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Participatory indicators of sustainability for the salmon industry: The case of Chile

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ABSTRACT

In this paper a methodological approach is proposed and applied to undertake a participatory process to obtain sustainable development indicators for the salmon sector in Chile including a common vision of sustainability for this industry. The selected indicators are a mix of bottom-up and top-down approaches, which capture the specific needs and perceptions of the different stakeholders related to salmon farming while allowing a high degree of international comparability. A detailed step by step description of the methodology allows understanding how to obtain acceptable social, economic and environmental indicators, a result that can be replicated in other natural resource based productive sectors that are common in developing contexts.

1. Introduction

In the last 15 years salmon farming in Chile has experienced explosive growth, becoming the fourth most important export in the country and establishing Chile as the second most important salmon exporter worldwide [5]. However, this industry faces complex sectoral challenges, as is also the case for many similar resource intensive sectors such as mining or forestry. Its development has been particularly sensitive to the perceptions of different stakeholders in terms of the sustainability at the national, regional and local levels. The underlying issue is that salmon farming represents a use of marine resources distinct from traditional activities, that puts pressure on urban services and infrastructure, brings in new people and culture, and many times competes for labor or with the development of other economic activities such as tourism. The acceptability of this industry is thus constantly questioned.

The complexity of identifying and assessing the net benefits associated with the development of salmon farming and of taking full account of the differing and competing interests, suggests the need for developing indicators [14, 22]. Considering that each stakeholder cares differently for specific dimensions, a set of indicators is required, as opposed to a single index that provides a one dimensional metric [3].[1]

In this context, a methodological approach is proposed and applied to undertake a participatory process to obtain sustainable development indicators for the salmon sector in Chile. A first important step for this is to develop a common vision of the competing groups with respect to the sustainability of salmon farming. Following a rigorous approach, a short list of indicators is then constructed that describes the performance of the industry in dimensions critical for relevant stakeholders, including local communities, academics and the industry. A bottom-up process was complemented by a top-down approach to develop this short list [30]. The practical process followed is described in detail and is a contribution of this paper.

The next section present the conceptual framework and specific methodology followed in this study. Section 3 describes the selection of stakeholders and how perceptions were elicited. Sections 4 and 5 describe the selection of indicators based on different criteria. Section 6 addresses how the indicators support a sustainability vision. Finally, Section 7 presents the main conclusions of the study.

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[1] Stiglitz el al. ([25], p. 12) state that "The issue of aggregation across dimensions (that is to say, how we add up, for example, a measure of health with a measure of consumption of conventional goods), while important, is subordinate to the establishment of a broad statistical system that captures as many of the relevant dimensions as possible."

2. Conceptual framework and methodology applied

2.1. Conceptual framework

The association between sustainability and indicators emerged with force in the 1990s [19]. As Rey-Valette et al. [22] point out; indicators were first designed per sustainable development pillar: economic, social, environmental and institutional. Initially, indicators were applied mostly in the economic area [26,31]. Subsequently, environmental indicators emerged that describe a system in terms of its pressure or state [20,10] and through response indicators [9]. Finally, sustainable development indicators (SDI) were introduced and have been applied in several countries [27].

In terms of process, initially, experts were called in to define the required indicators that should be global in scope, transferable, generic and scientifically valid [7]. However, such indicators generally lacked legitimacy and did not respond to the specific circumstances of an affected locality. More recent literature points to the importance of stakeholder participation in developing indicators, ensuring the quality of the selected indicators and greater effectiveness in monitoring sustainable development [24,21,12]. Indicators should allow a community to understand its current state, identify its goals and determine the progress it has made toward them. A participatory process promotes a sense of ownership of the indicators.

Chamaret et al. [7] indicate that "indicators are only relevant and useful if they fit the user's needs. A participatory (bottom-up) approach answers many of the needs for information and management tools of the actors… and also can enhance the legitimacy of such indicators." They propose that the challenges of legitimacy in the eyes of stakeholders and the major differences between the impacts in different localities, require that indicators from international frameworks (top-down) be complemented by indicators that more directly answer to the issues of a specific localities and its stakeholders. Additionally, Stiglitz el al. ([25], p. 12), indicate that "such a system must, of necessity, be plural (as opposed to a unique index) – because no single measure can summarize something as complex as the well-being of the members of society, our system of measurement must encompass a range of different measures."

Finally, Nevens et al. [18] and Meppem and Gill [16] indicate that to consider the long term impacts, indicators must be part of a common vision of the competing groups with respect to the sustainability of the productive activity. This vision incorporates the principal values of the different interest groups and should motivate and mobilize them, as well as guide the construction of future measurements.

There are few applications of participatory indicators for salmon farming. Vandermeulen [28] proposes indicators using a top-down approach. Boyd and Charles [4] analyze for Canada the impact of fisheries on sustainable development at the community level using a top-down approach. Main stakeholders are identified, a common vision is developed and indicators of sustainability are proposed. Studies for Chile are few and emphasize only some specific aspects. [1], examine the social impacts, specifically on employment, culture and traditional ways of life. Buschmann et al. [5] and Barton and Fløysand [2] study the socio-ecological impacts of salmon farming on stakeholders and its relation to public policies and regulations in Chile. Velasquez et al. [29] present an informatic system to monitor sustainability indicators, however does not present the process required to define the indicators.[2] There is no study for Chile that presents indicators associated to the three dimensions of sustainability nor that considers a bottom-up approach complemented by a top down approach.

2.2. Methodology applied

As discussed, the construction of lists of indicators is usually based on two approaches. The first bottom-up approach captures the specific perceptions of the stakeholders. Relevant stakeholders must be actively involved. The second top-down approach draws on expert opinions and the international literature. In this paper an eclectic approach is applied that combines both, to take advantage of their respective strengths [30].

In parallel, a vision that includes the long-term principles that should guide salmon farming development was built participatively with the relevant stakeholders. The indicators are then associated to each principle and used as a measure of the achievement of the desired vision of sustainability for the salmon sector. Whereas the principles and vision should be maintained over time, the indicators will most probably evolve and change.

The specific methodology to construct the list of sustainability indicators of the salmon industry was developed in five steps, shown in the diagram below. Each step is discussed in the following chapters presenting the main issues and methodological concerns required to obtain concrete indicators acceptable for all those involved in the process Diagram 1.

3. Identification of stakeholders and survey of their perceptions[3]

The first step of the methodology consisted of identifying the groups related to salmon farming and planning the survey of their perceptions through workshops and interviews. The geographic areas of direct and indirect influence of the salmon industry were defined, and the stakeholders identified. Their main perceptions and needs were surveyed in a participatory process in a series of workshops. The approach was bottom-up to capture stakeholder concerns that would then be covered by the indicators. Through this approach the vision of sustainability (described in Section 6) was identified.

3.1. Defining the areas of influence of the salmon industry

The area of influence of the salmon industry was defined as communities where a significant percentage of the economically active population (EAP) is involved in fisheries[4] based on secondary information, such as census data and maps showing populated areas in the 10th and 11th Regions of Chile. The communities were then ranked according to the importance of commercial fisheries. Data such as the companies related to the salmon industry and the location of associated facilities were incorporated to more precisely define the areas of influence of the industry.

Finally, the communities where salmon farming is important were identified. This analysis was focused on communities such as Puerto Montt and Calbuco where main offices of salmon producers and service and product providers of the industry are located. Also, communities were identified where there is a high concentration of salmon-farming activities, as well as communities with a high concentration of companies and significant projected growth in

[2] The study by Velasquez is complementary to the one presented in this paper. Both are part of the same original study.

[3] See "El Proceso Participativo para el Levantamiento de Percepciones de la Salmonicultura" by Regina Massai and Miguel Bahamondes, in final report of the Project INNOVA Chile, "Sistema de Indicadores de Desarrollo Sustentable de la Industria del Salmón en Chile: Asegurando la Competitividad en el Largo Plazo".

[4] This includes small-scale fishing and salmon farming associated mainly with commercial activities.

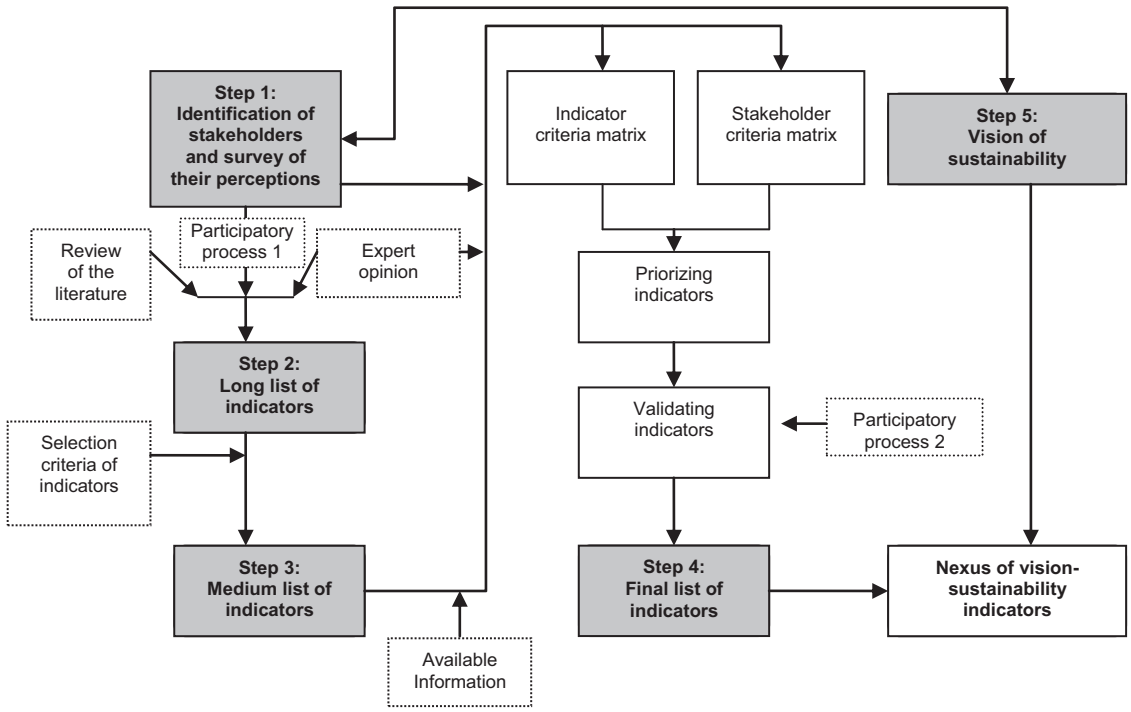

Diagram 1. Steps of the process of selecting indicators and the vision of sustainability.
Source: the authors.

Table 1
Presence of salmon farming.
Source: authors based on the CASEN survey and the study "Sistema de Indicadores de Desarrollo Sustentable de la Industria del Salmón en Chile: Asegurando la Competitividad en el Largo Plazo", Universidad de Chile [15].

	Municipality	Province	Region	Percentage of the population involved in fisheries compared to total PEA (%)
1	Guaitecas	Aysén	XI	45.7
2	Puqueldón	Chiloé	X	38.2
3	Cochamó	Llanquihue	X	37.5
4	Quellón	Chiloé	X	37.2
5	Curaco de Vélez	Chiloé	X	34.7
6	Queilén	Chiloé	X	34.5
7	Quemchi	Chiloé	X	33.5
8	Hualaihue	Palena	X	32.7
9	Cisnes	Aysén	XI	30.7
10	Calbuco	Llanquihue	X	28.6
11	Quinchao	Chiloé	X	27.5
12	Dalcahue	Chiloé	X	26.4
13	Chonchi	Chiloé	X	23.3
14	Aysén	Aysén	XI	22.7
15	Maullín	Llanquihue	X	22.0
16	Ancud	Chiloé	X	18.2
17	Chaitén	Palena	X	16.4
18	Castro	Chiloé	X	12.8
19	Puerto Montt	Llanquihue	X	10.7

the future. As a result, the 19 communities presented in Table 1 were identified.

3.2. Identification of stakeholders

Once the main areas of salmon farming had been identified, the different stakeholder groups related to this activity presented in Table 2, were consulted about the impacts of the industry. Eight sub-groups were identified and divided into three generic groups defined in the international literature:[5] community and non-governmental organizations; decision-makers and administrators; and technical experts and advisors.

3.3. The participatory process

Once the stakeholders were identified, a participatory process was developed to gather their perceptions and associate these with different areas of interest. An interview methodology was designed to obtain the perceptions of stakeholders and semi-structured interviews were conducted in the field.

An initial workshop was then held to present the systematized results of the interviews. The comments obtained were again incorporated and, a second workshop was held with stakeholders, who were presented with the systematized results for discussion and validation. Table 3 shows the list of institutions that were invited and participated in each workshop.

3.4. Systematizing perceptions

The perceptions gathered in the workshops were complemented with information from international sources and consultations with experts. As a result, thematic areas were selected that distinguish social, economic and environmental dimensions.[6] Because the interviews generated a long list of perceptions, it was necessary to systematize the results distinguishing for each dimension between general issues and specific areas. Table 4 presents the results.

[5] See [23].
[6] A fourth issue identified through this process was the role of the State in enforcing and promoting sustainable practices. For the purpose of this study, this issue is grouped in the social dimension.

Table 2
Stakeholders related to salmon farming.
Source: the authors.

Groups	Sub-groups
1. Community and nongovernmental organizations	The community: representatives of indigenous peoples and neighborhood organization from the affected zones Supplier companies and productive actors Workers from the salmon farming sector Workers from small-scale fisheries Non-governmental organizations (NGOs)
2. Decision-makers and administrators.	Public sector: national, regional and municipal government representatives Salmon farming sector companies: cultivating and processing
3. Technical experts and advisors	Academic community/technological institutes, others

Table 3
Institutions invited and participating.
Source: the authors.

Institutions	Workshop 1		Workshop 2	
	Invited institutions	Representatives that attended	Invited institutions	Representatives that attended
Community	6	3	7	4
Public sector	11	6	14	5
Salmon farming companies	7	6	8	1
Supplying companies and other productive activities	4	4	5	2
Workers from the fish-farming sector	4	2	4	0
Workers from the small-scale fishing sector	4	0	4	1
NGO's	4	3	4	0
Academic community/technological institutes and others	4	3	3	4
Total	**44**	**27**	**49**	**17**

4. Long and medium indicator lists

The second methodological task was developing a first list of indicators for the issues and areas identified in the previous section. This list is the result of both the indicators gathered in the workshops with stakeholders and a top-down selection approach using the international literature. Integrating these two approaches resulted first in a long list of indicators and then, based on diverse criteria, a medium list.

4.1. Long list of indicators

Several studies in the international literature were drawn upon first to construct the long list of indicators, notably those dealing with mining [17], FAO studies that identified sustainable development indicators for different productive sectors [11], the Global Reporting Initiative Guide, and the quality of life indicators of the UK Environmental Audit Commission. Aquaculture sector studies were also used [6,32,13] and indicators and areas common to Chilean salmon farming, ECASA[7] and "Defining Indicators for Sustainable Aquaculture Development in Europe" [8], provided valuable information.

These indicators, together with those obtained from stakeholders and experts, allowed developing a "long list" of unfiltered indicators for each substantive area. In total, this list had 414 indicators. Appendix 1 shows the indicators according to the pillars and sources of information: 121 economic; 185 social; and 108 environmental. Since indicators were derived from many and diverse sources, many were very similar, others very vague.

4.2. Evaluation and recommendations of indicators: medium list

These 414 indicators are certainly not practical for managing the sustainability of the sector. Consequently, the third methodological step was to construct a list with fewer indicators, which respected stakeholder perceptions and covered all relevant areas. For this, three selection criteria were used: that each indicator respond to an area identified by at least two stakeholders; the inclusion of all the indicators proposed in the last stakeholder workshop where the process of gathering perceptions was consolidated; and finally at least one indicator per area. These criteria allowed reducing the number of indicators from 414 to 163: 52 economic, 52 social and 59 environmental.

Based on this shorter list, the information available to construct each indicator was analyzed. To do this, studies, periodic surveys and census results were examined. It was concluded that the available information would allow constructing a significant number of economic and social indicators, but only a few of the environmental indicators.

In fact, of the 52 economic indicators, 43 could be constructed with existing data, and of the 52 social indicators, 32 could be constructed systematically. In contrast, of the 59 environmental indicators, only 17 could be constructed with existing public information, 15 would require difficult-to-obtain information from private sources, and the remaining 27 did not have the required information.

5. Final list of indicators

For adequate strategic management it is not possible to work with 163 indicators so it was necessary once again to reduce the list. Consequently, the fourth methodological step consisted of using the medium list of indicators obtained in the process described above, as well as applying prioritizing criteria, to develop a short list of indicators.

The following principles were a useful guide for this [12,20]:

- The indicators should be measurable and possible to analyze over time.

[7] For more information about the ECASA project see http://www.ecasa.org.uk.

Table 4
Issues and areas of sustainable development in the salmon farming.
Source: the authors based on participatory workshops, expert opinions and international literature.

Dimension	Issue	Areas
Social	Population	Migration
		Age structure
		New dynamics (habits) in the urban sector
		Health
	Education	Education
	Cultural identity	Abandonment of traditional social cultural practices
		Appearance/increase of social problems
	Poverty	Poverty
	Infrastructure, local mobility and transportation	Transportation and mobility
		Infrastructure/green areas
		Road deterioration
	Land use	Concessions
		Soil use
		Farmland and housing prices
		Quality of housing
	Government and social participation	Government and social participation
	Industry and community	Industry perception of local fish farming
		Relationship between companies and communities
		Conflicts with other productive sectors
	Institutional-state	Relationship between state institutions and salmon farming
		Scientific–technical development linked to salmon farming
		Management and coordination of risks
Economic environmental	Income and income distribution	Incomes level
		Income distribution
		Economic concentration and spatial segregation
	Regional contribution/economic performance	
	Contribution to GNP	
		Investment and spending
		Employment
		Productive linkages
		Properties of companies
		Changes in productive activities
		Incomes by rents/taxes
	Productivity and quality of employment	Characteristics of employment
		Unemployment
		Contribution to the development of Small and medium enterprises (SMEs)
		Labor productivity
		Training
		Quality of employment
	Administration	Environmental assessment
		Control, oversight and follow-up
		Research and development
		Territorial
	Inputs	Energy
		Feed: Demand for resources and conversion factors
		Use of chemicals and toxic materials
	Operation	Water use
		Management
		Biotechnology
		Production
	Sanity	Sanitation status
	Physical, chemical and biological impact	Biodiversity
		Water quality
		Greenhouse effect
		Waste
		Sediments

- The number of indicators should be limited.
- The indicators should be related to the objectives.

Based on these criteria, the methodology of Rice and Rochet [23], which involves eight stages[8], was used to obtain the short list of validated indicators. The first stage has already been employed in this study and presented in the previous sections, and consist of identifying user groups and their needs and a list of candidate indicators. The remaining stages are discussed below.

[8] Rice and Rochet refer to these stages as "steps" in their paper.

5.1. Assign weight to relevant selection criteria for candidate indicators

According to Rice and Rochet [23], nine selection criteria for indicators can be identified that have varying importance for different stakeholder groups. These selection criteria, presented in the following table, were applied in the analysis undertaken Table 5.

Additionally, the three main stakeholder groups with distinct interests in the fisheries sector proposed by Rice and Rochet (discussed above in Table 2) are also used. Each of these groups assigns different importance to the selection criteria of indicators, which can be of high, moderate or low importance. The importance of each criterion is then assigned according to the

Table 5
Selection criteria for indicators.
Source: the authors based on Rice and Rochet 2005.

Criteria	Description
1. Concreteness	Is the indicator evident in the physical, biological or economic realms, or is it an abstract concept? The indicator should be evaluated to determine if it can be measured using direct observations or is based on models and arbitrary scales
2. Theoretical base	Does the indicator originate from economic, social or biological theory or from empirical observations? The indicator should be evaluated to determine if it can be compared to minimal reference points with a certain theoretical base
3. Public awareness	Does the indicator respond to a high or low-level of public concern?
4. Cost	Does the indicator require familiar and low-cost measurement tools or more costly specific instruments?
5. Measurement	Can the variance and bias of the indicator be easily calculated and analyze the direction, size and consistency of these calculations?
6. Historical data	The historical availability, accessibility and quality of data is analyzed to construct the indicator
7. Sensitivity	The degree of sensitivity of the indicator to salmon farming activity is evaluated
8. Responsiveness	Does the indicator change in the short or long-term due to the implementation of measures by the salmon-farming sector
9. Specificity	The indicator should allow for analyzing the way in which changes in the environment affect its value and whether these changes are systematic or not

Table 6
Stakeholder-criteria matrix: relative weight of each criterion by stakeholder category.
Source: the authors based on [23].

Selection criteria	Technical experts and advisors	Decision-makers and administrators	Community and non-governmental organizations
Concreteness	1	40	80
Theoretical basis	60	1	1
Public awareness	1	30	100
Cost	1	60	30
Measurement	90	1	1
Historical data	70	20	20
Sensitivity	100	50	50
Responsiveness	30	100	1
Specificity	30	80	10

preferences of each interest group. For example, technical experts and advisors give more importance to indicators being sensitive and measurable, while community and non-governmental organization give importance to indicators representing public concern and being concrete.

Specific values were assigned in accordance to the order of priority of each criterion. A criterion that presented the highest priority for a group was assigned a value of 100 while the criterion with the lowest priority was assigned a value of 1. Due to lack of studies in Chile, the priorities by Rice and Rochet are used in this stage. Table 6 presents the stakeholders-criteria matrix of 9 rows with selection criteria and 3 columns with the stakeholder categories, as well as the weight for each one.

5.2. Assigning compliance values to the criteria

In this stage each indicator from the medium list is assigned a value for compliance with each selection criteria. The degree of compliance was measured according to a four-point scale: high degree of compliance (H), fair degree (F), moderate degree (M) and low degree of compliance (L).[9]

An indicators-criteria matrix was created based on the above. In practice, each indicator was assigned a value for the degree of compliance with the relevant criteria: $H=10$; $F=7$; $M=4$ and $L=1$. In assigning these values to each indicator, consideration was given to the expert opinions of the team, the international literature review, the surveys, expert consultations and analysis of the availability of information and gaps associated with each indicator. The result is a matrix of indicators-criteria that consists of 163 rows with the medium list indicators and 9 columns representing the criteria.

[9] Each criterion breaks down into several sub-criteria that are detailed in Rice and Rochet [23].

5.3. Summary of results

In sum, two matrices were obtained:

1. Stakeholder-criteria matrix (9 rows of selection criteria and 3 columns of stakeholders) that incorporates the importance that each group gives to the selection criteria.
2. Indicators-criteria matrix (163 row of indicators and 9 columns of criteria) that indicates the degree of compliance of the indicators with the selection criteria.

To rank the indicators according to the importance stakeholders assigned to the criteria, these matrices were multiplied, resulting in 163 indicators, each with a specific value, divided into three lists, one for each stakeholder group. Each list was then ordered according to priorities, with indicators of greater importance for each stakeholder group having higher values.

A usual theme of debate regarding this methodology is whether the scale used to weigh the criteria and define the degree of compliance of the indicators can influence the relative ranking among the indicators. To determine if there were problems in this case, a sensitivity analysis was developed for the values assigned to the matrices, which determined if the indicators substantially changed in the context of variations in the values of priority (0–100) and compliance ($H=10$; $F=7$; $M=4$ and $L=1$). The results show low sensitivity of the prioritizing of the indicators to these variations, which indicates they are sufficiently robust.

5.4. The total number of indicators to be used

To obtain a manageable number of indicators, approximately ten indicators per dimension were considered for each of the three groups of stakeholders, although it is not desirable to arbitrarily limit the number to exactly ten. In fact, in some cases, there was a smaller set of

Table 7
Final list of social indicators.
Source: the authors.

Area	Indicator
Poverty	1. Poverty rate in salmon-farming communities
	2. Homes with incomes below the minimum wage
Appearance/increase of social problems	3. Percentage of persons arrested in salmon-farming communities
	4. Reported crimes in salmon-farming communities
Education	5. Level of schooling in salmon-farming communities
	6. Percentage of high school graduates in salmon-farming communities
	7. School enrollment rate
Soil use	8. Surface area seeded per type of crop in salmon-farming communities
Housing	9. Quality of housing in salmon-farming communities
	10. Percentage of population that rents housing in salmon-farming communities
Abandonment of traditional social cultural practices	11. Number and type of electrical appliances per household in salmon-farming communities
	12. Permanent and seasonal employment per economic sector
Migration	13. Migration in salmon-farming communities
	14. Population growth rates in salmon-farming communities
Indirect development of infrastructure	15. Authorized constructions in salmon-farming communities

Table 8
Final list of economic indicators.
Source: the authors.

Area	Indicator
Quality of employment	1. Workers with permanent employment in the salmon-farming sector
	2. Work-related injuries in the salmon-farming sector
	3. Complaints of anti-union practices in salmon farming
	4. Occupational illness in the salmon-farming sector
Income	5. Income of households that declare salmon farming as the main income source
	6. Income of main occupation in salmon farming
	7. Income of the main occupation in salmon farming by level of education
	8. Average salmon industry salaries compared to average salaries nationally
	9. Salary levels in salmon-farming area compared to the national average
Employment	10. Direct employment offered by the salmon industry in salmon-farming communities
	11. Employment by type of qualification
Employment characteristics	12. Participation of women in the salmon industry labor force
	13. Employment of women per economic activity
Tax revenues	14. Percentage of taxes paid by the salmon industry that remain in the region
Contribution to GNP	15. Real GNP of the salmon sector
	16. Contribution of the salmon sector to GNP
Unemployment	17. Rate of layoffs in the salmon industry
Training	18. Workers in the salmon-farming sector that have received training
Investment and expenditure	19. Sectoral investment as a percentage of the sectoral GNP

indicators that clearly had greater value for a given dimension for a stakeholder group, and only these were chosen, allowing us to reduce the number of indicators. In other cases, a slightly larger number of indicators were identified and all were included.[10]

5.5. Validation of the final list

The last stage of the selection of the final list of indicators consisted of consultations in the field with the stakeholders who had participated in the workshops, with the objective of validating the selected indicators. In general the interview subjects were in agreement with the selected indicators. Their recommendations for changes were incorporated to develop a final validated list.

5.6. Final selection of indicators

As a result of this process, 53 sustainable development indicators were selected, 15 of them social, 19 economic and 19 environmental, and presented in Tables 7, 8 and 9.

[10] With no overlap among the groups, 90 indicators would be obtained, 30 for each stakeholder group.

6. Vision of sustainability

The final methodological step is to develop a vision of sustainability that can be related to the indicators. This vision, needed to effectively manage salmon farming, was developed during the participatory process with stakeholders discussed above. The result is ten key principles required for the sustainability of the sector presented in the first column of Table 10.

Each principle of this vision can be valued quantitatively to a greater or lesser degree through one or more of the short list indicators as can be observed in the second column of the table.

The first principle, that salmon production be compatible with the conservation of biodiversity, can be measured through seven indicators of environmental character. In particular, sedimentation, greenhouse gas emissions and anaerobic conditions resulting from salmon farming, as well as the impact on biodiversity resulting from escaped salmon.

The second principle, that the natural balance of the areas where the industry operates is not put at risk, can be monitored with six environmental indicators (chemical products, feed and energy) and their relationship to total production, and also an indicator to measure freshwater use.

Table 9
Final list of environmental indicators.
Source: the authors.

Area	Indicator
Operations	1. Total produced per year (in tons) 2. Number of farming centers in operation per year 3. Salmon produced per year in lakes (in tons) 4. Liters of freshwater used (per processed ton)
Administration	5. Tons harvested per licensed hectare per year 6. Percentage of surface under cultivation with a maximum production limit defined by load capacity 7. Percentage of non-compliance per visit by the National Fisheries Service 8. Expenditures for enforcement per harvested ton 9. Number of SCIELO[a] publications by Chilean institutions on salmon-farming environmental themes per 100,000 t harvested per year
Physical, chemical and biological impacts	10. Percentage of farming centers per year that have received citations to reduce production due to repeated anaerobic conditions 11. Number of escaped fish per year 12. Number of centers in protected areas per region 13. Greenhouse gases emitted per year (in tons)
Health/sanitation	14. Percentage of farming centers with cases of high risk diseases per year
Inputs	15. Kilos of antibiotics used per ton of product per year 16. Kilos of chemical products used per ton of product per year 17. Dry weight of feed used per dry weight of salmon produced 18. Phosphorous discharged in lakes per year (in tons) 19. Kilowatt hour consumed per ton harvested per year

[a] SCIELO is an electronic library of scientific publications covering all areas of knowledge.

Table 10
Sustainability principles and indicators.
Source: the authors.

Principles	**Indicators**
1. It is compatible with the conservation of biodiversity	Environmental indicators 1, 2, 3, 10, 11, 12 and 13
2. The natural balance of the areas where the industry operates is not put at risk through the rational use of resources and responsible waste disposal	Environmental indicators 4, 15, 16, 17, 18 and 19
3. Production is compatible with the load capacity of the water bodies involved	Environmental indicators 4, 5 and 6
4. Production is accompanied by relevant scientific development and innovation	Environmental indicator 9
5. The benefits of the industry translate not only into jobs, but also salaries that reflect the real contribution of the labor force in obtaining the product	Social indicators 1 and 2; and economic indicators 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 17 and 18
6. The industry is capable of generating a network of national suppliers with significant weight among the set of inputs employed	Social indicator 15; economic indicators 15 and 16
7. The industry contributes indirectly to improving living conditions in terms of health, education and the provision of basic services like housing	Social indicators 1, 5, 6, 7, 9 and 10; economic indicator 14
8. There is coordination among the businesses that make up the industry and with the public sector to deal with risk situations and take advantage of opportunities	Environmental indicator 14
9. It establishes relations of trust and respect with local communities, maintaining two-way communication and involving the communities in decision making related to the management of the impacts of production	Social indicators 3, 4, 8, 11, 12, 13 and 14
10. There are appropriate public institutions for the control and regulation required to develop the sector	Environmental indicators 7 and 8

To ensure that production is compatible with the load capacity of the water bodies, three environmental indicators that characterize and evaluate salmon farming based on the concentration of production and load capacity can be used together with an operational indicator related to freshwater.

Principle four, that production is accompanied by science and innovation can be measured using the number of Chilean academic publications as a proportion of the total volume of publications.

The fifth principle includes social indicators relate to poverty, and economic indicators linked to quality of employment, incomes and salaries, generation of direct and indirect employment, and characteristics of employment and training.

Principle six, that refers to linkages, in particular that the industry is capable of generating a network of national suppliers, is measured through a social indicator of indirect development of infrastructure and two economic indicators that measure the contribution of this sector to GNP.

Principle seven requires that the industry contribute indirectly to improving the living conditions in terms of health, education and the provision of basic services. It is addressed with the social indicators of poverty, education and housing indicated in Table 8 and the economic indicator of the proportion of contributions from this sector that remain in the region.

Coordination among the businesses and with the public sector to deal with risk situations is monitored by the environmental indicator that shows the sanitary state of the centers. While it does not directly monitor the coordination among companies and the public sector, it does provide what should be the result of a coordinated process. This point is of particular importance given that the propagation of the ISA virus in 2007–2008 was due to a lack of coordination among companies.

To measure how the industry establishes relationships of trust and respect with local communities, seven social indicators of changes and trends in delinquency and habits among the population in salmon farming areas, the evolution of permanent and

seasonal employment, changes in soil use and crops, migration and population levels have been identified.

Finally, the last principle of the vision, appropriate public institutions for control and regulation of the development of the sector, is covered by two environmental indicators related to the control and oversight undertaken by public institutions, one of compliance with environmental standards and another related to enforcement.

This result highlights the importance of the process followed in this study that identifies both the principles and the short list of indicators. The former are the objectives to be reached by the sector to fulfill its vision, and the latter allow measuring how salmon farming is advancing in reaching the vision.

7. Conclusions

The process outlined in this paper has allowed constructing indicators that respond to the perceptions of stakeholders in salmon farming and a common vision of long-term sustainability. In particular, a list of sustainable development indicators using a participatory methodology was developed for the first time for Chile.

The selected indicators are the result of two approaches, one bottom-up and the other top-down. The first captures the specific needs related to salmon farming and allows a better receptivity of the indicators. The latter allows scientific validity and a high degree of international comparability.

A key result is a common vision of what constitutes a sustainable salmon industry according to all stakeholders consulted. This vision considers 10 principles. Given that each principle can be associated with at least one indicator, it is possible to develop follow-up and monitoring of compliance and consequently measure the evolution of this vision over time.

The construction of diverse lists (long, medium, and short) maintains the information gathered in the participatory process, made the selection process more transparent and provides a record of the information gaps that could be addressed in the future. The validation of the shortlist of indicators was fundamental to complete the cycle of the participatory process with the stakeholders.

Another contribution of this work is the description of the step by step application of the methodology. Although it is focused on salmon farming, it can be applied to other productive sectors to develop participatory processes for measuring sustainability at the sectoral level.

Finally, there are indicators that, though desirable, cannot be constructed due to lack of information. Specifically, respect, dialog and coordination are three important concepts that were mentioned during the participatory process, and that must be included in future initiatives. However, this was beyond the scope of the study.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.marpol.2014.09.010.

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