Stakeholder's multidimensional perceptions on policy implementation gaps regarding the current status of Chilean small-scale seaweed aquaculture

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Stakeholder's multidimensional perceptions on policy implementation gaps regarding the current status of Chilean small-scale seaweed aquaculture

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ABSTRACT

Seaweed aquaculture is growing worldwide in coastal areas as an alternative to increasing income and food security. Despite these potentials, there is growing concern about the distribution of net benefits and sustainability of local communities. Consequently, governance must be able to include cross-sectoral dimensions related to aquaculture development given these challenging scenarios. Chile, the main seaweed producer of the western world, is implementing a new policy framework for sustainable development of small-scale seaweed aquaculture, principally through the transfer of funds for artisanal fishermen and small-scale farmers. Although supported by the existing demand for raw material and a reliable technological basis for cultivation, lack of added-value products and low-priced biomass may have a critical impact on the livelihood of those involved in aquaculture operations creating uncertainties for sustainable expansion. This study applied a multi-criteria decision analysis (i.e., hybrid SWOT – AHP analysis) to interpret stakeholders' multidimensional perceptions on policy implementation gaps regarding the current status of Chilean small-scale seaweed aquaculture. Both social and institutional dimensions presented diverging opinions among counterparts with relation to economic, technological and environmental topics. This operating inconsistency will require significant attention on complementary objectives beyond funding, such as innovation, enhancement of commercial channels, the creation of internal markets, mainstreaming, education and social equity. Comprehensive and efficient governance able to promote participatory management may improve its own capabilities to overcome an increasingly unfavourable scenario for small-scale seaweed aquaculture.

1. Introduction

The world demands seaweed-derived products either as food or in the production of a wide range of pharmaceutical and industrial items [1,2]. Whilst developed countries have advanced towards the production of functional ingredients for food, cosmeceuticals, nutraceuticals, pharmaceuticals and biofuel [3], developing countries are widely based on commercialization of low priced raw material for phycocolloids extraction [4,5]. Although the exportation of raw material has continued to rise [3,6], the current demand has resulted in overharvest, thus undermining the sustainability of wild-stocks and the livelihood of fishermen [2,3,7,8]. The commercialization of seaweeds in developing nations is based on high-volume, low-unit priced raw material, resulting in a low-income activity usually perceived as secondary by many fishermen and small-scale harvesters [9–11]. Moreover, progress toward standardization of restocking and/or cultivation techniques, selection of cultivars and application development required to establish a more profitable business focused on added-value products are still at early stages [1,7,12,13]. This scenario evidences that seaweed aquaculture has been slow to embrace innovation despite a growing demand [14].

Several governmental initiatives have been put in practice to change this scenario in some developing nations, promoting seaweed aquaculture while enabling diversifying livelihood of coastal populations [7,9,11]. In this context, Chile, the main seaweed exporting country in the west (c.a., 375,000 tons; FAOSTAT, 2016) has recently established diverse policies and regulations to encourage seaweed farming as an alternative to diversify Chilean aquaculture (dominated by salmon and mussel production) and also as a livelihood option for artisanal fishers. The main initiative is a novel funding policy to secure the sustainability of commercial seaweeds. The Subsidy for Restocking and Cultivation of Seaweeds (from now on referred to as SRCS), seeks to ensure the sustainable development of cultivation and/or restocking of commercial seaweeds through monetary incentives to artisanal fishers and small-scale farmers. This policy is supported by additional legislative efforts such as the Supreme Decree No. 96 (Issued in January 2016),

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introduced to facilitate the implementation of aquaculture activities within Management and Exploitation Areas for Benthic Resources (MEARBs) by introducing modifications to existing regulations. In Chile, there are over 700 MEARBs co-managed by fishers' organizations, in addition to aquaculture concessions managed by fishers and small-scale farmers, with great potential to develop seaweed aquaculture. The government has also announced the creation of the National Institute for Sustainable Development of Artisanal Fisheries and Small-scale Aquaculture (i.e., INDESPA; SUBPESCA 2016), an agency in charge of coordinating, executing and financing actions to improve the productive and/or commercial capacity of the artisanal fishing and small-scale aquaculture sectors; and a proposal to establish a National Algae Policy (official version currently available at www.pnal.cl) to establish consistent and coherent regulations for environmental, social and the economic sustainability of commercial seaweeds.

This governance framework, leaded by the SRCS, has the potential to change the current scenario in the short-term providing opportunities for future investors, promoting entrepreneurship and increasing the productivity and capacities of targeted groups of stakeholders (i.e., fishers, small-scale farmers). In addition, it could foster a rapid socio-cultural transformation of coastal fishers' livelihood, challenging both the adaptive capacity of those involved in fishing/cultivation activities and the performance of public policies that seek improvements in profits.

Funding-oriented policies (e.g., subsidies) are usually implemented by governments along with other public or private agencies to help increase profits in a specific productive sector. However, its role as capacity-enhancing tools has been identified as detrimental for marine resources sustainability, for instance, increasing fishing capabilities of large-scale fisheries [15–17] in detriment of small-scale ones [18]. This trend seems to be exacerbated by poor governance and the existing gaps among science, policy and socio-ecological dimensions for both fisheries and aquaculture (Kaiser & Stead 2002, Costa-Pierce 2010, [19]. This gap involves uncertainties and conflicts among multiple and interdependent factors from scientific, policy-making, social and environmental dimensions. The particularities of every dimension are, in turn, heavily influenced by political and commercial drivers, as well as the socio-cultural and economic context of every nation [17]. Hence, governance plays a critical role in the direction of public policies in order to reflect priorities, concerns and needs of those directly and indirectly affected by policies scope [20]. However, many policies and planning processes neglect an integrated socio-ecological approach to promote opportunities for production both in fisheries and aquaculture [19].

Consequently, there is a need for accounting factors that may hamper or facilitate the mission of regulatory tools to secure the sustainable development of seaweed aquaculture by artisanal fishers and small-scale farmers. In this context, a synthetic and multidisciplinary approach is required to support and inform policy-makers to develop a coherent and holistic planning process capable of integrating scientific and stakeholder inputs. This is essential to align relevant policies with a social-ecological system such as aquaculture [21]; Kaiser & Stead 2002, [19,22]. To achieve this goal, MultiCriteria Decision Analyses methods (MCDA) are useful tools to assess complex and interconnected systems enabling coherent decision-making and strategy formulation [21]. With that in mind, the SWOT analysis method (i.e., Strengths, Weaknesses, Opportunities and Threats) is commonly used to assess internal and external scenarios to apply a systematic approach to strategic planning in business management and has been recently applied to support environmental management and governance [23–29]. Additionally, the Analytic Hierarchy Processes (AHP), is a widely applied method for the determination of overall priorities and uncertainties suitable for decision-making problems [30,31]. In earlier works, a SWOT — AHP hybrid method has been presented and applied to systematically evaluate SWOT factors and determine their relative magnitudes through AHP, which can be then plotted in a coordinate system [29,32–34]. The combined approach overcomes limitations of traditional SWOTs when

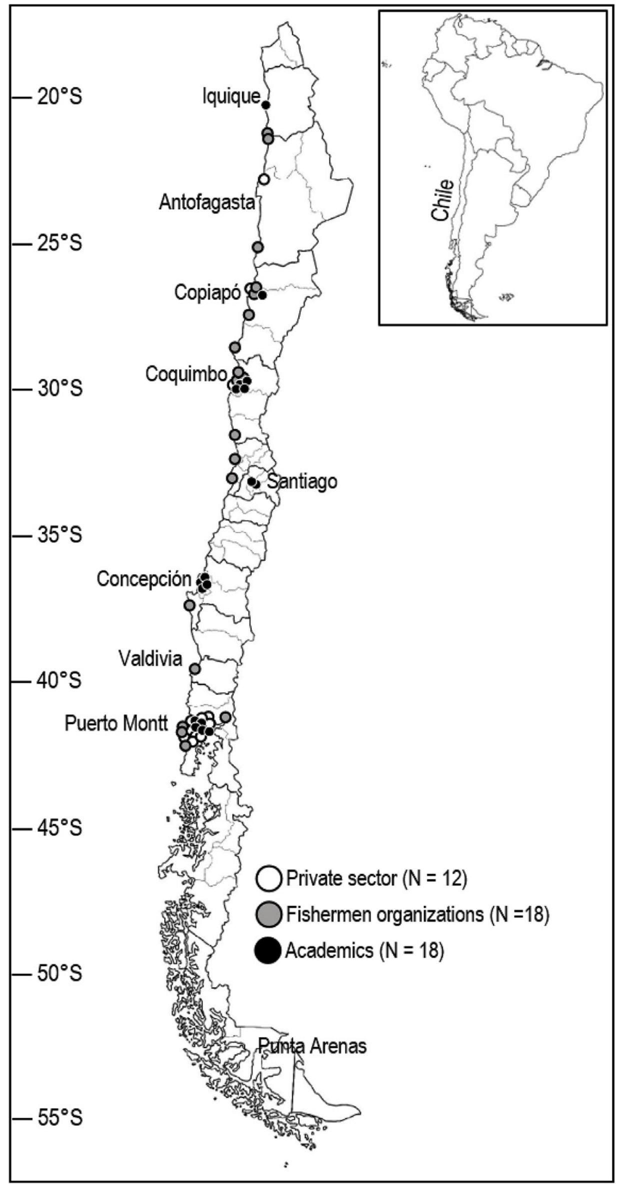

Fig. 1. Distribution and number of experts interviewed across Chile. Clear circles = Private sector; Grey circles = Fishermen organizations; Black circles = Academics. Names indicate major cities.

measuring the relevance of interdependent factors within a diverse range of criteria, which frequently result in a brief list of factors individually prioritized (e.g., generalizations) [29,32,33]. Using this approach, this study analyses stakeholders' perceptions regarding the current status of "Chilean seaweed aquaculture system" considering social, economic, technological, environmental and institutional dimensions [19] and their respective tier-up factors for the implementation of a new funding policy framework for small-scale seaweed aquaculture. It also explores the inherent advantages, weaknesses, potential threats and opportunities of the current situation of seaweed aquaculture that may hinder or promote a positive impact of the SRCS and complementary legislative tools. This analysis will help identify cross-sectorial gaps, determine key operational factors and overall priorities to inform future decision-taking to sustainable small-scale seaweed aquaculture.

2. Methods

A survey was undertaken in nine administrative regions across Chile

(Fig. 1) and included the most relevant regions in terms of seaweed landings, i.e., the Coquimbo Region in the north and Los Lagos region in southern Chile [35]. A heterogeneous group of 48 experts that included academics, private sector (investors, small-scale farmers) and leaders from small-scale fishermen organizations were surveyed to ensure a better insight on relevant factors involved in seaweed cultivation and restocking. Preparatory briefings on the concepts, objectives and methods took place before conducting every interview to ensure awareness of the experts on the topics of the questionnaires. Additionally, a glossary of specific terminology was presented to every interviewee for consultation if required. Academic experts were chosen for their significant contribution on topics such as ecology, phenology, physiology, reproductive biology and aquaculture of seaweeds, with 15–50 years of experience in their fields of study. Private sector included small-scale farmers and managers from purchasing and processing Chilean seaweed companies. Leaders from small-scale fishermen organizations that have been historically involved in cultivation and harvesting of commercial seaweed, were also included. The group of experts answered two types of surveys, one for the AHP method, where the importance of one subject compared to another was expressed in a semantic scale ranging from 1 to 3 (i.e., *Equally important*, *Slightly more important*, *Much more important*). The second survey sought to determine SWOT factors to develop the quantified SWOT— AHP analysis described in Kurtilla et al. [33], and Chang & Huang [32] as follows:

2.1. Identification of high-level dimensions to be compared

The priority groups (referred to here as dimensions) were defined as elements of the environment in which aquaculture actions are implemented. This environment was composed of social, economic, technological, environmental and institutional dimensions.

The number of dimensions to be compared does not exceed the critical number of items (i.e., ≤7) proposed by Saaty (1980, [31]; which sought to reduce ambiguity in the responses of interviewees. The relative importance of each dimension was determined through consultation with experts, and the resulting hierarchy was used to weight the overall importance of the key factors comprised by each dimension. Accordingly, the first survey was focused in developing a pairwise comparison multicriteria analysis using the AHP to determine the relative priority of high-level dimensions for the implementation of seaweed aquaculture in Chile (Appendix 1). In line with [32]; the following steps were included to weight the high-level dimensions:

- Establishment of a reciprocal matrix for pairwise comparison of the relative preference of the five high-level dimensions producing a matrix of 5^{x} 5 elements.
- Calculation of the priority weight of every high-level dimension and principal eigen value λ_{max} throughout the determination of eigen vector averaging technique for each pairwise comparison matrix described by Refs. [36,37].
- Calculation of consistency index (C.I.) and consistency ratio (C.R.) to measure overall coherence of stakeholder's subjective judgement regarding the prioritisation of each high-level dimension. The consistency/coherence ratio was calculated as follows (equation (1)):

$$\text{C.R.} = \frac{C.\,I.}{R.\,I.} = \frac{\frac{(\lambda max - N)}{N-1}}{R.\,I.} \quad (1)$$

where C.I. is the consistency index, calculated using the main eigen value λ_{max} of each interviewee's matrices and the number of alternatives N (= 5). The Random Index (R.I.) is a randomly generated number, assuming that all the pairwise comparison matrices are completely random. C.R. values smaller than 0.1, the answers are considered to be consistent, any deviation beyond this threshold value will impoverish the coherence of the responses [32,36,37]. Nevertheless, some authors have suggested that C.R. < to 0.2 should maintain consistency within acceptable levels [38,39].

2.2. Identification of internal and external key factors to develop a hierarchical structure

Additionally, a second questionnaire encompassed 28 combined quantitative and qualitative questions to identify key constraints and enabling factors for the development of seaweed aquaculture in Chile (Appendix 2). Internal (Strengths and Weaknesses) and external (Opportunities and Threats) key factors were identified from this questionnaire. Key factors were classified within a corresponding high-level dimension such as social, economic, technological, environmental or institutional and, in turn, classified as strengths, weaknesses, opportunities and threats. This hierarchical structure is shown in Figs. 4 and 5.

2.3. Calculation of the performance of key factors

Within the SWOT analysis, the performance of key factors was calculated as the proportion of experts who referred to the factor (i.e., the priority of every factor within the groups) divided by the total number of experts. This was then presented as the relative percentage reached by any given factor.

2.4. Calculation of SWOT coordinates for the main dimensions

Recent advances have integrated the SWOT analysis and quantitative approaches such as the AHP [33]. This generates a hybrid method of quantified SWOT analysis, which systematically assesses the SWOT factors and indicates their significance as follows:

- Following comparable approaches (See Refs. [29,32] factor scores or the priority of each factor within a given dimension calculated in the SWOT analysis was multiplied by that dimension's priority, determined previously with the AHP method. The scores of strengths and opportunities maintained a positive sign, while the sign of the score of weaknesses and threats was inverted. Next, internal (i.e., strengths and weaknesses) and external (i.e., opportunities and threats) scores were summed, generating values for every dimension.
- Calculation of a benchmark value determined as the average value of external and internal factors of every dimension.
- Calculation of SWOT coordinate scores for every dimension subtracting the benchmark value from the weight of internal and external scores of every dimension, thus obtaining a coordinate value.
- The coordinate values were plotted in a four-coordinate system where the external situation of every dimension (i.e., opportunities and threats) is represented as the ordinate (*y-axis)*, whilst the abscissa (*x-axis*) shows the internal situation (i.e., strengths and weaknesses). From here, a given dimension presents more strengths and opportunities when its coordinate value is larger than the benchmark value. Conversely, a dimension with more weaknesses and that face more threats will show smaller coordinate values compared with the benchmarking value. Consequently, in this plot the position achieved by every dimension will represent their overall internal and external performance thereby depicting the current context of Chile and the complementary legislative tools facing the implementation the new funding policy.

3. Results

3.1. AHP analysis

The analysis showed that no dimension stands out significantly above the others evidencing a relatively similar status for all dimensions. However, vectors priority values ranged between 0.14 and 0.24, allowing the establishment of an order of importance (Fig. 2 A).

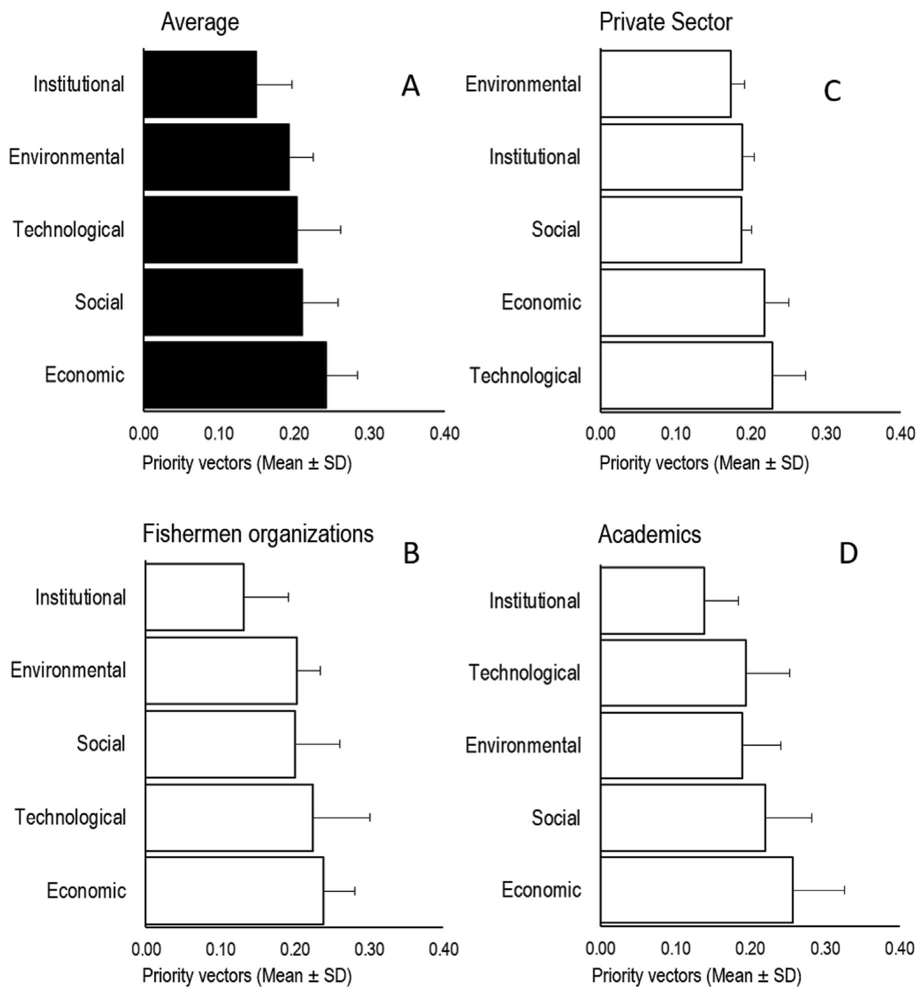

Fig. 2. Analysis of Hierarchical Process expressed as mean value of priority vectors of each dimension according expert's judgement. (A) Academics, n = 18; (B) Private sector, n = 12; (C) small-scale Fishermen organizations, n = 18 and total averaged weight, n = 48.

Apparently, the economic dimension was the most important for implementing seaweed aquaculture (0.24) followed by social and technological dimensions (~0.21), whilst environmental (0.19) and institutional dimensions (0.15) presented the lowest priority according to the analysis. The analysis also revealed slight differences among groups of experts, whereby users (i.e., small-scale fishermen organizations, the private sector) prioritise dimensions similarly (Fig. 2 B and C). For these groups, economic and technological dimensions seemed to be more relevant, while economic and social aspects were shown to be the priority for academics (Fig. 2 D). The overall consistency ratio was 0.14, which slightly departs from 0.10. Given the divergent nature of the high-level dimensions regarding seaweed aquaculture and the broad spectrum of experts, this amount of inconsistency can be expected.

3.2. Internal and external key factors

A total of 20 internal and 30 external key factors were identified after a comprehensive review of the surveys. The hierarchical structure (Figs. 3 and 4) showed that technological factors were the most abundant (n = 10) for the internal operating environment of seaweed aquaculture, whilst, considerably fewer economic (n = 4), environmental and social (n = 3, respectively) appeared. Institutional factors were absent and thereby the institutional dimension scored zero in the quantitative assessment. However, for the external operating environment, institutional factors were the most abundant (n = 14) and were generally classified as threats. whilst few economic (n = 8), environmental (n = 5), technological (n = 2), and only one social factor also were described.

3.3. SWOT analysis

The SWOT analysis demonstrated that seaweed aquaculture is widely recognised as having a reliable technological basis according 84% of the experts (Fig. 5), whilst short cultivation cycles and the acknowledgment that seaweed aquaculture is a real source of additional revenues was viewed as a strength by 34% of the experts. Affordable initial investments (14%) and uncomplicated cultivation techniques (12%) were also identified as advantages of this activity. In addition, the perception that seaweed aquaculture is positive for the environment (i.e., continued delivery of ecosystem services), the idea that cultivated biomass provide better quality products, and the fact that it is not associated with the deleterious effects caused by harmful microalgae blooms were identified as competitive advantages by the group of experts (10%, 8% and 6% respectively). The lack of requirement for additional sources of food for cultivation and the adaptability of some commercial species to different environmental conditions (e.g. *Macrocystis pyrifera*), were marginally mentioned by about 2% of experts.

On the other hand, 64% of the experts suggested that a lack of experience in cultivation at commercial scales in most of the species may be a major disadvantage. In addition, the need for partnership among organizations and the reduced number of bio-economic evaluations were mentioned as disadvantages by 34% and 32% of the interviewees respectively. Likewise, 28% of the experts emphasised that a limited capacity to generate products with added-value may also encompass a

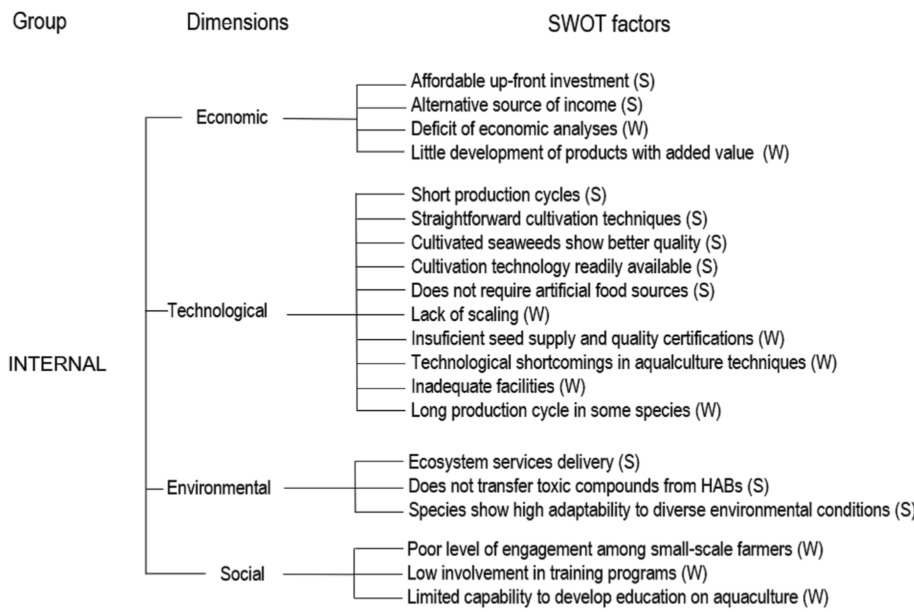

Fig. 3. Hierarchical structure of internal SWOT factors. S = strength, W = weakness, O = opportunity, T = threat.

major weakness for small scale initiatives. Although stated above as a major strength, 20% of the experts indicated the need for more complete development of cultivation technology. A similar number of experts mentioned the need for a network of seed supply to facilitate the implementation of the small-scale projects. Other internal factors also recognised as weaknesses were: inadequate facilities (18%), low involvement from users in training programs focused on seaweed aquaculture (8%), slow cycles of cultivation for some potential species such as *Gigartina skottsbergii* (2%) and a general need to shape a culture of communication and education surrounding aquaculture practices (2%).

Regarding the external assessment (Fig. 6, opportunities), 58% of the experts consistently stated that a continuous demand for raw material may guarantee a relatively reliable commercial exchange, whilst

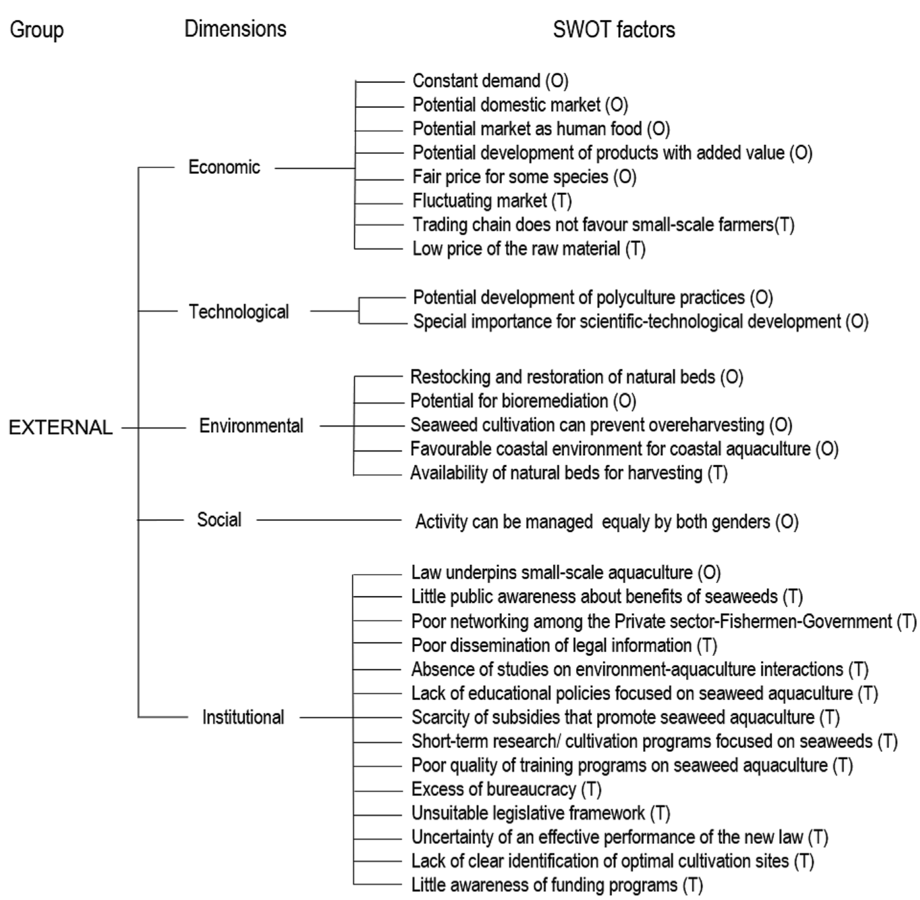

Fig. 4. Hierarchical structure of external SWOT factors. S = strength, W = weakness, O = opportunity, T = threat.

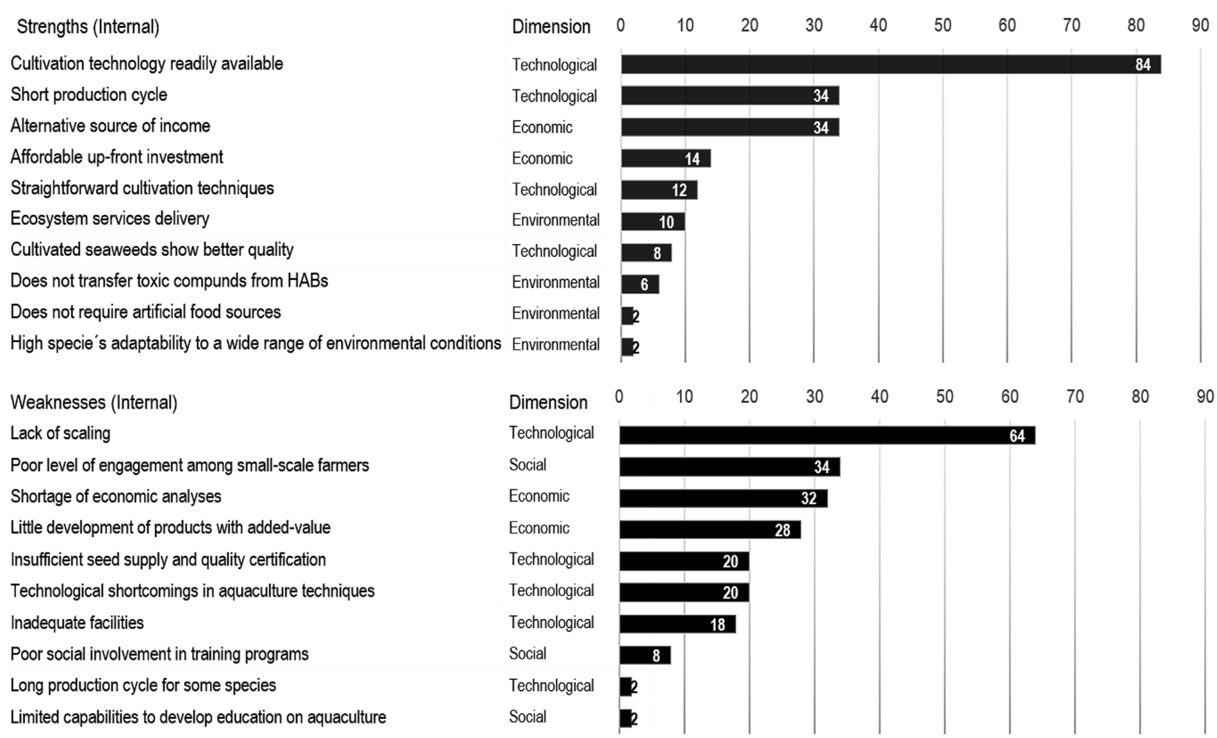

Fig. 5. Internal factors priority within groups expressed as percentage of expert's preference.

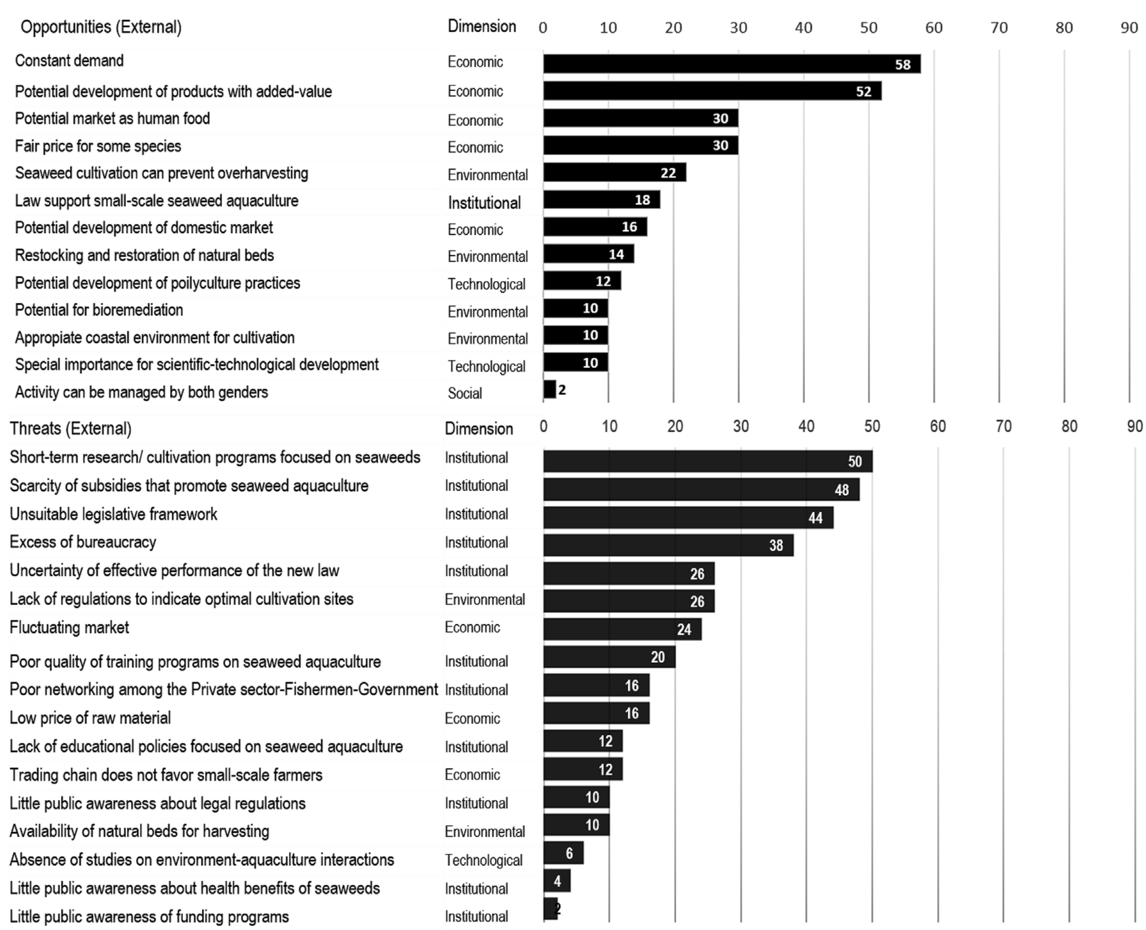

Fig. 6. External factors priority within groups expressed as percentage of expert's preference.

the opportunity for development of added-value products and human food was indicated by 52% and 30% of the respondents, respectively. Thirty percent of the experts also considered that some species can reach fair prices, thereby increasing the interest for cultivation. Additionally, the opportunity to reduce the current status of exploitation of wild stocks through seaweed aquaculture was stated by 22% of experts. Similarly, it was recognised that the new policy favours the growth of the activity significantly (18%) and this may promote the potential creation of a local market around seaweed aquaculture (16%). The premise that this activity may increase restocking and restoration initiatives was identified by 14% of the experts, and 12% indicated the possibility of increased polyculture initiatives. Likewise, the potential for bioremediation was indicated by 10% of the experts. Furthermore, 10% referred to the potential of the Chilean coast for aquaculture development and its importance for the generation of a knowledge base and technological progress. Only 2% of the interviewees acknowledged the fact that this activity may be equally managed by both genders.

Threats mostly comprised institutional and administrative factors recognised by all groups of experts (Fig. 6). The short-term nature of funding programs for research and training activities was consistently stated by 50% of the consultants and the need for subsidies to develop seaweed aquaculture was indicated by about 48%. The lack of an adequate legislative framework (44%), and excessive of bureaucracy (38%) that may lead to uncertainties in the performance of the new law (26%) also appeared as major threats. On the other hand, the experts stated that the adequacy of Chilean waters for aquaculture by itself does not guarantee the success of productive initiatives as a result of spatial and temporal variability. Consequently, the need to identify optimal sites for cultivation was perceived as an external risk by 26% of the respondents. In addition, when experts were asked about the economic environment surrounding seaweed aquaculture, a fluctuating market based on commodities exportation was perceived as a threat by 24%. Similarly, 20% indicated the poor quality and certification of training programs, and 16% the need for a permanent network to ensure permanent cultivation initiatives among stakeholders (i.e., investors, fishers' organizations and the governmental managers). Sixteen percent of experts indicated that the weakening of international commodity prices fostered by Asian competitors may result in price drops affecting local production. The lack of education programs able to encourage seaweed aquaculture as a means of economic development in communities that rely on fishing activities was stated by 12% of experts. Whilst 12% indicated their disconformity with the trading chain, usually modulated by intermediaries, which do not favour small-scale harvesters. Also, 10% indicated the accessibility to natural beds readily available for exploitation as a threat for aquaculture initiatives since low costs of harvesting may result in a loss of interest for further investment in cultivation. Finally, the need of studies on the interaction and effects of seaweed farms on the environment (6%), lack of public awareness of health benefits of seaweeds (4%) and a reduced number of funding programs (2%) were also pointed out as threats.

3.4. SWOT — AHP quantified analysis

There was high dispersion among high-level dimensions for seaweed Chilean aquaculture as shown in the four-coordinate plot (Fig. 7). In general, economic, technical and environmental dimensions were widely better positioned than social and institutional dimensions. However, the averaged value representing the overall status of Chilean seaweed aquaculture was still positioned on the weaknesses side of the SWOT and was clearly influenced by social and institutional dimensions.

In particular, the economic dimension, the most relevant according the AHP analysis, was well positioned along the opportunities axis (i.e., *y-axis*), identified earlier as having great potential. Yet a number of weaknesses led by the deficit of bio-economical assessment and the lack of added value products counterbalanced intrinsic economical strengths

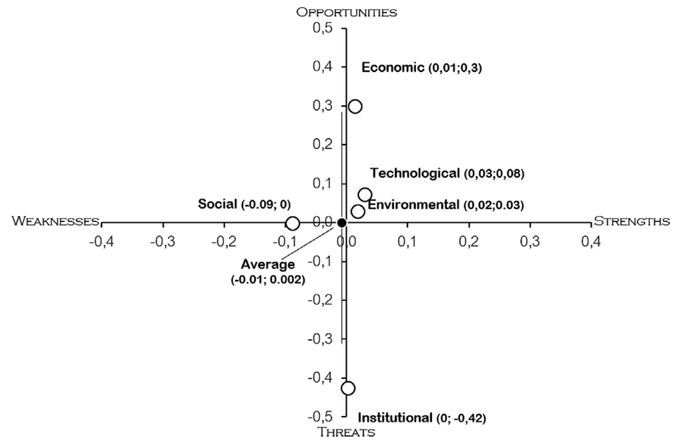

Fig. 7. Four-coordinate plot on the Quantitative SWOT — AHP analysis of seaweed aquaculture in Chile. The solid circle shows the averaged coordinate value of all dimensions (Mean ± SD). Cleared circles correspond to the high-level dimensions evaluated. y-axis represents Opportunities, Threats and x-axis accounts for Strengths and Weaknesses.

diminishing its overall position along the strengths' axis (*x-axis*).

On the other hand, the social dimension, although of lesser relevance according the AHP analysis, remained as part of the weaknesses, most likely due to low engagement among users, poorly performed training programs and a lack of cultivation education. The biggest concern was related to institutional issues, characterised by major threats, such as scarce funding programs, short-term funding policies, weak legislation and cumbersome bureaucratic processes, among others.

4. Discussion

Despite being moderately favourable, there are certain underlying issues that need to be addressed in the implementation of small-scale seaweed aquaculture currently promoted by Chile's new policy development process. The group of stakeholders acknowledged widely known possibilities of economic development and technologic-environmental advantages [12,14]. Within this relatively optimistic situation, micro-entrepreneurs (i.e., fishermen and farmers) may be able to channel fresh funds and use key economic, technological and environmental strengths to adopt new strategies. However, the analysis also revealed an unequal status between social and institutional dimensions and a clear separation between them and the remaining dimensions (economic and technological, environmental), which scored positive values within the opportunities and strengths quadrant. In short, this suggests prioritisation of trading, technological and ecological motivations in detriment of social implications and governance. This trend has been argued as a major drawback for the expansion of sustainable aquaculture [21,40]; Costa-Pierce 2010, [19]. Moreover, this scenario seems to represent the current status underlying Chilean seaweed aquaculture.

This gap defined as the lack of participation of stakeholders in decisions related to aquaculture and policy-making (*sensu* [19] in this case was related with the poor level of organization among small-scale producers, little interest in training programs and scarce adaptability to aquaculture practices. This study strongly recommends considering this gap in the ongoing regulatory and policy framework. Accordingly, counseling and supporting programs to enhance further levels of co-management, partnership and adaptive capacities among future small-scale farmers should be a key driver in the policy-making agendas. The challenge for the further development of INDESPA and the National Policy of Seaweeds will be to coordinate and secure a coherent transition from fishing to small-scale aquaculture beyond productivity-enhancing subsidies.

On the other hand, participation, adaptability, and association among fishermen must rely on the articulated development of socio-economic motivations. In this analysis, stakeholders also projected a clear disparity between social and economic dimensions (both being the main priorities according to the AHP). Stakeholder's judgement suggested that the economic dimension was strongly represented by external potentialities albeit not underpinned by internal strengths. This suggest s in turn, that despite a demand for raw material, a paucity of bio-economic analyses, little development of added-values products and low-priced biomass could jeopardize the social integration sought by the SRCS. Moreover, this tendency seems to be more critic considering similarities with environmental and technological dimensions along the strengths axis, which showed even fewer opportunities. Consequently, the potential for socio-economic growth seems affected by poor market development. The implementation of technological proposals and innovation have been suggested as priorities for sustainability of seaweed aquaculture in earlier reviews both for Chile [12,14] and other developing countries [1,2,7]. Although commendable efforts lead by the Chilean government, universities and the private sector have significantly fostered the advance of innovation, namely food products (Gutiérrez 2001, Gutierrez et al., 2006), fertilizers (Cruz 2003) and biofuel (Buschmann et al., 2014, Camus et al., 2016), further establishment of a more profitable business is still lacking for fishermen. Furthermore, as suggested by Ref. [41]; factors that will promote innovation among small-scale aquaculture producers are also correlated with particular socio-economic conditions, such as education, access to internet, participation in organizations and alternative markets.

If new market options are still lacking, one of the main purposes of the new policy framework, which is to increase the availability of relevant species of seaweeds could lead to oversupply, resulting in price drops. More importantly, this may be exacerbated if beneficiaries favour cultivation of traditional species that currently present an established market (e.g., for *Agarophyton chilensis*). Although aquaculture innovations may still be promoted in governmental agendas, the role of governance in coupling the need for seaweed cultivation with enhanced demand and price is essential to avoid fishermen discontent. This may rapidly lead to apathy and lack of motivation to engage and trust in further governmental initiatives [42]. Consequently, poor economic policies may increase vulnerabilities as in the case of funding policies in the fisheries sector, largely focused on increasing fishing capacity undermining marine resources, the livelihood of small scales fisheries and ultimately sustainability [15–18].

The analysis also suggested that the current institutional administrative framework may not be suitable for a prompt implementation of new policies. The abundance of threats, lack of opportunities and strengths showed by this dimension seems of major concern due to the key role that administration plays on the execution of nationwide development programs [19,20,43–45]. Stakeholders acknowledged that short-term governmental research programs focused on technological innovation and diversification appeared as a complication for a coherent development of seaweed aquaculture. Research programs (i.e., 2–3 years) seem to postpone the identification of concrete steps to transfer and validate successful knowledge and management skills for future producers. Essentially, this type of programs has limited resources for projects continuity, resulting in the partial generation of knowledge, a short-term basis for monitoring and poorly transferred results. Furthermore, the fundamental need for educational policies focused on groups of interest that include dissemination of results and appropriate training programs have also contributed to increase the gaps among dimensions. In addition, poorly promoted funding programs among fishers and little public awareness on the benefits of seaweed consumption, for instance, in human health may delay further interest of new and innovative alternatives of marketing that could, otherwise, encourage emerging local markets. This also has major economic relevance, because the creation of new internal markets can reduce dependency and competition of world trade markets (i.e., Asia) [13,14]. On this point, knowledge dissemination through targeted marketing and mainstreaming may be key to raise public awareness as have been indicated with the development of the ecosystem approach to aquaculture, discussed recently by Brugèr et al. [46], and organic aquaculture production in Europe [47].

Of particular relevance was the idea that cumbersome bureaucracy seems to be one of the most important barriers to rapid development. Apparently, institutional overlapping has led to complex and time consuming bureaucratic licensing processes, which in turn, may have increased public apathy about the functioning of new policies. This has been exacerbated by little public awareness on how the current regulation works highlighting the need for closer engagement between government and stakeholders. Similar issues have been stressed in earlier reviews of legislative tools such as the National Aquaculture Policy [48].

At this point, the little relevance reached by institutionality in the AHP analysis, is interesting, because it suggests that a system perceived as complex and bureaucratic is perfectly foreseeable and therefore, endured by users as part of a fixed “way of being”. Therefore, the inconsistency among highly interdependent dimensions may become a major challenge for governance. This calls for a modification of the administrative apparatus given the SRCM and the additional policy framework.

Despite the relatively optimistic scenarios for current technological-environmental dimensions fundamental research on seaweeds is still required. Although there is scattered research available on the production of secondary metabolites [49], bioactive compounds [50,51], identification and selection of strains [52], domestication [53], and optimisation of cultivation techniques [54] for different species (e.g., harvesting methods, harvesting periods, plague controls), consistent biological information to secure production and quality is still lacking for many species in developing countries. Currently, only a few universities and private actors have the capacity for seeds production of commercial seaweeds across Chile [10]. A limited network of seed supply is an important operational constraint for future producers given Chile's long coastline and geographical features. This topic could be included in the 2018–19s SRCS program (Pers. Obs.). However, other social subjects discussed above may be also implemented by the governmental agencies (e.g., SUBPESCA), for instance, during the formulation of “Guidelines for annual programs” (Section a, Article 6°, SRCS) and “Developing activities” (Section c, Article 6°, SRCS). This can secure rearrangements of priorities, the coordination between program aims and coherent use of resources from the government.

The implementation of a national network of seeds supply for future producers has important technological but also environmental implications. The identification and selection of propagules sources (strains), is crucial for enhancing productive capacities and to avoid genetic diversity losses by translocation [3,52,53], but also to foster the expansion of sustainable aquaculture. In addition, proper scaling methods are not clear for many commercial species as well as the potential impact that commercial seaweed aquaculture may have on the surrounding habitat. So far, few studies have suggested ecological effects associated with increases in algal detritus [55,56] and flow reduction around farms [57] that will require attention.

Overall, the social and institutional dimensions represented a major concern to secure small-scale seaweed aquaculture as an economically viable option for long-term sustainable development for artisanal fishermen. This social-institutional disparity has been indicated in earlier reviews as a general deficiency in the development of a holistic approach of aquaculture [9,11,19]. The disparity among all dimensions may impair both long-term benefits pursued with the new policy scenario and intrinsic advantages. Accordingly, the system capability gap may hamper a rapid growth of seaweed aquaculture in Chile. Legitimate solutions require compromise, trade-offs between multiple and conflicting aims such as innovation, enhancement of commercial channels, the creation of internal markets, mainstreaming and education. Comprehensive and efficient governance able to promote participatory management may improve its own capabilities to overcome an increasingly unfavourable scenario for seaweed aquaculture.

In summary, the present study shows a more comprehensive understanding of the status of Chilean seaweed aquaculture and better recognition of national scale priorities from the stakeholders' perspective. This being said, considering the broad spectrum of experiences regarding seaweed aquaculture throughout the pronounced Chilean latitudinal and socio-ecological gradient certain level of inconsistency can be expected [38,39,47]. Nevertheless, this was considered as a part of the complex country-level realities around commercial seaweeds.

However, once stakeholders answer the first survey, key factors are obtained and weighted accordingly, which reduces uncertainties [32]. The previous interview to elucidate these factors, which then constitute the high-level dimensions, in turn, increase interviewee's knowledge and care on the subject. Then, the high-level dimensions are prioritized with the AHP method. This focuses the pairwise comparison process on a unique subject (i.e., the seaweed aquaculture) rather than independent thematic surveys, common for multi-level AHP studies (see Ref. [47]. From the benchmark and the coordinate values, the overall trends are expressed in the coordinate plot revealing the *status quo* of every dimension. The visualisation of contrasting positions simplifies communication of results highlighting gaps, differences and conflicting subjects to develop a rational strategy. Consequently, the synthesis of the message promotes a more effective participation in policy-making through the rationalisation of a concise message to policy-makers. This resulted in an unprecedented country-level analysis on policy implementation gaps based on current stakeholders' knowledge. The study was able to condense and quantify multiple inputs in a hierarchical structure, allocates priorities and reflects potential scenarios for management in a complex system [33]. Consequently, although focused on Chile's seaweed aquaculture, the insights of this study are widely suitable for evaluation and diagnosis of any system. The results enabled the delivery of advice for the enhancement of national policies and setting agendas to effectively address future regulatory responses harnessing acknowledged institutional capacities of the Chilean government to promote sustainability [40].

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpol.2019.02.042.

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