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Exploring typologies of artisanal mussel seed producers in southern Chile

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A R T I C L E I N F O

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Heterogeneity

A B S T R A C T

Aquaculture is one of the most dynamic food production systems in the world, with a fast expansion, especially in developing countries. Among this sector, the Chilean mussel industry has experienced a substantial increase, turning Chile into one of the leading producers and global exporters of mussels. Among the different links in the mussel production chain, the natural seed collection conducted by artisanal fishers of southern Chile has been a fundamental pillar for the development of the industry. Often, this sub-sector has been thought of as a homogeneous group, with similar responses to different challenges and public policies. However, this is likely an unrealistic assumption, making it necessary to understand the complexity of the local context and the heterogeneity of producer groups within the territory. Using surveys and multivariate statistical analysis, we explore typologies of artisanal mussel seed producers in southern Chile. The results proposed four seed producer entrepreneur typologies associated mainly with socioeconomic features and their interactions with the environment. These variables explain heterogeneity in organizational structures and equipment. Spatial location and environmental conditions are important factors that directly or indirectly influence the fishers' investment in equipment and sales contracts. Our findings suggest that seed producer heterogeneity should be considered when designing, implementing, and providing policy incentives to support sustainable mussel aquaculture. Our results identified groups of fishers whose entrepreneurship capacity is vulnerable to environmental and market changes, informing future needs for technical assistance and support.

1. Introduction

Aquaculture is the fastest growing food production system in the world (FAO, 2014). The rapid expansion of aquaculture is taking place mostly in developing or middle-income countries, areas in which small-scale fisheries play important roles for livelihood security. Consequently, socially and economically sustainable aquaculture production needs to ensure local small-scale fisher communities and supply chains continue to function and provide socially and ethically acceptable working conditions. Indeed, aquaculture is still in its infancy regarding issues related to small-scale fisher participation in the aquaculture supply chain and the design and implementation of management and policy aimed at achieving successful engagement of small-scale fishers within aquaculture.

Some examples of small-scale fisheries participating in the aquaculture supply chain can be found in India and northeast Brazil for the shrimp industry, or in Chile for the mussel industry. The latter is one of the most important Mytilidae production centers around the world (FAO, 2016a) experiencing a substantial increase from 30,000 tons to 283,307 tons during the past fifteen years (SERNAPESCA, 2014; SSPA, 2016). This increase in production has made the Chilean industry the world's number one exporter of mussels, with 59,300 tons shipped in the first nine months of 2015 (FAO, 2016a).

Mussel production is commonly divided into four stages of production, seed uptake, seed fattening, mussel processing and mussel marketing (Rivera et al., 2017). The seed uptake process is mainly carried out by artisanal fishers, who act as aquaculture entrepreneurs (Vik and McElwee, 2011). Seed uptake occurs mainly in rural areas during the spring and summer seasons of the year (October to March) and represents both an important source of income for fishers and other

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small-scale aquaculture entrepreneurs (Figueroa and Dresdner, 2016), and an alternative livelihood aimed at alleviating poverty. Seed uptake, is an essential pillar for mussel aquaculture as the seed represents the main raw material for the entire industry. Thus, any limitation in this input will affect the following stages of the production chain and therefore, the final supply. In Chile, 100% of the seed needed for the mussel aquaculture industry is obtained from the natural environment through seed uptake (Bagnara Vivanco, 2008; Carrasco et al., 2014; Saavedra Gallo and Macías Vázquez, 2016). These features have made seed uptake play a key role on both the entire production chain and the income of small-scale artisanal fishers, underscoring its vulnerability to environmental changes.

The seed is up-taken by collectors, which are artisanal gill nets that provide a surface for larvae settlement. Each collector is 20–25 cm in diameter and 4-meters-long and are installed in long-line systems which can be single or double. There are 3 legal mechanisms to carry out the activity: concessions, temporary permits (1 season), and Management and Exploitation Areas for Benthic Resources (MEABRs). The latter are legal concessions that assign exclusive user rights to extract benthic resources in specified areas of the seabed (Gelcich et al., 2010). These permissions are exclusive for artisanal fisher organizations that are legally constituted, who once authorized can install collectors in up to 40% of the assigned area. The members of the organization can organize in three different ways to carry out seed uptake activity in MEABRs: either collectively as organization, in smaller groups of members of the organization, or by individual members.

In recent years, seed producers have continuously faced several challenges related to environmental factors that influence seed production. For instance, during 2012, a significant decrease in mussel seed uptake was observed (Carrasco et al., 2014; SSPA, 2014). In addition, the Los Lagos Region is constantly hit by the "red tide" phenomenon, which severely affects industry productivity. Although this is a naturally recurrent phenomenon in southern Chile recorded during the past four decades (Buschmann et al., 2006; Cabello and Godfrey, 2016), the extent and the intensity of the latest phenomenon (in 2016) has been unprecedented (Cabello and Godfrey, 2016). On the other hand, seed producers also face changes in market conditions, where mussel prices have shown an important variability since 2005 (Figueroa and Dresdner, 2016; SERNAPESCA, 2014; Uriarte, 2008).

From a policy perspective, the Chilean government is launching a large program promoting small-scale aquaculture. This as a way to develop alternative income and entrepreneur opportunities for coastal communities which depend heavily on overexploited fish stocks. However, knowledge about the best way to move forward in the implementation of this program is scarce. Specifically, there is little knowledge on drivers of coastal users' production and labour decision making processes. Moreover, there is no clarity about how to design and implement effective policy instruments to support small-scale aquaculture. A key stakeholder group to develop investment and support policies for small-scale aquaculture are artisanal fishers, despite their importance, there is little knowledge about their decision-making behaviour under different stressors or their reactions to past policy instruments supporting aquaculture related activities.

Researchers and policymakers have called for studies that help to understand producer groups' responses to both environmental and economic stressors (Carrasco et al., 2014) or their responses to support policies. An unrealistic expectation would be to think that these challenges affect all groups of artisanal fishers involved in seed uptake in a similar manner. Likewise, it is unexpected that public policies aimed at tackling these problems have homogenous responses from the various groups of producers. From agricultural economics, we know that the Identification of farm types through cluster analysis is commonly suggested as the first step to portray farm-system responses through different modelling approaches (Köbrich et al., 2003). In this context, identifying typologies of producer groups is an important step that can constitute the so-called recommendation domains which represent "for whom we can make more or less the same recommendations" (Byerlee and Collinson, 1980; Köbrich et al., 2003).

Although cluster analysis is a common method used in agricultural economics literature to identify producer typologies (Bidogeza et al., 2009; Briggeman et al., 2007; Daloğlu et al., 2014; Köbrich et al., 2003), it is not a widespread approach in aquaculture. Examples can be found for the shrimp industry (Joffre and Bosma, 2009; Marques et al., 2016); brackish-water pond aquaculture systems in the Philippines (Stevenson et al., 2007); the French oyster industry (Le Grel and Le Bihan, 2009); the Asian carp farming systems (Michielsens et al., 2002); and Greek small-scale fishermen (Tzanatos et al., 2006). However, as far as we know, this approach has not been applied to the mussel industry or to the subsector of mussel seed production.

In order to achieve successful support and long-term engagement of small-scale fishers within the mussel industry, a typology of the mussel seed production subsector is critical. This, to 1) determine appropriate interventions per group of seed producers according to their specific characteristics; 2) understand how appropriate interventions can be scaled; 3) design a strategy for promoting artisanal fisher based entrepreneurship in aquaculture activities; and 4) improve the *ex-ante* impact assessments modelling (Stevenson et al., 2007).

In this study, we aim to build seed production group typologies for artisanal fishers, to strengthen the link of small-scale fisheries and the mussel industry. Due to the available information on environmental and productive conditions, this study focused on MEABRs managed by fishers. Thus, through multivariate statistics, we capture the diversity of artisanal fisher mussel seed production groups that operate within MEABRs in two districts within the Los Lagos region in Southern Chile. The results should help policymakers to understand the heterogeneity of agents involved. Therefore, findings can help determine and identify relevant policy actions targeted to specific needs of heterogeneous users.

2. Methodology

2.1. Study area and unit of analysis

Data collection was conducted in the Cochamó and Hulaihué districts located in the Los Lagos region of Chile (Fig. 1). These districts are the main zones where seed uptake takes place. Although there are three legal mechanism to carry out the activity, due to the information available on environmental and productive conditions this study focused on the small scale fishers as entrepreneurs that collected seeds in MEABRs. Further, the unit of analysis defined is the production group working in the MEABRAs, independently of the way in which they organize the work.

The number of fishers working within the MEABR in mussel seed collection is not known because there is no official record in Chile of these producers. However, the total number of seed collector structures authorized to be installed in each MEABR is known. The survey considered 86 production groups operating in 32 MEABR who performed seed uptake between 2008 and 2013. Altogether the 86 groups installed 805,700 collectors that represented 45% of the total collectors authorized to be installed in the MEABRs in 2014, according to statistics provided by the National Fisheries and Aquaculture Service.

The questionnaire included three topics: 1) socioeconomic characteristics of the producers (experience, age, gender, production organization, funding for activity, training); 2) production statistics (number of collectors installed and harvested, collector yield, production losses, seed price, cost of seed); and 3) other occupations/livelihood alternatives of producers (main economic activity and income of complementary activities). The sample comprised 32 MEABRs, representing 58.2% of MEABRs that perform seed uptake within the Los Lagos region.

Surveys were performed in areas close to environmental monitoring stations located at seven localities within Cochamó and Hualaihué.

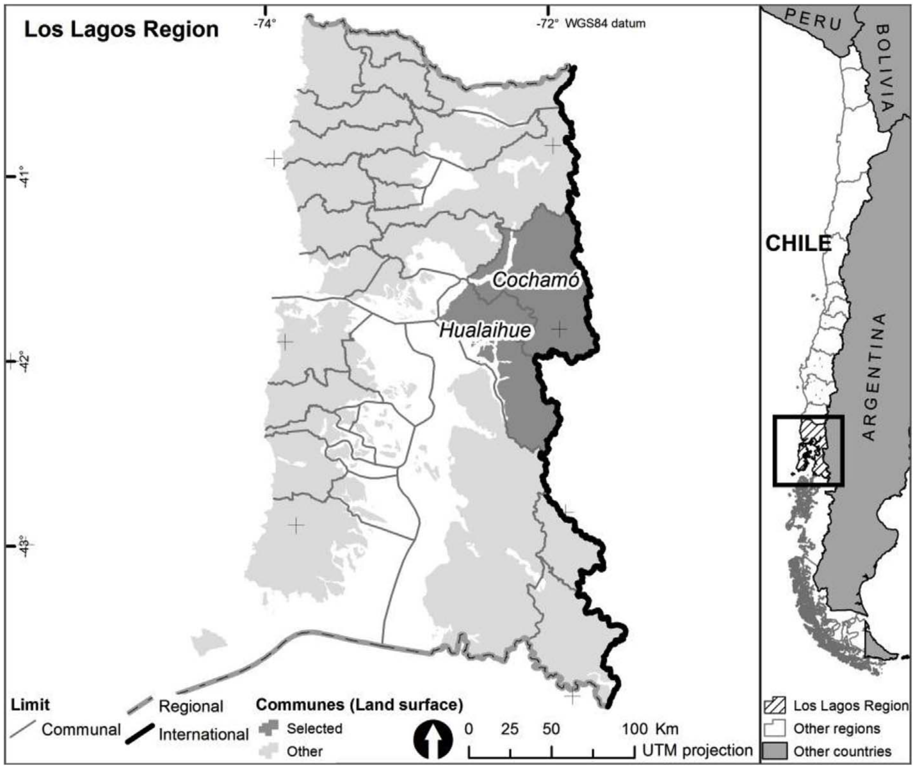

Fig. 1. Cochamó and Hualaihue districts in the Region de Los Lagos, Chile.

These stations have performed monthly monitoring of key environmental variables, such as temperature, salinity and chlorophyll concentration, since 2012. These environmental data are available from the Chinquihue Foundation,[1] a public-private organization that supports the artisanal fishing sector in the Los Lagos region. The coordination of both datasets will allow us to construct a typology that will consider the heterogeneity in environmental conditions present within different districts.

2.2. Typology construction

Through a Principal Component Analysis (PCA) and a hierarchical clustering of the PCA results, we constructed the typology of the mussel seed production groups. Before the clustering and the PCA analysis, we developed a thorough review of the survey information for the selection of key variables that were used in the statistical analysis.

For the selection of variables, we used a framework built on four pillars. First, we based it on a structural typology, centering mainly on variables that describe resources and asset levels (Alvarez et al., 2014) and those variables related to their interactions with the environment (e.g., salinity, temperature). Second, we considered different recommendations regarding farm typology construction. Among them, key recommendations are related to the limited number of variables that researchers should use for typology construction (Kostrowicki, 1977) or with the factors that should be accounted for to discard some variables (Aldenderfer and Blashfield, 1984; Daloğlu et al., 2014; Escobar and Berdegué, 1990; Köbrich et al., 2003; Valbuena et al., 2008). The average value of each variable between 2008 and 2013 was used. Third, for the data control of the PCA, we checked data, finding missing values, potential errors, outliers, strong correlations and controlling for variable distribution. We first ran a PCA analysis to assess 1) those variables not well represented on the planes identified and 2) those variables that seem not to provide additional information. Next, a second PCA run was made to test whether the percentage of explained variability increased. The variables used for the final PCA analysis are the collectors installed (Inst_coll), the Total cost of production (Ttl_cst), funds received (Funds), training hours (Hrs_train), Share of woman in the production group (Female), the number of member in the production group (Members) and the salinity presented (Salt).

Once the last key variables were selected, we ran the final PCA analysis using R-package 'ade4' (Chessel et al., 2004; Dray and Dufour, 2007; Dray et al., 2007) and determined the principal components (PC) using the Kaiser criterion, where all axes with an eigenvalue higher than one were chosen (Alvarez et al., 2014). We also calculated the cumulated percentage of variability, considered as a criterion previously fixed, that the number of PC chosen must explain 60% or more of the variability (Hair, 2010). Finally, we applied a Hierarchical Clustering (HC) over the PCA results using the WARD method (Ward, 1963). We chose the number of clusters based on the overall appearance of the dendrogram, the number of clusters and their interpretability, and an examination of the heights delta (James et al., 2013). A complete report of the PCA and cluster analysis with their results can be found in Appendix A.

3. Results and discussion

3.1. Principal component analysis and cluster results

The clustering performed on the outputs of the PCA is presented in Fig. 2. This figure shows in the left-hand panel a bar plot of the height, which is an indicator of the dissimilarity within clusters related to the number of clusters. The bar on the far right shows the maximum dissimilarity (all seed production groups grouped in one cluster). The heights decrease from right to left in the bar plot figure, and the overall structure of the dendrogram (right-hand panel) suggest to make the partition of the dendrogram at the height of approximately 13 (the dotted line), leading to the partition of the dendrogram into 4 clusters.

Fig. 3 shows the results of the Principal Component Analysis, and

[1] http://www.fundacionchinquihue.cl/web/?cat=57.

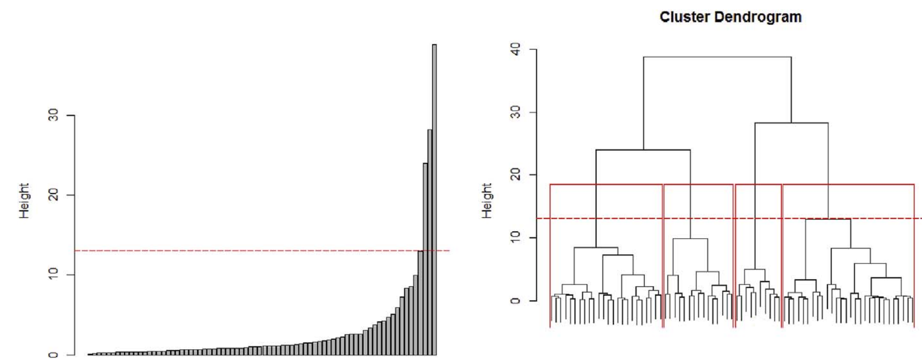

Fig. 2. Bar plot of the height and dendogram.

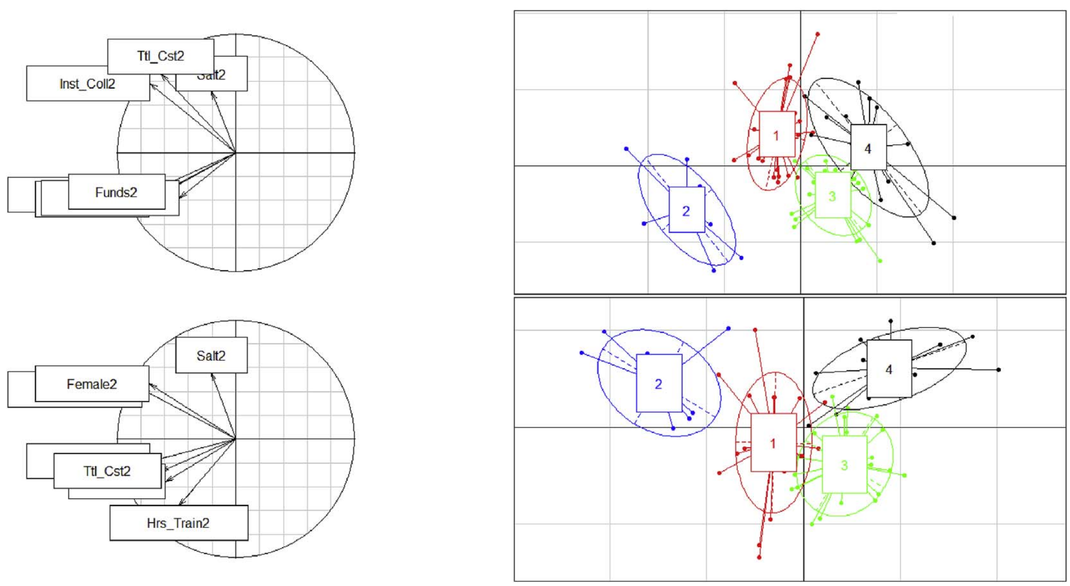

Fig. 3. Results from the principal component analysis and hierarchical cluster.

the hierarchical cluster used together to interpret the meaning of each cluster. In the left-hand panels, we have plotted the correlation circles of the variables selected for the principal components PC1-PC2 and PC1-PC3. The right-hand panels show the positioning of the mussel seed production groups in the principal components planes PC1-PC2 and PC1-PC3. Considering correlations greater or equal to 0.50 for interpretation purposes, Fig. 3 shows that the first component (PC1) was closely related to the variables describing number of members (*members*) and collectors installed (*Inst_Coll*). Thus, it seemed to explain the human capital and equipment intensity of seed producer groups. The second component (PC2) correlated with Total Cost (*Ttl_Cst*), while the third component (PC3) was related to environmental variables (*salt*).

3.2. Cluster description

In the application of the PCA and HC analysis to the 86 surveyed mussel seed production groups, four groups were identified. We named them based on two features, 1) their equipment intensity, based on the ratio between the number of harvested collectors per worker of each group; and 2) the number of members of each group. The main characteristics of the clusters resulting from PCA and HC analysis are presented in Table 1.

The four clusters generated represent four different mussel seed production group types, representing the heterogeneity of the organizational structure and their difference in equipment intensity and environmental conditions within MEABRs. From these group types, 59.7% belong to the Hualaihue district, while 40.3% belong to the Cochamó district. A detailed description of each of the producer group types follows below:

3.2.1. High-equipment-medium-size

This is a highly equipment intensive group type (1879 collectors/producers) with a medium-small size (in a range of 2–3 members). This type of seed uptake group accounts for 36.4% of all teams surveyed, and 85.7% of them belong to the commune of Hualaihue. It presents the greater average concentration of salinity observed (25 ppt). Labor and fuel costs represent 49.7% and 26.6% of total costs by the collectors, respectively, also presenting a higher average total cost for the all production process ($923,023 CLP). On average, they present production losses of nearly 17%. A total of 96.5% of all seed producers within this group perform complementary activities, with the seed uptake process being the most important (in terms of profit) for 57% of the group, while artisanal fishing is the most important activity for 25% of them.

3.2.2. Low-equipment-big-size

This is a low equipment intensive group type, with an average of 294 collectors/producers, with a large size. This cluster represents mainly those producers working in an organization that has an average of 19 members, representing 12.9% of all groups surveyed, where 60% of them belong to the district of Hualaihue. Among the four clusters observed, this group presents major government support in the form of initial funding, with an average of $2,984,522 CLP by the group. They present an average of 6% of production losses, and labor and fuel costs

Table 1
Mussel seed producer typology.

Cluster	Coll_Ins (#)	Contr (%)	Fem (%)	Members by group	Train (acc. hours)	Fund (th. $CLP)	Salt (ppt)
High-equipment-medium-size	4885	36	23.1	2.6	46.7	659.53	25.04
Low-equipment-big-size	5442	58	43.7	18.5	61.7	2984.52	21.8
Mid-equipment-small-size	1396	0	21.2	1.6	66.9	180.84	15.9
High-equipment-small-size	1751	54	17.3	1.5	0	99.00	24.9

Coll_Ins: Average Collectors Installed by group; Contr: Average share of contracts by group; Fem: Average female participation; Train: Average Accumulated training hours per group; Fund: Average Funds received by group; Salt: Average Salinity per group.

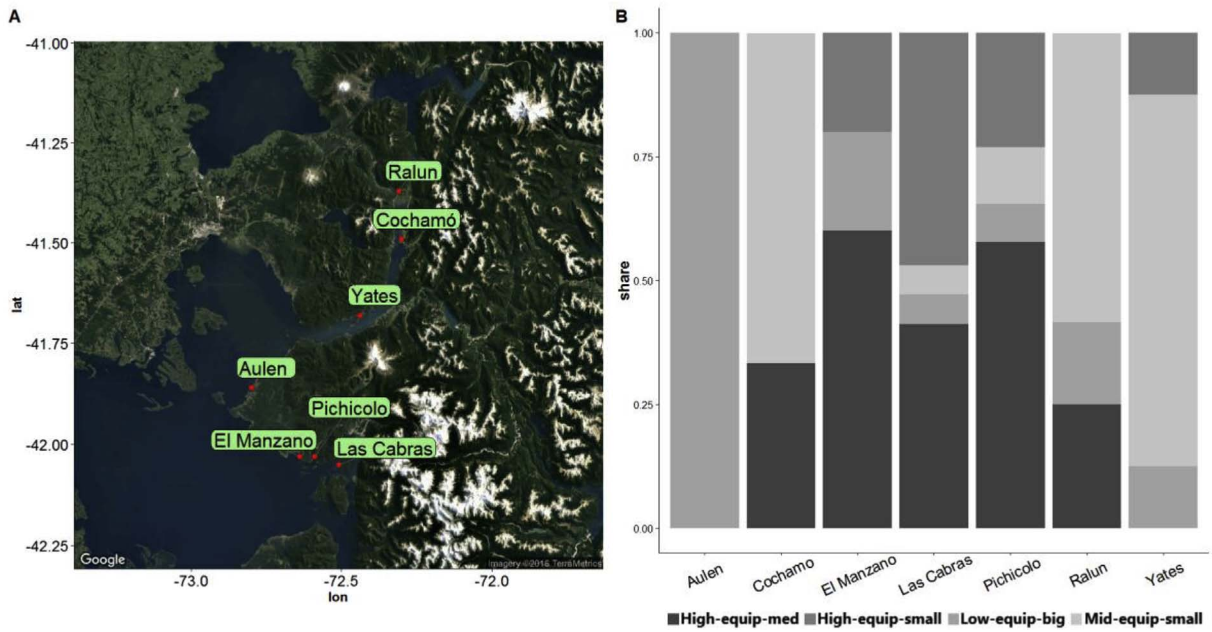

Fig. 4. A) Maps with sectors surveyed B) Distribution of cluster within each sector.

represent 52.7% and 21.9% of all cost by collectors, respectively, with an average total cost for the entire process of nearly $820,000 CLP. All the fishermen that belong to this group perform seed uptake as a complement to other economic activities. Among these activities, seed uptake is the most important for 50% of producers, artisanal fishing for 40% and diving for salmon farms for 10%.

3.2.3. Mid-equipment-small-size

This is a medium equipment intensive group type, with an average of 872 collectors per producer, with a small size regarding members by group (in a range of 1–2 members). This type of seed uptake group accounts for 31.2% of all teams surveyed, and 87.5% of them belong to the district of Cochamó, while 12.5% belong to the commune of Hualaihue. The largest share of teams surveyed of this cluster belong to the Cochamó commune, which explains the lowest level of salinity (15.9 ppt). The average age of the producers of this cluster is approximately 40 years, and they are the most experienced producers among the four clusters observed, with an average of 5 years of experience. Moreover, the average accumulated hours of training are high compared with the other clusters (67 h). Labor and fuel costs represent 44.9% and 37.2% of total costs by the collector, respectively, with an average total cost of $213,435 CLP. On average, they present a percentage loss between 12% and 15%. A total of 87.5% of all seed producers within this group perform complementary activities, with seed uptake the most important for 37% of producers, diving for 29% of producers and fishing for 16.7%.

3.2.4. High-equipment-small-size

This is a highly equipment intensive group type (1167 collectors/producers) with a small average size (in a range of 1–2 members). This cluster represents mainly the youngest and least experienced producers, with an average age of 36 years and less than three years of experience. In addition to this, they do not have any accumulated hours of training. Considering the average size of this production group type, most of their members work as a group team of two people or organize production individually. This seed production type group represents 19.5% of all groups surveyed, and 86.7% of them belong to the commune of Hualaihue. Among the four clusters observed, this group obtains the least economic support from the government in the form of initial funding, with an average of $99,000 CLP. They present an average of 6.8% of collector losses, and labor and fuel costs represent 39.7% and 35.8% of all costs by the collectors, respectively, with a total cost for the entire production line of $210,980 CLP. This is the group with the lowest level of producers doing complementary activities (80%). Among those producers, seed uptake is the most important activity for 53.3% of them, while fishing is the most important for 26.6%. The remaining 20% work in other jobs.

3.3. Spatial analysis

The four clusters presented above are related to environmental conditions and landscape elements. Thus, it is important to highlight that the mussel seed production process is a spatial activity. In this context, to assess the relationship between the group types and the geographical conditions, it is useful to understand their distribution and the spatial organization of the different group types. In Fig. 4 (Panel A), we present a map with the location of the seven sampling stations where the environmental data was extracted, which represent the geographic space where the seed uptake process is developed by the different groups. Among them, the sectors of Ralún, Cochamó, and Yates belong to the district of Cochamó, while the sectors of Aulén, El Manzano, Pichicolo and Las Cabras belong to the Hulaihué district. Panel B of Fig. 4 shows the distribution of the four clusters identified close to the seven sectors described.

Panel B of Fig. 4 shows that the sectors of the Cochamó district mainly comprise mussel seed producers belonging to the *Mid-equipment-small-size* group type. The analysis revealed that 87.5% of the *Mid-equipment-small-size* group type is in this district, particularly in the sectors close to Yates and Ralún. The Communities of the Reloncavi estuary (Cochamo district) have been established as clean natural areas with traditional seashore cultures (Skewes et al., 2012), with high mussel seed potential and with good transport links to and from the region's port (s). Additionally, since the 1990s, the estuary has been the base for several projects and interventions with the aim of increasing the productive and commercial capacity of the local economies (Saavedra Gallo and Macías Vázquez, 2016), particularly those activities related to mussel seed uptake (e.g., FONDEF-HUAM Project[2]). The socioeconomic, environmental, cultural and development features of the estuary may have played a major role in the characteristics of this group. First, the traditional seashore culture and the sufficient conditions for seed uptake probably influenced for the establishment of producers that are currently the most experienced. Second, both the good links to urban areas and the several interventions conducted in the estuary likely provided more availability of training activities for them. Finally, it is important to mention that due to the hydrobiological conditions of this area, a high-quality fattening process in the estuary is not possible (Saavedra Gallo and Macías Vázquez, 2016), a condition that may play a major role in the absence of contracts for this group, who probably sell to local intermediaries.

The sectors that belong to the Hualaihue district are mainly held by highly equipment intensive groups, particularly those sectors at the southern part of the study area (close to El Manzano, Pichicolo and the Las Cabras sectors). Their high intensity on equipment is probably due to both socioeconomic factors and environmental conditions related to the spatial location. On the one hand, their equipment intensity is likely related to the low number of members participating in the seed uptake. In this case, both group types (*High-equipment-medium-size* and *High-equipment-small-size*) have a range of members between 1 and 3, so the number of collectors per producer is greater than 1000. On the other hand, an environment with favorable conditions probably strengthens productivity in this area. Several authors have indicated that greater concentrations of salinity are favorable for the growth and reproduction of mussels (Braby and Somero, 2006; Helm and Bourne, 2006; Rajagopal et al., 1998). Helm and Bourne (2006) indicate that the gametes from bivalve mollusks that are cultivated mature in conditions of salinity concentration higher than 25 ppt. In this case, our results show that both groups present the highest salinity concentration among the clusters observed (see Table 2). In this case, it is important to highlight that, despite the similarities regarding intensity of equipment between both groups, differences arise regarding the policy instrument that they receive. There is a highly equipment intensive group that is not receiving policy supports through funding and training courses for producers (*High-equipment-small-size*). However, the fact that both groups mostly share the same areas discards spatial localization as a factor that may contribute to the non-receiving of policy instruments.

Finally, it is important to mention that the cluster *Low-equipment-big-size*, although it represents just 13% of all groups surveyed, is the only group that is relatively distributed in an even way among the sectors that comprise the study area. Thus, it is hard to draw conclusions about their characteristics and their relationship to the geographical space and its conditions.

[2] http://www.conicyt.cl/fondef/lineas-de-programa/instrumentos-pasados/huam/.

3.4. General discussion and policy implications

Artisanal small-scale fishers have been recognised during the last decade as a key sector for poverty alleviation and food security, especially in developing countries (Béné et al., 2007). The engagement of small-scale fishers in the aquaculture supply chain is going to play a fundamental role in addressing these challenges. The mussel industry in Chile is a good example of engagement of small-scale fishers within aquaculture, in which they are considered the main responsible for the process of mussel seed uptake. Although this link has proved to be an important source of income for fishers, there are still gaps regarding the design and implementation of management and policy aimed at supporting and encouraging entrepreneurship in the aquaculture sector. These gaps, are mainly related to the assumption that small-scale fishers will respond homogeneously to different challenges or to a given policy. Our results, shed lights about the variability among groups of fishers, suggesting that their responses to different challenges or policy instruments depend on their characteristics.

In a first place, the results revealed a positive connection between the number of entrepreneurs who comprise the production team and the funding received. This result has two implications. On the one hand, the literature indicates that the number of members of an organization is a sub-dimension of social capital (Rosas et al., 2014). In this sense, the literature suggests that those organizations that possess high social capital (as based on extensive social networks and network size) are more likely to receive funds from private or public sectors than those organizations that are lower on this dimension (Baron and Markman, 2003). On the other hand, some evidence suggests that fisher groups with high social capital are likely to receive income from complementary activities due to the low incomes earned in the fishery activity (Rosas et al., 2014).

Our results have shown that the *Low-equipment-big-size* cluster has the greatest number of members and it is who accounts for higher fund availability. At the same time, this cluster accounts for a smaller number of collectors installed per member, which indirectly indicates less individual income per member. In line with previous studies (Rosas et al., 2014), the relevance of complementary activities as income source is high. Indeed, it is the only group in which all producers receive income from complementary activities, with seed uptake being the most important economic activity for 50% of the producers and fishing the most important activity for 40% of them. A reasonable hypothesis in this regard is that the funding aimed to support the activity is not helping to increase the income coming from seed uptake activities. Thus, fishermen should look for complimentary activities to fill the income gap.

The results also revealed differences in the percentage of collectors with contracts across group types. Despite several studies establishing that contracts are a tool designed to reduce risk and transaction costs (Karaan, 2002; Larsen and Asche, 2011), our results show important differences regarding the production sales contracts among all clusters, with variables such as age and distance as potential explanations. For instance, the *Mid-equipment-small-size* production type (with a relatively large share of older producers) is less likely to use contracts than the other groups, which are characterized by younger participants. These findings are consistent with studies in the agricultural industry (Bellemare, 2012; Davis, 2002; Simmons et al., 2005; Wang et al., 2014) that indicate that the younger producers are more likely to be involved in contracts than older producers. On the other hand, the distance to the subsequent link in the productive chain seems to have an important influence in whether there are sales contracts in place. As it was shown in Fig. 4, the hydrobiological features of the Reloncavi estuary (Cochamo district) are not appropriate for the fattening subsector (which is the subsector that uses the seeds as input). Thus, the producers located in this area, such as the *Mid-equipment-small-size group*, are likely involved in networks of local intermediaries who do not use contracts as a model of commercialization.

The analysis of the spatial distribution of seed production group types revealed that both highly equipment intensive clusters (*High-equipment-medium-size* and *High-equipment-small-size*) are located mainly in the Hualaihue district and their local communities. Although this high intensity in equipment is likely a consequence of several socio-economic and environmental factors, our results shed light on the importance of spatial location in this context and how this may play a major role in the equipment intensity levels' decision. Among the environmental conditions associated with the spatial location and equipment intensity, salinity may be an important factor and can be a proxy for different environmental conditions (e.g. temperature). Communities from the Hualaihue district move away from the intake of freshwater that the producers who inhabit the Reloncavi estuary receive; therefore, they develop their activities in an environment with higher salinity concentrations. This condition has been suggested by the literature as an important factor for the growth and reproduction of mussels (Leiva et al., 2005).

An interesting finding is the difference across groups with a high ratio between the number of collectors installed and their number of members, regarding the benefits received from policy instruments, such as funding or training courses. Despite both *High-equipment-medium-size* and *High-equipment-small-size* clusters share the same location, presenting high levels of equipment intensity, and having similar work organization forms, policy instruments are unevenly distributed among them. The *High-equipment-small-size* cluster has the lowest level of funding without any accumulated hours of training. In this case, the absence of technical assistance suggests that this cluster is one of the most vulnerable in the region. This finding is in line with similar studies that have underscored how groups without support are more vulnerable to environmental or market changes (Marques et al., 2016). The vulnerability identified in this study can be an important warning information about where technical assistance and support are needed.

Policies aimed to reduce artisanal fishers vulnerability and strengthen the synergy between small-scale fisheries and aquaculture should consider the findings previously discussed. Indeed, two facts should be underscored: 1) a uniform policy cannot fit everyone needs and 2) the capacity of income generation of the seed uptake sector is mainly driven by environmental variables (salinity). Thus, policy interventions are confined to the way in which fishers are organized, perform their tasks, and provide incentives for entrepreneurship in aquaculture.

One possible strategy is to follow the Food and Agriculture Organization (FAO) recommendations regarding strengthening fishers organizations and collective action (FAO, 2014, 2016b). By encouraging collective action, considering fishers heterogeneity, it is possible not only to improve their access to services and markets that will increase their seed uptake income, but reduce the inequalities on the negotiations with the industrial sector, decreasing their dependency on intermediaries and encouraging greater engagement of these small-scale fisher entrepreneurs in the aquaculture supply chain.

4. Conclusion

Small-scale fishers participation in the aquaculture supply chain can be critical for the industry.

In Chile, small-scale fishers have become entrepreneurs engaging in mussel seed production processes that are fundamental for the entire mussel aquaculture industry. Thus, the development and growth of the mussel seed uptake process is a priority; however, such development and growth are challenged by different environmental and economic factors. Therefore, coping with these challenges is a key element that requires the attention of policy makers and researchers, who need to improve their understanding of producer groups' responses to both environmental and economic variables and the public policies aimed at tackling these problems.

The output of our multivariate analysis indicates that four clusters represent the heterogeneity of the organizational structure and their differences on equipment intensity and environmental conditions. The results emphasize several aspects that deserve consideration to formulate appropriate policy instruments for seed producers, understand how these interventions can be distributed in a large scale, and produce the basis for comparative analysis. Our representative classification of mussel seed producer groups in the Los Lagos region reflects the complexity of this subsector, which is often thought of as a homogeneous group. This finding is particularly useful for researchers and policymakers, as it outlines policy domains around which targeted interventions can be assessed, Further, our results suggest that the spatial component and its environmental conditions are important factors in determining the heterogeneity of seed uptake groups, directly on variables such as the intensity of equipment used or indirectly on variables such as the share of collectors with sales contracts. This is useful information for policy makers wishing to design and assess policy instruments that incentivize the use of sales contracts to reduce the risk of seed producers under scenarios of market and price variability. Additionally, under climate or environmental scenarios that negatively affect the seed uptake process, our results shed light on the different responses that groups localized in different districts will probably have, thus allowing for targeted policy interventions.

On the other hand, an important contribution to the subsector and for policy makers is the finding that there is a significant difference in the way current policy instruments are working for different producer clusters. Our findings suggest that current policy instruments, such as funds or training courses, seem to be unevenly distributed in the study area. Identifying the heterogeneity of the seed uptake subsector revealed the co-existence of different groups in similar spaces, where the key difference is access to these policies. Related to the later, the producer typology could assist policy makers on the instrument design to foster each group according to their characteristics. Our findings identify those groups that are more vulnerable to market and environmental stressors, providing valuable information for stakeholders and policymakers to target assistance and support where needed.

Finally, for future research, we highly recommended the complementary participation of seed producers themselves in typology construction. Although our results are reproducible and generalizable, due to the quantitative technique applied, stakeholder participation through qualitative methods may incorporate further insights into the factors that drive diversity and a greater understanding of likely responses to future challenges and policy interventions.

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Conflicts of interest

Disclosure of potential conflicts of interest: Authors declare that they do not have a conflict of interest.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ocecoaman.2018.03.013.

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