and/or mixing of chemical compounds to assure safe and accurate dosage?	Minor Must
AB. 3 Chemical Compounds **AB. 3.2 Empty Containers and Non-used Chemicals**	AB. 3.2.1 Are empty chemical compound containers not re-used unless risk assessed by a technical competent person? Are chemical compound containers disposed of by a legally licensed chemical compounds waste subcontractor or returned to the supplying company for recycling?	Major Must
	AB. 3.2.2 Does storage and disposal of empty containers and non-used chemical compounds take place in a manner that avoids spillage and exposure to products, humans and animals?	Major Must
	AB. 3.2.3 Are unused chemical compounds disposed of by legally approved chemical compounds subcontractor or returned to the supplying company?	Major Must
AB. 5.2 Fish Health & Welfare	AB. 5.2.1 Is a Veterinary Health Plan available, updated during last 12 months or for last production cycle or when new medicines or treatments not previously used have been added? Does a veterinarian recognized by the competent authority sign it off?	Major Must
	5.2.12 Are fish monitored for health indicators and welfare problems affecting individuals?	Minor Must

AB. 5.3 Treatments	AB. 5.3.7 Are stock vaccinated according to the VHP under AB 5.2.1?	Major Must
	AB 5.3.10 Are unused medicines or medicated feed past their use-by date and empty medicine containers or empty medicated feed bags disposed of in a controlled manner that will not result in subsequent misuse?	Major Must
AB 5.4 Treatment Records	AB 5.4.1 Do all farms maintain dated records of medicines and treatment purchases or deliveries and are records of their administration to stock accurately recorded and up to date? This includes medicated feed.	Major Must
	AB 5.4.2 Is the producer able to provide a complete history and current overview and trend analysis of fish treatments and application methods and that these are carried out according to VHP?	Major Must
	AB 5.4.3 Is there a system in place to identify batches of fish having received treatment, for which there is a required pre-harvest withdrawal period?	Major Must
AB 5.8 Biosecurity (In addition to Food Defense requirements of All Farm module)	AB 5.8.1 Does the site have a documented biosecurity plan?	Major Must
AB. 7.3 Storage of Aquaculture Feeds	AB. 7.3.2 Are feeds, including all medicated feeds, stored and handled in accordance with good practice and manufacturer instructions to minimize any risk of contamination?	Major Must
	AB. 7.3.3 Are there written instructions on how to deal with excess medicated feed and flush feed? Are these instructions followed?	Major Must
	AB. 7.3.4 Are medicated feeds kept in separate, clearly labeled and identified bulk storage or bags?	Major Must
AB. 9.1 Environmental Management	AB. 9.1.5 Is there a sampling program to monitor the impact of the farming activity on the benthic fauna and recipient water body sediment?	Major Must
AB. 10.2 Effluent (as per local legislation)	AB. 10.2.1 Are measured impacts in accordance with legislation and following the results of the EIA/EMP?	Major Must
AB. 15.6 Food Safety System	AB. 15.6.1 Does the organization have a food safety system in place at the time of inspection?	Recommended
AF. 15 Food Safety Policy Declaration	AF. 15.1 Has the producer completed and signed the Food Safety Policy Declaration included in the IFA checklist?	Yes

Appendix B: Linking indicators to scheme standards

Table B 1: Relation of indicators to scheme certification standards

No.	Indicator	ASC	BAP	GLOBALG.A.P.
1	Compliance with local and international regulations.	1.1.1, 1.1.4,	1.1, 1.3	AB. 1.1.1, AB. 1.1.2, 10.2.1
2	Discontinuing the use of antibiotics banned in exporting and importing countries.	5.2.2, 5.2.11	11.1	AB. 5.3.1, AB. 5.3.2
3	Data collection on the use of antibiotics, including their type and their degree of effectiveness.	5.2.1	10.10, 10.11, 10.8	AB. 5.4.1, AB. 5.4.2
4	Testing resistance to potential prescribed antibiotics.	5.2.9, 5.2.10, 5.3.1, 5.3.2	10.0 Described as part of a written procedure (p. 18)	AB. 5.2.1 (p. 46) monitoring of sensitivity and rotation of medicines to avoid resistance
5	Using antibiotics exclusively to treat fish bacterial diseases, as diagnosed by authorized fish health professional.	5.2.3, 5.2.7, 5.1.2	10.2, 10.4, 10.5, 10.9, 11.5	AB. 5.3.6, AB. 5.3.8, 5.3.3, 5.3.7, 5.2.12, 5.8.1
6	Choice of antibiotics application method.	5.1.1	10.1, 10.9	AB. 5.3.3 (as authorized by fish health professional) AB. 5.4.2 It refers to trend analysis of fish treatments and applications methods (p. 54)
7	Monitoring medicated feed and accumulation of antibiotic residues in sediments and water near net pen areas.	2.2.6 Other standards refer mainly to water quality, nutrient loading, hygienic conditions, including veterinary drugs	Mainly applicable to organic loading 8.1, 8.4, 8.6, 8.9, 9.8	9.1.5 3.1.1, 3.1.3, 3.1.5, 3.1.6, 3.1.7, 3.1.8 3.2.1, 3.2.2, 3.2.3 5.3.10 7.3.2, 7.3.3, 7.3.4

No.	Indicator	ASC	BAP	GLOBALG.A.P.
8	Monitoring bacteria and microorganism biodiversity.	2.1.2, 2.1.3 It concerns fauna and macrofauna	None	9.1.5 It concerns fauna and flora biodiversity protection. It also refers to chemical residues in the benthos
9	Prohibition to use “critically important” antibiotics for the exclusive use of human medicine, as per WHO list.	5.2.8	None	AB. 5.2.1 “…the veterinarian shall give justification in writing for each occasion of this use” (p. 46).
10	Monitoring amount of antibiotics usage and associated risks.	5.2.1 (grams per ton of fish produced). No risk metrics related to antibiotic type.	None	5.4.2 It refers to trend analysis. No risk metrics related to antibiotic type.
11	Compliance with withdrawals periods after antibiotic treatments, as well as antibiotics Maximum Residue Limits (MRL).	5.2.4	10.10, 11.3	AB. 5.3.5, 5.3.9 AB. 5.2.1 p. 46 Part of Veterinary Health Plan AB. 5.4.1 It refers to treatment records (Major Must) 5.4.3 It refers to treatment records and identification of batches (Major Must) 5.4.4 (p. 54) (Major Must) AF. 15.1 AB. 15.6.1