



Barriers to the adoption of a fish health data integration initiative in the Chilean salmonid production

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ABSTRACT

The fish production, health and management data routinely collected on aquaculture farms represent a significant resource that could better support epidemiological research than traditional surveys and other studies. To this aim, a collaborative data integration platform was developed in late 2017 with the Chilean salmon and trout production industry (an initiative named 'Plataforma Integrada de Investigación Sanitaria para la Acuicultura', PIISAC). Initially supported through a joint government-industry program, it was planned that the PIISAC initiative would transition towards ongoing industry ownership and governance in 2019. However, this transition did not occur, due to lack of industry support. In this qualitative study, we used semi-structured key informant interviews to explore the perspective of stakeholders on the implementation of PIISAC and identify barriers to sustained adoption. An inductive, semantic thematic analysis was conducted. While informants reported that the platform was valuable for the industry, they also identified many concerns and barriers. These elements were grouped under two main themes, i.e., factors related to the environment for the data integration platform, and issues linked to the project implementation. Within the first main theme, sub-themes included competitive advantages, privacy concerns, and lack of trust between stakeholders and towards third parties. Regarding the project implementation, the identified factors included project attributes such as relative advantage, complexity and observability, as well as participation-related factors such as the critical mass. These factors were consistent with established theory on diffusion of innovations. Additional findings include that in-country presence is critical to support and maintain participation, and that effective communication is equally important as robust design principles to overcome existing perceptions and barriers to participation. The findings of this study can inform the design of future successful and sustainable partnerships. Our work emphasizes the need to conduct targeted consultations during the design stage of such initiatives, to identify context-specific challenges related to the environment and the stakeholders. These consultations are critical to inform the implementation plan and better address the needs of the participants.

1. Introduction

Chile was the fourth largest finfish producer worldwide in 2016, with a production of over 700 thousand tonnes (FAO 2018), most of which being salmon and trout. Most salmonid farms in Chile are operated by large companies operating farms in different regions or multinational companies. Collectively, the routine fish production, health and management data gathered on farms (e.g., records concerning movements of fish groups, weight gain and variability, mortality, veterinary

treatments, feed distribution) form a comprehensive and complex picture of what is happening day-to-day on these farms. Such data also includes much of the variability in management systems adopted and environmental conditions encountered by salmonid producers in the country. Collaborative efforts are required to create national information systems to support health research in both public and animal health. However, most of animal health initiatives to date were developed at the instigation of non-industry stakeholders such as authorities or research institutes. Examples abound, from early systems such as the National

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Swedish animal disease recording system (Emanuelson 1988), surveillance systems for companion animal health (O'Neill 2012; McGreevy et al. 2017), to cloud-based systems such as Indonesia's integrated animal health information system (Hutchison et al. 2018). A few initiatives of collaborative data integration and analysis have been described within the agriculture sector, for instance in the United States (Shekhar et al. 2017; Stubb 2016) and in Switzerland (Faverjon et al. 2019). In the aquaculture sector, two initiatives were identified in Norway, the AquaCloud platform for improving sea lice management (Hoel 2018) and the fish health module in BarentsWatch (<https://www.barentswatch.no>). These types of initiatives are likely to become more common in agriculture and aquaculture with (i) the increasing availability of real-time data from precision farming technologies, both in terrestrial animal production (Berckmans 2014) and aquaculture (Føre et al. 2018; O'Donncha and Grant 2019), and (ii) the increasing recognition of the value of public-private partnerships in the veterinary domain (OIE 2019).

A collaborative platform where producers regularly contribute routine data would support ongoing research in fish health in Chile and could facilitate the provision of data to third parties such as the Chilean regulatory body for fisheries and aquaculture (Servicio Nacional de Pesca y Acuicultura, Sernapesca) and the Chilean salmon farming association (SalmonChile). In late 2017, a project was commissioned by Chilean stakeholders to build an integrated platform for epidemiological research in the Chilean aquaculture industry ('Plataforma Integrada de Investigación Sanitaria para la Acuicultura', PIISAC). This approach was complementary to another approach commissioned by the Chilean government in the aquaculture sector, the 'Sistema Integrado de Manejo para la Acuicultura Austral de Chile' (SIMA), a recently deployed information and modelling platform (Steven et al. 2019). The SIMA platform uses regulatory databases as well as publicly available data (e.g., climate, weather, remote sensing) to support better policy and management decisions. At the time when the development of PIISAC started, 21 aquaculture companies were operating commercial salmon and trout sea farms in Chile. Consultations with the industry to develop the PIISAC collaborative platform started in January 2018, with the first companies providing data in April 2018. By the end of the government-executed project in December 2018, 10 companies were participating and three epidemiological risk factor studies based on the PIISAC data had been completed (Happold et al., 2020a, 2020b; Meyer et al., 2019). The PIISAC initiative showed that an operational platform could be set-up and populated during the project duration (December 2017 – December 2018). During that period, the development and maintenance of the platform as well as the recruitment of companies was entirely funded by the government, through a joint government-industry program ('Programa para la gestión sanitaria en la Acuicultura', PGSA). However, after the end of the project, the proposed transition towards industry ownership, governance and funding of the platform has proven difficult and PIISAC was discontinued in September 2019. The research question investigated in this study can be formulated as follows: how can a public-private data integration initiative transition into a sustainable industry program? We analysed the case of PIISAC to identify factors which may affect the sustainability of such initiatives and inform the design of successful future partnerships.

2. Methods

A qualitative study was designed to explore the perspective of stakeholders on the implementation of PIISAC. Data were collected via semi-structured individual interviews of informants selected from relevant stakeholder groups. In this section, we first present key features of the platform that are useful to interpret the results of this study, then report the study methodology according to the COREQ guidelines (Tong, Sainsbury, and Craig 2007).

2.1. Key features of the platform

The PIISAC initiative was based on a people-centred approach to animal health surveillance previously presented in a discussion paper (Hutchison et al. 2018). The purpose of the platform was to integrate data across multiple companies in order to answer research questions that could not be answered by examining a single company's data alone. The platform was based on data *integration* in a secure environment, with controlled access to the data by authorized participants, rather than data *sharing* between companies. Thus, companies could not access data from other companies but could visualize data summaries and de-identified results from the analyses conducted for specific purposes, maintaining each individual company's commercial privacy and respecting antitrust legislation (Decree Law no. 211 from 1973 and subsequent amendments and rulings). The platform was designed as a flexible and comprehensive data source that could be used to conduct observational epidemiological studies to answer fish health questions prioritized by the industry. In addition to this long-term goal, the short-term goal of the platform was to provide rapid access to their own data to companies, via an online interface. Data from production databases were integrated using automated algorithms. This process was designed to avoid the need for manual data extraction by company personnel, in contrast with current systems for reporting to government authorities and existing data service providers.

2.2. Research team

The research team jointly developed the semi-structured interview guide (Supplementary material), while the interviews were conducted by a native Chilean Spanish speaker (NR). Some of the authors had previously worked with the informants during the implementation of PIISAC, while NR had not been involved in the implementation.

2.3. Study design

2.3.1. Informant selection

Veterinary staff or technical managers (fish health and production) were selected from the following groups, using a purposive sampling strategy (Robinson 2014; Gentles et al. 2015): salmon producing companies who actively participated in PIISAC ('participating companies'), salmon producing companies who did not actively participate in PIISAC, and third-party stakeholders (Sernapesca and SalmonChile). To increase the validity of the results across the industry, we aimed at interviewing one informant from each company as well as one informant from Sernapesca and one from SalmonChile. The informants were approached by email and telephone to arrange for an interview. As four companies did not reply to our requests, and on two occasions we interviewed two informants from the same company, we conducted a total of 20 interviews. All informants except one were men, and they had between 10 and 30 years of experience in the aquaculture industry or regulatory area.

2.3.2. Data collection

Roger's diffusion theory, initially published in 1962, proposed a framework to understand the diffusion process of new ideas and innovations in a social system (Rogers 2003). We used the five stages of the diffusion theory (knowledge, persuasion, decision, implementation, confirmation) to develop and structure the semi-structured interview guide used in the present study. The interview guide was slightly refined after the first two interviews. The interviews were conducted between January and April 2020, either in person ($n = 13$) or using a teleconference tool ($n = 7$). The interviews were conducted at the workplace, in a location that prevented the conversation being overheard, and were audio recorded.

2.4. Data analysis

The interview records were transcribed and translated into English by NR before being imported in RQDA (Huang 2018), a package in the R environment (R Core Team 2019) for analysis. An inductive, semantic thematic analysis was conducted by the first author, following the approach described by (Braun and Clarke 2006; Braun and Clarke, 2014). In the coding stage, the interview materials were read carefully, and each individual idea in relation to the research question was identified and marked ('code'). Then, themes and sub-themes were derived from the data itself, via an iterative and systematic process of reviewing, summarizing and cross-checking the codes previously identified. The sub-themes described in this work cover the ideas identified in the interview materials in an exhaustive manner, while the narrative provides indications of the differences and similarities between the informants.

2.5. Ethics

A study information sheet was provided to each informant prior to the start of the interview as well as a short video explaining the reasons for conducting the interviews. Then, they were informed that they were free to withdraw consent at any time and given an opportunity to ask questions regarding the study or their participation. Finally, consent to participate was obtained and documented via signing a written consent form. This study was approved by the Science-Geosciences Ethics Review Board of Utrecht University under the reference number DGK L-19302.

3. Results

Two main themes were identified in the interview materials when exploring the research question. These two themes were divided into 19 sub-themes (Table 1) which are presented in more details in the sections below.

3.1. A difficult environment for a data integration platform

The first theme gathers a number of issues related to the Chilean aquaculture industry and its operating environment that were discussed by the informants as obstacles to the initial uptake of PIISAC.

3.1.1. Existing data management systems are considered good

Decision-makers in the surveyed companies inform their fish health related decisions with a combination of results from internal analyses, expertise and historical knowledge from technical personnel and outputs obtained from external data service providers. Most companies'

Table 1

Set of themes and sub-themes identified in semi-structured interviews of key informants in the Chilean salmonid production industry (N = 20).

A difficult environment for a data integration platform	Issues linked to the project implementation
<ul style="list-style-type: none"> Existing data management systems are considered good Crowded market for data services Role of the antitrust laws Generic climate of distrust Concerns related to data privacy Collaboration within the industry is difficult Importance of competitive advantages Complex industry-government relationship Competing priorities in 2018 	<ul style="list-style-type: none"> Results did not meet expectations Quality of the data and analyses Cost of ongoing support for PIISAC PIISAC as a foreign initiative Insufficient knowledge of the industry Lack of understanding regarding privacy and security Project timeline was too short Project participation as a critical factor Considering internal company dynamics Data integration requires joint efforts

information management systems (IMS) in terms of fish health data are based on a combination of tools. These tools include commercial production software, spreadsheets and other tools storing fish health data. Substantial improvements in data management and analysis over the years were reported during the interviews, leading to improved support for decision making. Most informants felt that their company's IMS meets their information needs for fish health management: "I really do not see any area that we need that the tool does not comply with" (interview 03). However, several informants reported that there was room for improvement, such as a lack of data analysis tools in existing IMS. Some reported that they would benefit from a more user-friendly access to and better visualization of company production and health data, with fewer manual inputs and more integration. Several informants felt that more consolidation of existing data is needed to better support decision making: "this industry has way too much data, but very little information" (interview 16).

3.1.2. Crowded market for data services

A few organizations (private companies and the industry association) currently provide data consolidation services as well as benchmarking tools to producers, leading to a crowded market for data services available to the industry. In this context, several informants saw PIISAC as a service in competition with existing data service providers. Some informants highlighted that the results from PIISAC studies were similar to those obtained from other data service providers. Those providers were generally deemed as delivering good value and concrete outputs in terms of information to assist with fish health management, complementing information available in-house via the company's IMS. Some of these data service providers have been working with the industry for a long time, gaining substantial experience with the industry's data and expectations. In this context, PIISAC was seen as a new player providing competing services, without the advantage of local contextual experience. Talking about an existing data service provider, one informant said that it "is like a competitor for [PIISAC], has more years of experience and knows the work better and does similar things" (interview 02).

3.1.3. Role of the antitrust laws

Antitrust regulation was repeatedly highlighted as one of the major obstacles to the integration of fish health data within the industry. Restrictions on the amount and variety of data that can be shared by producers affect existing data service providers and most projects involving some form of data exchange. One of the options to maintain compliance with these regulations is to delay the publication of consolidated reports containing results related to production. This strategy, used by some providers, reduces the value of the information for ongoing decision making. The informants raised the lack of clarity of antitrust regulations and existing jurisprudence regarding the exchange of data related to fish health as an important issue. Informants reported receiving competing advice from lawyers, who recommend a more conservative attitude, and from other services or individuals, who advise that fish health data does not fall under antitrust restrictions. This lack of clarity around legal boundaries and interpretation of the law, as well as past accusations of collusion against some industry players, created a climate of fear around the subject of exchanging fish health data. Informants evoked the risk of being accused of collusion as an important reason for the producers' reluctance to participate in PIISAC in particular, and for the cautious attitude of the industry to publicly discuss practices in general.

3.1.4. Generic climate of distrust

One informant said about Chileans that "it is in our nature not to trust" (interview 01). Many informants described a general atmosphere of distrust within the Chilean industry, affecting all stakeholders for different reasons: between companies, with government services and with third parties. Third parties, academic bodies, government and

NGOs were sometimes perceived as potential adversaries due to past use of industry data resulting in negative consequences for producers. Such past events seem to have anchored the climate of distrust faced by PIISAC and other related projects: “one never knows how this will be used against you” (interview 01). One informant said that in the wake of these events, “today the attitude towards information [sharing] is not so open” (interview 14) than it was previously. Several informants reported that obtaining the participation of companies in research projects was notoriously difficult in Chile. The issue of distrust regarding sharing fish health data with a third party appeared to have been a critical factor for deciding whether to participate in PIISAC.

3.1.5. Concerns related to data privacy

The element of distrust described above appeared particularly focussed on the issue of data privacy. Although this issue has affected many industry-level projects in the past, most informants reported that the industry is increasingly favourable to data integration initiatives. Despite these changes, most informants reported a cautious attitude of companies where their production and health data are concerned. Perceived or potential issues around data confidentiality and privacy were reported as one of the major obstacles to data exchange across the industry. Distrust that strict confidentiality would be adequately maintained during the project was a key reason for companies not participating in PIISAC. For example, one informant mentioned that they had a strong interest in the project but preferred to observe its implementation from the outside for this reason. Another one expressed that they knew from the start that the project could not succeed for the very reason that companies would need to share data. A few informants felt that automatically copying the fish production and health data from source was less acceptable than manually sharing a subset of these data. However, attitudes toward data sharing were varied among the informants. One informant challenged the need for fish production and health data to be kept confidential and that these data are “the heart of the company” (interview 10). Another contrasted the claim of companies to have “nothing to hide” (interview 15) with the strong reluctance to share information. In their opinion, some companies “believe [they] have the latest technology, the latest secrets, but that is not so” (interview 13).

3.1.6. Collaboration within the industry is difficult

Informants expressed diverse views on attitudes to collaboration within the industry. Most agreed that it was a complex issue, with views ranging from the Chilean industry “is one of the most collaborative in the world in the area of aquaculture” (interview 09) to “the Chilean industry isn’t as open [towards collaboration] as one would think” (interview 01). In general, it appeared that the companies were historically not very transparent about their data and practices and reluctant to collaborate. These attitudes were reported to have changed over time, in particular since the infectious salmon anaemia crisis starting in 2007. This crisis triggered an evolution in practices, as companies realized the need for more collective actions. Although data privacy remains critical, as discussed above, the industry became more open to sharing information. The decreasing number of companies operating in the country (from 21 in 2018 to 18 in 2019) was suggested as a facilitating factor in the collaborative process. Another factor is the increasing recognition of the value of research and development activities. While investing in such activities may not be accessible individually for small companies, it may be more cost-effective collectively. Last, companies are increasingly recognizing that they are “carrying out [their] activities on a shared national good” (interview 08) and that the long-term sustainability of these activities depend on industry-wide collaboration.

The extent and impact of these changes to date differed according to different informants. Issues that may remain relevant to date include a general lack of communication and dialogue within the industry and a reluctance to change and innovate. Several informants considered that there is still insufficient collaboration within the industry and that this negatively affects areas such as disease preparedness and early warning.

Some mentioned that participation in collaborative projects is a critical issue in Chile but that this issue is not openly discussed within the industry. Others highlighted that there are some recent examples of successful collaborative initiatives in Chile as well as informal collaboration, which demonstrate the improvements achieved over the past few years. The attitudes reported by the informants were very diverse. While some companies appear more likely to choose to work independently only, others are very supportive of collaborative initiatives, with intermediary attitudes being also widespread.

3.1.7. Importance of competitive advantages

The reluctance towards collaborative initiatives discussed in the previous section also appeared to relate to the competitiveness within the industry: “there is an issue of competitiveness, of how we do things versus how the rest does them” (interview 15). One informant noted that advancing together as an industry may result in levelling up the competitive advantages of some of the participating companies. The gains from a collaborative initiative benefit the industry as a whole and participating companies individually, but these individual benefits may vary by company. In such situations, the cost-benefit analysis of participating in a collaborative initiative is not necessarily positive. Such balance depends on the respective weight given to individual company interests versus interests for the industry as a whole. In this regard, a condition for participation is that the project’s objectives are “in alignment with [the company’s] interests” (interview 04). A few informants thought that even in the absence of direct individual company benefits, companies should show the example by participating. In their opinion, all companies would ultimately benefit, and a long-term vision should prevail.

Some informants strongly associated the concept of analysing integrated data with the loss of the specificity of individual farm sites, in terms of local management, personnel and environmental conditions. The availability of tailored information was highly valued, as it allowed “taking into account [their] own realities at each sea site and its environment” (interview 12) in the decision-making process. In a few cases, this attitude was linked to the company being different from the rest of the industry, in terms of practices, the geographical distribution of sites or the choice of salmonid species, for instance. The benefits of data integration appeared smaller for these companies due to these distinguishing characteristics, influencing their decision to participate.

Informants largely agreed that most initiatives in the Chilean industry, including PIISAC, face similar problems when it comes to securing participation. The absence of an industry body representing the entire industry was cited as an issue for such industry-wide initiatives. As there is currently no pathway for collective decision making, transversal projects must secure participation individually, a difficult process as discussed in these two sections. Consequently, some informants reported that they felt their companies were disconnected from the rest of the industry.

3.1.8. Complex industry-government relationship

Many informants reported an underlying distrust in industry-government relationships. Some government measures were deemed as not science-based, and others as harmful to businesses. In addition, informants argued that government initiatives tend to lag behind situations of concern, and not address current problems in a timely manner. As such, industry-led initiatives were judged more useful and appropriate than government ones. Several informants considered that the government did not consult the producers enough when developing policy or that government policies were too repressive. As a result, the current relationship between government and industry appeared tense and complex. This climate of suspicion and distrust was deemed to affect participation in government-supported initiatives such as the program to which PIISAC belonged. This may have created distrust in the project, due to the concern that government may obtain access to the data provided by participating companies. Even if confidentiality were

maintained, one informant expressed suspicions that the project outputs may be used to develop additional regulations that would burden the industry.

By contrast, several informants reported that the industry-government relationship had vastly improved over time. As mentioned previously regarding within-industry dynamics, the infectious salmon anaemia crisis had fostered improvements in the government-industry working relationship as well. While past government initiatives had not been highly valued by industry, the recent industry-government partnership, including PIISAC, had shown significant improvement in that area. Voluntary government initiatives using incentives were deemed more successful than compulsory programs associated with sanctions. In this context, several possible effects of the industry-government relationship on participation in PIISAC were reported by informants. Some reported that the participation of government services can make initiatives more robust and give them additional credit, especially in the public opinion, while others thought it was an obstacle. Two informants reported that they “felt forced to participate at first” (interview 19) due to the involvement of the government. Another informant considered that Chilean companies tend to participate only when obliged to, contrasting it to the attitude in some other countries where companies “act on [their] own responsibility” (interview 18).

3.1.9. Competing priorities in 2018

Several informants from companies which did not participate in PIISAC reported that this was mainly due to competing priorities at the time. At the individual level, company employees are solicited by many internal and external demands, such as internal IMS enhancements and projects such as PIISAC, which they prioritize for action. At the company level, several merging and selling operations were under negotiation or implementation in 2018. These activities were cited by several informants as preventing participation in PIISAC, either due to unclear strategies at the time or to the ongoing transfers of decision-making power. Last, at the industry level, adjustments in practices and management required to meet regulatory changes around the time of PIISAC implementation were also mentioned as a competing priority.

The topics covered in this theme summarize the obstacles faced by the project that were related to the context and environment of its implementation. The second theme gathers issues reported by informants related to the PIISAC project itself that affected its long-term sustainability.

3.2. Issues linked to the project implementation

Most informants reported supporting the project at the beginning of its implementation but felt that their interest faded over time. Reasons for initial support included the potential of PIISAC to provide additional benefits over existing tools, hope that the industry coverage would be higher than that of existing services, interest in gaining new knowledge regarding the management of *P. salmonis* and sea lice on farms, assurances provided about data security aspects as well as an approach that appeared different from previous initiatives. In this section, we analysed the possible issues which may have led to this drop in the initial level of support.

3.2.1. Results did not meet expectations

Although informants reported high initial expectations from PIISAC, most considered that the epidemiological risk factor studies based on the PIISAC data (hereafter referred to as ‘studies’) obtained by the end of 2018 had not met those expectations. Two different reasons were suggested by informants: some thought that there were inconsistencies between the studies’ results and existing knowledge within their companies or the industry in general. On the other hand, the majority of informants thought that the results were not novel and that they did not contribute additional information to what was already known in the industry: “the answers that we got were obvious answers. We already

knew that” (interview 11). Most informants reported frustration with the results, as they felt that these results did not provide applicable solutions to the industry for the main issue at hand (*P. salmonis*). However, a few informants considered that the studies’ results were interesting as they provided evidence to support existing informal knowledge. This disappointment with the studies was reported as the key reason for companies discontinuing their support to PIISAC. The staff from participating companies were not convinced that this tool would help them improve their own fish health management and therefore that it justified further support and investment. One informant summarized their concern as “there was no benefit in the future use of the platform” (interview 17). Several informants said that the participating companies did not perceive additional benefits from using PIISAC compared with existing data service providers, resulting in drop-out at the end of 2018.

3.2.2. Quality of the data and analyses

Many informants expressed doubts regarding the quality and accuracy of the study results because they felt that the data verification and cleaning process had not been adequate. Consequently, they did not trust the validity of the input data used in the studies. “Without fixing these data, we aren’t going anywhere” (interview 04). Some informants were confident that there was potential in PIISAC to provide more robust results in a following phase, given that the first studies were conducted over a short time frame. The lack of data standardisation existing across the industry was cited as a key issue affecting the data verification and cleaning process. This may have affected the nomenclature of veterinary products such as vaccines for example. Some informants considered that the complexity of the data and the diversity in data recording practices had not been sufficiently taken into account in the studies. In addition, some informants did not fully understand or agree with the analytical methodology used in PIISAC’s studies. Last, some informants reported that including economic aspects in the analyses would have substantially increased the usefulness of the results for decision making.

3.2.3. Cost of ongoing support for PIISAC

A couple of informants reported that they did not “consider [costs] as a barrier” (interview 11) or that “maybe this cost was worth it” (interview 19). However, several others mentioned the cost of participation in PIISAC from 2019 onwards as a reason for the drop-off of participating companies. They considered that the cost-benefit analysis was not in favour of ongoing support due to the low perceived benefits once participation became associated with a fee. One informant felt that scientists in general tend to present research outputs in terms of their scientific value, with a lesser emphasis on presenting the expected “impact translated into numbers” showing the economic benefits (interview 13).

3.2.4. PIISAC as a foreign initiative

Several informants reported that language and geographic distance had acted as barriers during the implementation of PIISAC. They felt that the use of translation services was insufficient to develop effective communication and understanding by all stakeholders involved. The concerns related to sharing data with a third party (see above) were amplified by the facts that this third party was not a Chilean company and that the data would be stored outside of Chile. This was deemed by informants to have raised too much uncertainty regarding data security and confidentiality. One informant felt that such a project “has to have presence, office, servers here, based in Chile” (interview 16).

The project team being based abroad, some informants reported that there were insufficient in-person interactions to allow for solid trust building and obtaining full industry support. One informant said that “there was lacking a little promotion and initiative from their side to promote the platform more” (interview 14). Some informants raised the importance of a previous working relationship with the team proposing such an initiative as well as a solid track record of implementing such initiatives.

3.2.5. Insufficient knowledge of the industry

Some informants considered that the project team did not spend enough time understanding the industry's dynamics and analysing the needs of the companies before developing PIISAC. One informant felt that this was a common feature of government-initiated efforts, which should be "a little more inclusive" (interview 07) instead. Another informant reported that the platform collated lots of data but "lack[ed] direction in getting the best value out of it" (interview 15). They suggested that a more active participation of companies in the analyses would have provided such direction.

While informants reported that the project team had expertise in terms of epidemiology and statistical analysis, several informants considered that the project team lacked local expertise in terms of practices and products to assist with the data verification and cleaning process as well as the interpretation of results. Close interaction between the producers and the data service providers was reported as key to support and improve the data integration process. For instance, the company's technicians and veterinarians can provide additional key information that is not recorded in the fish health and production database and can substantially affect the interpretation of these records.

3.2.6. Lack of understanding regarding privacy and security

As detailed under the first theme, data security and confidentiality were a key concern among the companies. It appeared that some of the informants did not trust that the data transfer and analysis process used in PIISAC would meet these objectives. A few informants also mentioned a lack of understanding around the proposed security and privacy-related aspects of the project. One informant was concerned about the uncertainty around the future use of the datasets. Another informant said that the industry needed more clarity on what would happen to PIISAC after the project, its future objectives and also what would potentially be made public in time. Overall, these elements may have amplified the initial distrust around sharing data with a third party, as reported by this informant: "when you don't understand the mechanism very well [...], there will always be a certain amount of doubt" (interview 05).

3.2.7. Project timeline was too short

An informant referred to a previous large collaborative initiative on sea lice in Norway, which lasted more than six years, to highlight that such initiatives require long-term efforts. Many informants mentioned the project timeline as one of the key challenges for PIISAC. They reported that data integration, standardization, validation and epidemiological analysis were time-consuming tasks, and that, consequently, the 12-month funding of PIISAC was too short. One informant said that PIISAC was still at an early stage by December 2018, "it was too new" (interview 06). For this reason, the potential of the platform to provide industry benefits had not been realized yet by the time that financial commitment was sought from the companies: "given the time it took for the companies to start participating, we were not able to obtain all of the information and to analyse all of the information" (interview 13). Some informants regretted that the project had not delivered a fully functional online user interface by the end of 2018. One informant said that this interface could have helped people to demonstrate the usefulness of PIISAC within their own companies to stimulate ongoing participation.

Given more time, several informants thought that PIISAC would have been able to integrate a broader range of data, produce more and better analytical results, as well as become integrated as a new tool in the companies' existing processes. In addition, one informant mentioned that the participating companies "did not know how to organize themselves in establishing guidance for a platform like this" (interview 17). Several informants suggested that the government should have provided support for a second phase to enable these issues to be resolved. They considered that once PIISAC would have had demonstrated the benefits that it can provide, the industry would have been much more likely to endorse the ongoing costs.

3.2.8. Project participation as a critical factor

The recruitment of companies was also a time-consuming activity. Some of the informants reported that their companies had not been able to join, as by the time they had dealt with other priorities or obtained high-level authorizations, the project was closing: "we were left at the stage of trying to join and transfer our information" (interview 15). One informant considered that the participation in PIISAC increased at too slow a pace, generating doubts for the remaining companies and causing the initiative to significantly lose momentum. Informants felt that participation had influenced the success of the platform in two ways. First, the quality, robustness and validity of the results were influenced by the number of companies which data were included. A higher level of participation would have allowed the results to better represent the industry reality. Second, informants felt that a high level of participation would have decreased the perceived risks related to confidentiality of the shared information.

Overall, the level of participation in PIISAC was mentioned by many informants as a key factor. Several informants initially expected that this level would be rather high, given that it was free for the duration of the project: "it was another opportunity of integrating data in the industry where there was more participation than what [existing data service providers] had" (interview 02). An initiative which would gather the entire industry would have much higher chances of being sustainable according to the informants. Such an initiative would have a distinct advantage over existing data service providers and other initiatives, which lack complete coverage: "these tools are the correct ones, or they contribute a lot. What happens is that the representativity is not what you want" (interview 12).

3.2.9. Considering internal company dynamics

Several informants mentioned that while veterinarians and fish health managers are generally aware of the value of industry-wide information to support decision making, general managers give more weight to data privacy concerns and economic benefits of participation than technical employees. While technical staff can champion the project within their own team and contribute to the decision outcome, some informants believed that the efforts of the project team to convince the decision-makers directly had not been sufficient: "it needed a little more convincing" (interview 10). Last, some informants reported that a company's decision to participate might rely on only one person who would be strongly supporting or rejecting participation.

3.2.10. Data integration requires joint efforts

Finally, several informants considered that the success of data integration initiatives requires joint efforts from all parties, and that participation does not only rely on providing data but also contributing substantial staff time to the initiative. One informant felt that this time (in workshops, for instance) would have helped to design the studies and outputs that the companies really wanted. Another informant said that many participating companies "didn't take the project seriously" (interview 13). Others reported some unrealistic expectations on the industry side, "they believe that science solves problems immediately, but these are very different timelines" (interview 10). The expectations of quick results were deemed as damaging for the platform, as they did not allow for the research to occur and created impatience. Last, a few informants thought that the project lacked a strong in-country leader (or leaders) to drive the implementation of the platform: "you have to have someone behind it to make things happen" (interview 20). It was suggested that the appointment of a spokesperson by the industry would have facilitated the communication between the stakeholders, including platform implementer, industry and others such as government, and coordinate their involvement.

4. Discussion

This study analysed the possible reasons why an industry-based data

integration platform to support epidemiological research in farmed salmonids in Chile was not sustainable. The interviews, conducted after the end of the project, provided valuable insights into the perspectives and decision-making processes of key stakeholders. Informants generally saw data integration as a worthwhile activity, expressed the need for more data analysis to support decision making, and considered that working collectively as an industry would make the production more sustainable in time. However, they also highlighted many issues and concerns, which were categorized under two broad themes during the analysis. The first theme gathered aspects related to the industry context, while the second dealt with issues identified by the informants in relation to the project itself. It is important that the lessons learned from this study can be considered when designing future data integration initiatives, to increase the likelihood of long-term adoption and support of these initiatives by stakeholders.

Although industry collaboration in Chile started as early as the late 1980s with the creation of SalmonChile, none of the initiatives to date has gathered all the producers at once. The industry association gathered 11 producers as of 2020 (SalmonChile 2020), suggesting the difficulty to foster industry-wide collaboration in Chile. Thus, the platform appeared to have been implemented in a difficult environment, which may have explained the moderate uptake of the platform during the first year (50% of the companies). Many of the barriers to data integration identified in our study were similar to those previously identified in the public health sector (van Panhuis et al. 2014), suggesting that these barriers are not specific to the aquaculture sector. Commercial interests, privacy concerns and general lack of trust between stakeholders and towards third parties are critical challenges to overcome for collaborative efforts. Unfair competition and misuse or monetization of data are recognized as potential risks from data integration initiatives, for instance, in agriculture (Maru et al. 2018). In addition, the complexity of data governance in commercial settings was identified as one of the major challenges for big data in agriculture (Weersink et al. 2018).

While informants generally reported that the platform was valuable for the industry, many felt that it needed further work to be considered as a tool with long-term potential. The concerns of the informants in relation to the results from PIISAC studies were diverse. Some valued the results as they provided evidence to confirm or dispute existing knowledge, but many felt that the results did not meet their expectations. This is critical, as new initiatives such as PIISAC need to compete for attention and resources with existing data service providers. In addition to the longer-term research outputs, PIISAC also intended to provide companies with user-friendly access to and visualization of their own data, in near-real time, via an online interface. Although existing information management systems provide some analytical capacity to support everyday decision-making, informants expressed the need for improved use of data for health management on a routine basis within companies. Further development of the interface would have likely been beneficial, as it would have provided more immediate benefits in comparison with the perhaps less tangible benefits of larger-scale epidemiological studies for company staff concerned by everyday challenges. The present study highlights the opportunity for targeted solutions which would complement existing information management systems in processing data into information. In summary, most of the informants in this study were not convinced that the expected benefits justified the costs involved by participation by the end of the first year. This view is likely to have been important in the decision of participating companies not to continue their support to PIISAC in 2019.

Many of the findings presented in this study demonstrated a gap between the way in which the platform was designed to address known challenges and stakeholder concerns and informants' perceptions of these concerns. For instance, all communication materials were translated in Spanish, while a simultaneous translation service was used during workshops. Despite these efforts, participants reported that language was a barrier in the project. Other areas where a mismatch between design principles and participant perceptions was noted include

respect of the antitrust laws and data security, access and confidentiality. We were not able to determine whether the measures to address these issues in PIISAC were inadequate in their design or implementation, whether the measures taken were not effectively communicated, or whether the project duration was not sufficient to build the required trust. This is a key lesson for future initiatives, as efforts towards project design alone are not sufficient, and communication efforts and the development of trust are equally important to counterbalance existing perceptions and cultural values.

The constraints and limitations of the 'project' framework and implementation schedule have been long recognized in the domain of international development (Chambers 1995; Craig and Porter 1997). A key lesson from international development which can be extended to the present commercial settings is the need to create space for the ideas of stakeholders to allow for sustainable participation. There is a large body of literature relating to best practices for stakeholder engagement in fields other than international development, for instance in relation to animal health (Allepuz et al. 2017) and environmental management (Reed 2008). In our study, stakeholder engagement appeared to have been the most important factor influencing the outcome of the initiative. Challenges associated with participation in PIISAC were similar to challenges identified for stakeholder participation in an evaluation of strategies for improving the management of fisheries in the US (Goethel et al. 2019). Some of the challenges identified by these authors are establishing and maintaining trust, unfamiliarity with analytical approaches and translation of results to workable solutions. Our study emphasizes the need for in-country presence in such projects to help overcome these challenges and lead the participant recruitment process. Such a key, labour-intensive role is critical for maintaining continuity in participation and should be a core component of the project plan.

Research in the diffusion process of interactive media in the late 1980s proposed the concept of "critical mass" (Markus 1987). The adoption of an innovation related to communication is slow until the number of users exceeds this critical mass, after which the adoption process becomes self-sustaining. This property was used by Markus (1987) to explain the increased vulnerability of new systems in the early stages of implementation. In the case of PIISAC, this self-sustaining process can be linked to two features. First, the benefits of collaboration were perceived as more likely to be realized once broad participation in the initiative was secured. Second, the perceived risks, for instance related to data privacy, were perceived as inversely correlated to the number of participants. For these reasons, the broad adoption of such an initiative starts with the early participation of some companies, called "innovators" in diffusion theory (Rogers 2003), who are less risk-averse than their peers. Roger's diffusion theory has been widely used in many disciplines (Haider and Kreps 2004), for instance in the medical research literature to help understand the adoption of telehealth (Helitzer et al. 2003; Spaulding et al. 2005; Walker and Whetton 2002; Brooks et al. 2012). The theory identifies four main areas which interact in influencing the adoption of an innovation (Rogers 2003): the social system in which it is deployed, the attributes of the innovation itself, time and communication. In our study, the industry environment was explored in the first theme, while the attributes of the project were explored in the second theme. The effects of time and communication were closely linked to the project implementation itself and were therefore grouped with the project attributes when structuring the results. Within each theme, identifying the sub-themes from the data itself allowed us to better represent the similarities and differences between the codes identified in our dataset. The specific elements discussed by Rogers (2003) regarding the social system, the stages of the diffusion process and communication networks were not well adapted to analyse and interpret the PIISAC data, given that the participants were companies rather than individuals. This difference substantially affected the adoption process and the way decisions were made. However, the issues linked to the project implementation (see above) appear to closely reflect the attributes required for successful diffusion of innovations, i.e.,

relative advantage, compatibility, complexity, trialability and observability, as well as the critical mass factor. In addition, the stages of the diffusion process provided a useful framework for structuring the interviews.

Lessons learned from this study can improve the design of future data integration initiatives in the field of fish production as well as other commercial animal production where digital information management systems are used (i.e., poultry, pigs and dairy). As this study was conducted in one particular country and industry, it is expected that the importance of these challenges may vary in other settings. While collaborative initiatives appear to be welcomed by the industry, high-quality outputs should be delivered rapidly to maintain interest, such as practical solutions that may be directly used to improve fish health on farms. Substantial in-country presence is recommended to build and maintain trust with the stakeholders. Clarity regarding data management, privacy and ownership is key to establish this trust. The time to obtain formal agreement and set up the data integration process should not be under-estimated. To this effect, key executive staff in charge of decision-making must be targeted in addition to technical, veterinary and research staff.

For future initiatives, context-specific challenges related to the environment and the stakeholders may be identified by conducting targeted consultations during the design stage of the partnership. These consultations allow the design of a suitable implementation plan to better overcome barriers and address the needs of the participants. Such consultations are critical to ensure the long-term participation of the stakeholders and the sustainability of the initiative, as shown by the results of this study.

CRedit authorship contribution statement

Anne Meyer: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing. **Melanie Bannister-Tyrrell:** Conceptualization, Methodology, Writing - review & editing, Supervision. **Catriona Mackenzie:** Conceptualization, Methodology, Writing - review & editing, Funding acquisition. **Arjan Stegeman:** Conceptualization, Writing - review & editing, Supervision. **Angus Cameron:** Conceptualization, Writing - review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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