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*Article*

# Performance and Challenges in the Value Chain of the *Anadara Tuberculosa* Bivalve Mollusk in Ecuador

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# Abstract:

The bivalve mollusk, Anadara *tuberculosa* (Black Shell, in Spanish Concha prieta, "CP"), is found on America's Pacific coast, where it is harvested for subsistence and commercial markets. This paper aims to diagnose the performance of the black shell's value chain. We also identify several challenges that must be addressed to improve the sustainability of the black shell fishery in Ecuador. The descriptive methodology was quantitative, with a non-experimental, field, cross-sectional, and ex post facto design. Similar questionnaires were designed, validated, and applied to each link in the production chain to collect information. The performance of the value chain was diagnosed in the dimensions of productivity, competitiveness, and quality of life, reaching a 75.1% index, a result that indicates that the value chain has a moderate to good performance level. However, the value chain can be improved if the following challenges are met: 1) Restoration of the mangrove ecosystem, 2) Promotion of low-intensity shellfish aquaculture, 3) Good sanitary management and purification, 4) Promotion of value-focused ventures, 5) Strengthening of organizations and agreements for the use and custody of mangroves, and 6) Strengthening of institutions that contribute to the advancement of these challenges.

JEL: D24, Q22, Q56

**Keywords:** Ecuador; American Pacific; Bivalve mollusks; Concha prieta; Value chain; Productivity; Quality-of-life; Competitiveness, Mangrove forest.

## 1. Introduction

From the Economic Commission for Latin America and the Caribbean (ECLAC) vision, economic and social development requires a progressive structural change aimed at activities with greater productive dynamism, favoring the care of the environment [1]. The concept of sustainability has been gaining ground, joining the supply chain (SC) in its three dimensions: economic, which translates into profitability to operate as a business; social, which includes fair, safe, equitable labor practices; and environmental, which refers to the responsible use of natural resources and the reduction of waste generation and polluting emissions. Environmental sustainability challenges are associated with more sustainable, productive activities in rural areas, emphasizing mitigation and adaptation to climate change [2]. In particular, inclusive growth is promoted by scaling up or complementing activities that produce greater added value [1].

This environmentally oriented approach considers the sustainable supply chain concept to preserve and protect natural resources to ensure their future availability [3]. The value chains of rural goods are usually made up of small producers who face various barriers to increasing productivity and competitiveness. For these reasons, scholars have

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suggested that productivity and competitiveness can be achieved through better articulation of the links, incorporating new actors, and economic and social improvements [4].

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For this research, the performance evaluation of the value chain is considered as the results obtained in a balanced way in terms of productivity, competitiveness, and quality-of-life by the organizations, entrepreneurs, and workers involved [5].

In this sense, productivity is seen as the relationship between the product generated in any production process and a unit of the factor or resource used for a given period [5]. While competitiveness is considered the effectiveness in meeting objectives, the value chain aims to achieve benefits by placing its products on the market [5]. The beneficial impacts expected as a consequence of increased productivity and competitiveness must be accompanied by advances in the participants' quality-of-life. This variable identifies certain shortcomings of the population. It characterizes poverty, defined as the situation of those households that fail to gather, in a relatively stable way, the necessary resources to satisfy the basic needs of their members [5].

This study assesses the performance of the value chain (VC) of *A. tuberculosa*, a bivalve mollusk commonly known as blood cockles or black shell found in mangrove forests along the Pacific coast from Mexico to Peru [6]. On the Ecuadorian coast, this mollusk is present mainly in the provinces of El Oro and Esmeraldas.

The cultural importance of *A. tuberculosa* lies in the fact that it constitutes the basis of the food diet and source of economic support for some 4,000 families of Ecuador that depend directly on the mangrove ecosystems [7]. It is a resource associated with the mangrove forest, and with adequate management, it can contribute significantly to the preservation and expansion of the approximately 160,000 ha currently found in Ecuador [8]. While the contribution of this shellfish to the Ecuadorian Gross Domestic Product is small compared with larger commercial sectors like bananas and shrimp, the production and commercialization of *A. tuberculosa* have great potential to satisfy the internal demand of Ecuador. It may further contribute to the expansion of Ecuador's export sector to neighboring countries and the possibility of venturing into the most demanding markets of the United States of America, Europe, and China. This study diagnoses the value chain performance of *A. tuberculosa*. It reveals its potential for a harmonious balance among shellfish collectors, traders, and restaurants, based on the dimensions of productivity, competitiveness, and quality-of-life [9]. The study further identifies challenges that must be addressed to improve sustainable economic and social use in harmony with the mangrove ecosystem.

## 2. Materials and Methods

The applied methodology was quantitative and descriptive [10]. Its design was non-experimental, field, cross-sectional, and ex post facto [11].

The research was carried out from January to October 2019 in the Jambelí archipelago, El Oro province, Ecuador (Figure 1), one of the most important shellfish capture areas in the Republic of Ecuador due to its high landing volumes [12], similar to those of the province of Esmeraldas.

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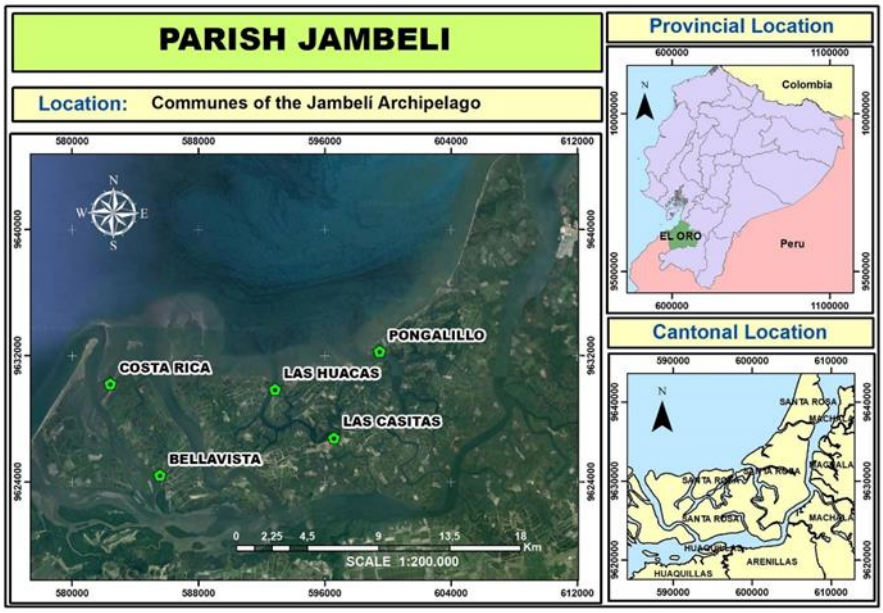


**Figure 1.** Location of research: Jambelí archipelago, El Oro province, Ecuador.

Source: Authors

The population under study was integrated by 565 individuals, made up of the strata of shellfish collectors, managers of shellfish associations, traders, and restaurants of the *A. tuberculosa* production chain, based on the information collected from the Unión de Producción Pesquera Artesanal de El Oro, Ecuador (UOPPAO), from the Asociación de Empresarios de Comercio y Servicios de la Provincia de El Oro, Ecuador, and through the on-site review of the restaurants located on the islands and in the area's coastline.

The sample size was estimated in 222 informants through the formula proposed by [13], using the following equation:

$$n = \frac{PQ}{\left(\frac{E}{Z}\right)^2 + \left(\frac{PQ}{N}\right)} = \frac{(0.5)(0.5)}{\left(\frac{0.0513}{1.96}\right)^2 + \left(\frac{0.5 * 0.5}{565}\right)} = \frac{0.25}{0.000685 + 0.000442} = \frac{0.25}{0.001126} = 222$$

Where:

- $n$: Sample size
- P: Probability of success (50%)
- Q: Probability of failure (50%)
- Z: Standardized normal table value associated with the confidence level (1.96)
- E: Maximum permissible error (5.13%)
- N: Population size (565)

The type of sampling used was probabilistic, random, stratified, and with proportional allocation, with an effective participation rate of the selected ones of approximately 80%. Those selected who could not participate were replaced by the next individuals on the sampling list.

To collect information, questionnaires were first designed, validated (opinion of academic experts and managers of the shellfish associations). Four similar questionnaires were applied to each link in the production chain: 138 shellfish collectors, 12 shellfish association managers, 27 traders, and 45 restaurant-cevicherías. Questions were designed to measure the performance construct of the value chain, its respective dimensions, and indicators.

The questionnaire was applied personally through the structured survey method, in writing and in each of the respondents' work areas. The research team traveled monthly to collect field information until the estimated sample quantity for each stratum was

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completed. The interviewer read the questions and possible answers to the respondents, and they responded freely. Finally, the interviewer marked or wrote the responses, as the case might be, on the questionnaire until it was completed.

The structured survey questionnaire was administered via face-to-face interviews. The performance construct of the *A. tuberculosa* value chain had three dimensions: productivity, competitiveness, and quality of life.

The original questionnaire was structured in two sections. The first one, of identification or classification, inquired about gender, location, experience, age, and association; with dichotomous, multiple- and open-answer questions. The second section explored the performance construct of the value chain and its dimensions, productivity, competitiveness, and quality of life. Most of the questions were formulated to be answered with the Likert scale.

The predominant measurement scale was the Likert scale with values from 1 to 5, representing the value of 1 "never," the value of 2 "rarely", the value of 3 "sometimes", the value of 4 "almost always," and the value of 5 "always". This 5-degree scale was transformed to a 100-point scale through extrapolation to convert it into an index that could be interpreted more intuitively, representing 100 points as the maximum desirable value for each dimension under study. Multiple scales and open questions were also applied for quantitative indicators and the identification of the remains.

The Concha Prieta Value Chain Performance Index (VCPI) is an original contribution of this research. It is an average of the competitiveness (CI), productivity (PI), and quality-of-life (ICL) indices. The method used to estimate these indices was developed by [14] and integrates the actual variables or response indicators observed in the questionnaire based on the Likert scale. The scale is transformed from the value of 1 to 5 to a value based on 100 points using the following model equation:

$$VCPI = \frac{\left(\frac{\sum Points}{Dimension\ IC}\right) * 100 + \left(\frac{\sum Points}{Dimension\ IP}\right) * 100 + \left(\frac{\sum Points}{Dimension\ QLI}\right) * 100}{n\ Dimensions}$$

Where:

- VCPI: Value Chain Performance Index.
- Points: These are the scores assigned by the interviewees to the different items based on the Likert scale of the applied questionnaires (1 to 5) for each dimensión.
- Dimension: Total value (5 * Number of Indicators) of the corresponding dimension (Competitiveness, Productivity, and Quality-of-life).
- n: Number of dimensions that apply (n = 3).

The same procedure was applied for each of the dimensions. The scores assigned by the interviewees to each item of the questionnaire in the respective dimension were added and then divided by the maximum value that can be obtained in each dimension (5 * Number of Indicators) to finally multiply by 100. In this way, the Likert scale is transformed into a percentage scale.

According to this research objective, the data recorded in the questionnaires were statistically processed with the SPSS v. 23.0 through univariate tests.

Once the data had been processed, considering the background obtained from the bibliographic review, the results obtained, and the researchers' experience, the most significant challenges for this supply chain were prioritized based on the performance achieved.

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## 3. Results and Discussion

### *3.1 Performance of the Anadara tuberculosa supply chain*

The results are presented and analyzed based on the dimensions of competitiveness, productivity, quality of life, and the subdimensions and indicators that compose them.

In this sense, as an original contribution of this research, the value of the performance index of the *A. tuberculosa* value chain was estimated at 75.1%. This result indicates that the value chain has a moderate level of performance in terms of competitiveness, productivity, and quality-of-life [9].

The competitiveness dimension was the one that obtained the highest index with 80.2%, followed by the productivity dimension with 77.1%. The lowest value was in the quality-of-life dimension, 67.3% (Figure 2). These results reflect that the human dimension of the value chain performance is the one that has a less favorable performance, based on the evaluated indicators, which will be explained below.

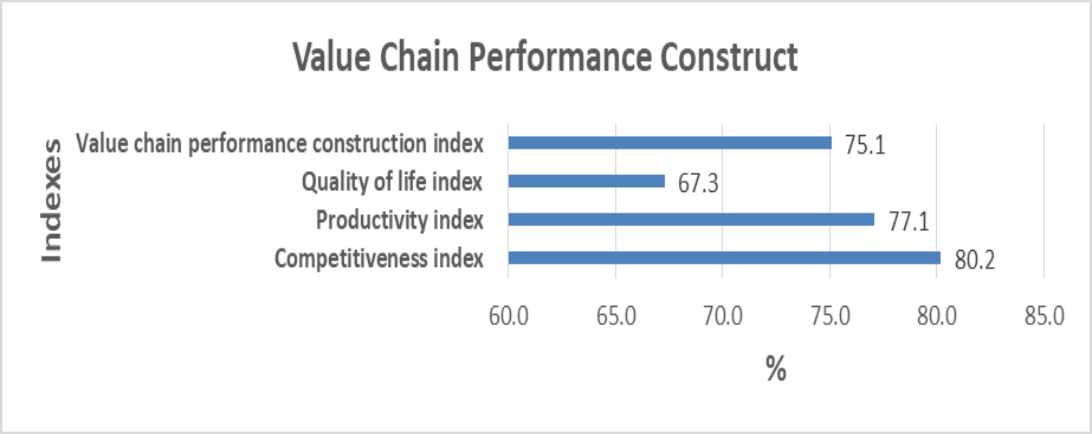


**Figure 2.** *Anadara tuberculosa* Value Chain Performance Indexes

Source: Authors

The competitiveness dimension comprises the subdimensions leadership in costs, differentiated product, and market segment, with their corresponding indicators. The highest levels of competitiveness are achieved, to the extent that production costs are kept below competitive products (shells from neighboring countries) and complementary products (other types of shellfish and seafood in general). Unique and desirable attributes are preserved and developed that allow the experience lived by end-consumers to be rewarding and memorable and to be able to position themselves in specific market segments that value their unique attributes and pay what corresponds to their value.

The productivity dimension was integrated by the indicators of the physical productivity subdimension and economic productivity. The productivity dimension investigated whether production was sufficient to satisfy customer demands, as Prado-Carpio *et al.* [15] indicated. In the economic productivity subdimension, it was evidenced that the participants in the CP production chain have always experienced moderate improvements in their income (35.4%). In comparison, 23.1% experienced that their income has rarely increased [15]. However, the monthly revenue per shell collector was estimated between 427 and 640 USD, a range below the basic family basket in Ecuador, 712.11 USD, equivalent to a 40% to 10% deficit.

Finally, in the quality-of-life dimension studied by applying the Unsatisfied Basic Needs (UBN) methodology, the results obtained indicate that those who participate in the A. tuberculosa supply chain have homes with relatively adequate domestic equipment for wastewater disposal. Wastewater is discharged mostly without pretreatment on the coast and the mangrove swamp, negatively affecting the quality of the environment where the mollusk breeds. On the other hand, there is no overcrowding in the houses, but the

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dwellers' educational level is relatively low, and many families live below the poverty line [16].

*3.2. Challenges of t A. tuberculosa he Anadara tuberculosa supply chain*

Based on the performance achieved [17], a set of challenges arises (Figure 3) that impact each of the dimensions under study (productivity, competitiveness, and quality of life). These challenges can enable the improvement and transformation of the CP supply chain into a value chain. Among them, the following have been prioritized:

- Restoration of the mangrove ecosystem.
- Introduction of good production practices of the *A. tuberculosa*, considering both natural populations and new populations derived from low-intensity aquaculture techniques.
- Implementation of systems of good practices of manipulation and purification of the *A. tuberculosa*.
- Promotion of ventures with a value creation approach.
- Strengthening shell organizations and Mangrove Sustainable Use and Custody Agreements.
- Development of an institutional support system that, based on innovation, contributes to advancing the challenges mentioned above.

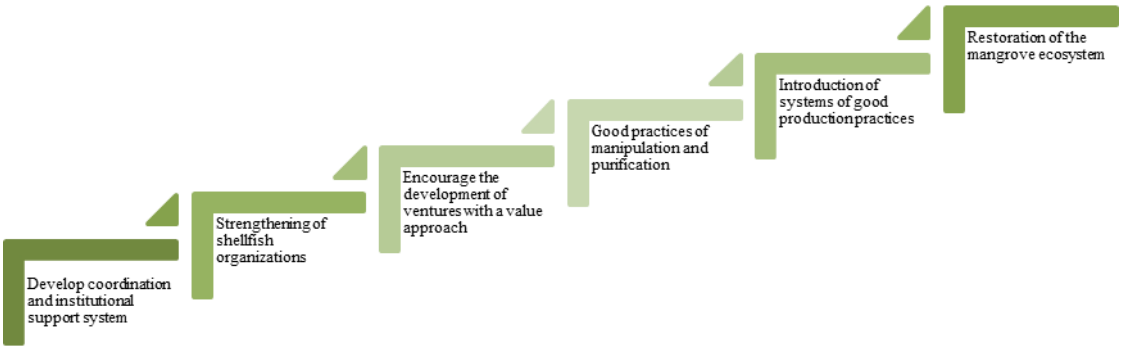


**Figure 3**. *Anadara tuberculosa* value chain challenges
Source: Authors

**Challenge Number 1.** Restoration of the mangrove ecosystem

The integrity of the ecosystem must be addressed to achieve and maintain a healthy supply chain of mangrove products. The mangrove ecosystem provides many goods and services (protection, food provision, $CO_2$ capture, blue carbon reservoir, wood production, habitat for biodiversity), so promoting its sustainable use is a priority.

Mangroves reduce vulnerability to climate change by capturing greenhouse gases, carbon sequestration and storage, erosion control, protection against extreme events, soil formation, and water quality improvement [18-20].

If the homeostasis of this crucial coastal wetland is preserved and complemented with sustainable management, the development of associated species will be allowed during their life cycle. By achieving the sustainable use of the mangrove, it will be possible to obtain a better natural production of the black shell and other biotic resources it supports (fish, crabs, shrimp, snails, among others), necessary to improve the food situation of populations. However, the degradation and reduction of mangrove coverage are affecting its capacities.

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The mangrove forests located on the coastal strip have been subjected to adverse impacts from shrimp breeding, tourism, industrial production, and urban growth, among others). These activities affect the watersheds with deforestation and burning, change the course of tributaries, and runoff of domestic, industrial, and agricultural discharges without adequate treatment [19].

In Ecuador, shrimp farming stands out as one of the practices with the most intense effects on mangroves since large areas are cut down to install breeding pools, and significant quantities of chemical products are used (food, fertilizers, pesticides, and antibiotics), with the direct contamination of the ecosystem.

Pollution caused by domestic effluents without treatment and containing concentrations of nitrogen, phosphorus, chlorides, sulfates, carbonates, and organic compounds can also present microbiological pathogens that are a human health risk [20-22].

The most applied practice to recover the mangrove surface has been reforestation. In this sense, [23-24] point out that this technique, whether by direct planting, seedlings produced in the nursery, dispersal by casting, or transplanting individuals from a nearby area in good conditions, has given good results in Mexico.

With associated actions, hydrological rehabilitation is another of the most frequently implemented strategies in mangrove restoration [25].

Every restoration project must include a program for diagnosis, implementation, monitoring, and training for those involved [26-27].

Based on these considerations, to achieve the restoration of the mangrove ecosystem, the following strategic objectives are proposed:

- Prevent, control, or mitigate all those impacts generated by anthropic pollution sources from industrial, agricultural, and domestic activities without physical-chemical-bacteriological treatment in all landscape units that make up the watersheds of mangrove forests.
- Prohibit the establishment of shrimp pools in the areas of influence of the mangrove ecosystem or, in any case, when new spaces are established in these sensitive areas compensate the negative impact with the sowing and replanting of mangrove surfaces.
- Improve the disposal of solid domestic waste mainly, favoring the reduction, reuse, and recycling.
- Developing programs for the maintenance or improvement of the environmental quality of the mangrove ecosystem will allow for a lower pollutant load towards the shellfish and, therefore, the final consumer.
- Promote restoration/reforestation actions of the mangrove ecosystem and its truly comprehensive associated resources.
- Promote integrated forest-aquaculture systems, where mangroves are planted near and within aquaculture pools.
- Reinforce the role and coordination with local communities to achieve success in mangrove ecosystem recovery programs.
- Consider carbon bonds or carbon credits as a strategy that allows mitigating the generation of greenhouse gases, benefiting companies that do not emit or reduce emissions and making those that surpass their allowed emissions pay.

**Challenge Number 2**. Introduction of systems of good production practices of the CP, both natural populations and new populations derived from low-intensity aquaculture techniques.

The *A. tuberculosa* grows and develops naturally, closely linked to the mangroves located on the coastline. Maintaining the balance of this ecosystem will allow its sustainable production. However, the mangroves are subject to intense pressures, as mentioned previously, which negatively affect the natural production of the CP, coupled with their overexploitation in some Ecuadorian coastal sectors.

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Therefore, based on the existing scientific experiences and the successful ones of the shellfish collectors, it is recommended to develop good practices that contribute to the restoration of the mangrove forest and shellfish production. The goals should be to preserve and stimulate the natural production of the black shell in the mangrove areas less affected by pollution and deforestation. The introduction of low-intensity aquaculture techniques in the most affected areas, which require an additional effort to stimulate mangrove restoration and *A. tuberculosa* breeding, should also be considered.

On the other hand, some studies have shown that the growth rate of *A. tuberculosa* varies between 1.54 [28] and 1.875 mm/month [29]. It could reach the commercial size in the span of one or two years, depending on growth conditions. Despite these challenges, sustainable aquaculture can represent a particular safety net for families dependent on this resource.

In this sense, to preserve the natural production of the black shell in the mangrove areas less affected by pollution and deforestation, the following strategic objectives are proposed:

- Encourage the natural production of *A. tuberculosa* in the areas least affected by anthropic activity through management practices. Among these practices, we can include self-aging or designation of periods in which they are not collected, scheduling of shellfish collecting activities, rotation of extraction areas, and pens to extract the shellfish in demarcated areas [30,31].
- Regulate the extraction of seeds from banks in times of exceptional abundance or scarcity based on purely technical criteria.
- Establish production goals in the different collecting areas, based on the dynamics of the market and the preservation of the resource, complying with the 45 mm total length (TL), which is established by the Ecuadorian standard for its extraction.
- Apply controls with sieves, in the manner of a table with iron mesh where all the shellfish collectors deliver their daily catch to avoid the extraction of shells from the mangrove with a size smaller than 4.5 cm total length. Small shellfish that fall through the screen should be seized and returned to the mangrove. Another option is applying sanctions on the number of shells, or reducing the number of days of shellfish collection for those who do not comply with the norm.
- Carry out a geographical delimitation of the coastal sector that considers reforestation, research, and commercial extraction areas.
- Encourage the production of seeds in hatcheries since it would reduce the pressure on natural banks, to repopulate areas with reduced CP populations.
- Strengthen capacities for prevention, control, and monitoring of aquaculture health.
- Promote training programs, including technical training to manage repopulation areas, natural banks, and seed collection.
- Design, disseminate and improve good practice guides for the extraction and production of *A. tuberculosa,* both for traditional systems based on extraction and the development of new production systems based on low-intensity aquaculture techniques. Such practices should improve production in terms of quantity, quality, and restoration of the mangrove ecosystem.
- Encourage the creation of a designation of origin for the Ecuadorian black shell.

**Challenge Number 3.** Implantation of systems of good practices of manipulation and purification of the CP.

The world production of mollusks has been negatively affected by diseases that have become a restriction for the development and sustainability of their culture and exploitation [32].

The shellfish must be free of microorganisms or viruses in concentrations that may constitute a health hazard. It must be free of toxins and chemical compounds such as heavy metals and organic compounds from industrial activities [33].

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In bivalve mollusks, their safety is of great importance since these species feed by non-selective filtration mechanisms, and therefore, they can become concentrators of various pathogens [34]. The preferred form of consumption of bivalve mollusks is raw, without cooking. Therefore, there is a potential risk to the health of the consumers.

Purification is a process that consists of keeping the mollusks in clean seawater tanks in conditions that allow maximizing the natural filtration activity and thus expelling the intestinal content. There are limitations to the types of microbes that can be successfully killed through this process [34].

In the case of the black shell, it is recommended to carry out the purification practice to achieve a safe product, of higher quality, with added value, and more competitive. It can also offer greater profits to producers and marketers and their foray into the international markets of North America, Europe, and Asia.

To face this challenge, it is recommended to advance in the development of the following strategic objectives:

- Carry out studies and monitoring that make it possible to accurately diagnose the quality of the shell that is extracted in the different extraction and production areas defined in the geographical delimitation.
- Implement systems of sound CP processing and handling practices based on techniques such as self-purification.
- Carry out pilot studies to determine the costs involved in establishing the system of good practices for handling and purifying the shell.
- Promote the access of the purified and processed shell to more demanding markets in terms of health and safety.
- Encourage levels of competition in the CP market based on quality and prices.
- Incorporate innovation and technology to ensure that the highly perishable shell reaches all Ecuador and neighboring countries under the recommended safety conditions.
- Demand compliance with safety from its production or extraction to its sale to the final consumer, ensuring that the product is not exposed to new contaminants and that adequate measures are taken for its conservation.

**Challenge Number 4.** Encourage the development of ventures with a value approach.

As previously mentioned, the production of the CP is a traditional business in which the members of the families of shellfish collectors, fishermen, and residents of the coastal areas participate, obtaining income from this activity. In this sense, developing an entrepreneurial and business culture in the participants with a value chain approach with social justice and equity is necessary.

The CP reception, storage, and distribution activities are carried out by the collecting and wholesale intermediaries, who distribute then the shellfish to the retail markets and restaurants. Within this internal logistics, it is convenient to achieve that the shellfish collectors have greater participation in the commercialization margin. This could be achieved through the existing shellfish organizations.

In the town of San Lorenzo, Esmeraldas, Ecuador, shell collectors usually sell the shell for between 8 and 10 USD for one hundred units, depending on the season. The establishments that receive their production sell it to intermediaries between 10 and 12 USD in the same municipality. According to the research carried out, the traders earn 1 dollar for every hundred units and the storage warehouse that buys the least amount per week is an average of 106,000 shells, representing 1,060 USD. If their average profit is one dollar per hundred units, they earn 1,060 USD per week. This translates into a monthly income of 4,240 USD, a much higher value than the income obtained by shellfish collectors. However, the best price at which the traders sell, 0.12 USD per shell, is still much lower than the price charged by restaurants and cevicherías in Ecuador, and the prices at which the shellfish are sold in Peru exceed USD 0.50 per unit.

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A positive experience to face this problem of inequity in the marketing margins in the value chain was developed by the Association of shellfish collectors and underwater fishing of Ancón, in Peru [35]. It was possible to confirm through an investigation that the higher the shared value practices, the higher the sustainability in its value chain. Shared value implies innovation and a significant benefit for society that is also of value for the business. It can create shared value in three different ways that complement each other, constituting a virtuous circle: conceiving new products and markets, redefining productivity in the value chain, and building local clusters where it operates. At the same time, it requires a difficult balance between social needs and business benefits [36].

Transforming the mentality of the shells and the rest of the participants in the production chain of the CP towards a focus on entrepreneurship and value chain is one of the most critical challenges to overcome. This transformation has been promoted in the different fishing and aquaculture production chains in the European Union, including bivalve mollusks. The aim is to increase value, create jobs, attract young people to the business, and promote innovation in all phases of the supply chain for fishery and aquaculture products [37].

In this context, entrepreneurship can be defined as a social and knowledge strategy for developing skills that allow the economically active population to carry out business projects for self-employment with a greater degree of certainty and possibilities of better quality-of-life [38]. Therefore, to overcome this challenge in the CP value chain in Ecuador, the application of good entrepreneurship practices and the development of strategic objectives mentioned below is recommended:

- Strengthen the organizational or associative processes that allow shells to market their catch directly to end customers.
- Improve knowledge of the market, making it more transparent through the registration of commercial operations.
- Prepare a business plan at the national, provincial, municipal level and mangrove areas assigned to the shellfish collectors and fishers in the sustainable use agreements.
- Prepare a marketing plan for *A. tuberculosa* that stimulates its consumption nationally and internationally.
- Diversify the market with innovative products based on fresh and processed consumption and the alternative use of shells for industrial and artisanal purposes. Additionally, the development of tourist routes based on shellfish gastronomy, the contemplation of the mangrove, and its capture and collection adventure.
- Establish training programs aimed at shellfish collectors and other participants in the production chain of the black shell, stimulating the formalization of this social and productive activity and entrepreneurship at the micro-business level.
- Promote a seedbed of family businesses to develop the black shell business and its value chain at the family level.

**Challenge Number 5.** Strengthening of shellfish organizations and Mangrove Sustainable Use and Custody Agreements.

According to [39], from the 1990s, popular movements in defense of the mangrove ecosystem began to grow and consolidate in new civil society institutions dedicated to resource management, mangrove reforestation, and raising awareness among the people about their property rights. In this sense, the Ecuadorian State began to recognize the rights of the ancestral users of the mangrove according to Executive Decree 1102 of July 21, 1999.

In 2000, the Ecuadorian State granted the first concession of 579 ha of mangroves for ten years to the Costa Rica Association in El Oro for its conservation and sustainable use of resources, such as the *A. tuberculosa*. Currently, there are dozens of concessions of this type in Ecuador that represent community management of natural resources. Such is the case of the mangrove ecosystem and *A. tuberculosa*. The results show that

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mangrove stewardship, cooperation among users, and institutional collaboration are strategies that have improved the preservation of this ecosystem and the sustainable use of the CP [40,41]. However, despite the attempt to conserve the surface of these forests through the Sustainable Use and Mangrove Custody Agreements, the negative impacts of overfishing have not been alleviated [42].

This unwanted situation probably has its causes in that: 1) not all the associations are well organized to control the minimum catch size or to carry out a self-closure; 2) not all concessionaires are qualified to assume complete control of their areas in custody, for which other collectors and fishers freely enter these areas; 3) there are not enough collaboration and control mechanisms, since the necessary equipment to effectively manage the mangrove supervision is limited and 4) there is scarce or no presence of fisheries inspectors in the landing sites of the mangroves for the control of the minimum commercial size of the shells.

In the province of El Oro, Ecuador, the Management Effectiveness of Sustainable Use Agreements and Mangrove Custody "AUSCM" [43] was studied, showing that AUSCM is an effective tool for the conservation of the mangrove ecosystem and the economy of the ancestral communities in the province of El Oro. There are significant differences between the 20 custody areas. The Sociomanglar incentive is effective in improving compliance with agreements, as well as organizational strengthening. However, overexploitation of bio-aquatic resources and pollution persist, requiring more significant support and inter-institutional coordination from control entities. Part of the issue could be explained by the fact that Sociomanglar programs are not designed to manage fisheries; instead, they are designed to address forest conservation. More ecosystem-based management and community-based approaches could allow for the design of more locally appropriate management strategies.

Based on the challenges of user organizations, a set of strategic objectives are proposed to meet and overcome the challenge, among which the following stand out:

- Elaborate alternative development projects for the independent shellfish gatherers and associations that do not have custody of the mangrove to reduce the negative impact of excessive people collecting shellfish.
- Motivate and support the defense and restoration of the mangrove forest based on strengthening the activities of the organized communities of shellfish and fishers.
- Promote the figure of mangrove custodians through agreements between the communities and the government, which contain specific action plans to meet the challenges and strategic objectives set out in this research.
- Integrate communities and authorities to face the insecurity problem of people and property in the extraction areas and on the boat transportation routes.
- Through the National Network of Users and Ancestral Custodians of the Mangrove in Ecuador, set up a non-governmental organization to defend the restoration of the mangrove ecosystem and its sustainable use. The organization should have sufficient institutional weight to manage the conflicts that arise with the companies' shrimp farms and other stakeholders and the capacity to establish links with social organizations with similar purposes at the international level.
- Promote and coordinate water transport routes that take the shellfish collectors to the extraction areas in a programmed and organized manner with quality and competitive prices.
- Promote developing a national registry of shellfish collectors, association managers, traders, and restaurant-cevicherías, culminating in granting a license or certificate that authorizes the extraction, commercialization, and elaboration of shellfish dishes enabling the supervision and good performance of their work.

**Challenge Number 6.** Develop coordination and institutional support system that, based on innovation, contributes to advancing the previous challenges.

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The five previous challenges will be easier to achieve if there is an innovative system based on the support of government institutions, the economic sectors, academia, international cooperation, and the organized community that contribute to the best performance of the *A. tuberculosa* value chain. As a reference, some experiences are presented.

Chile is widely acknowledged as the regional leader in aquaculture production [44]. Thanks to the mussel farming industry, it is the leading mollusk-growing country and has shown remarkable growth and development. The National Council of Innovation has promoted these results for Competitiveness (CNIC), whose fundamental mission has been to design and facilitate a national innovation strategy and propose public policies that promote national development based on knowledge and innovation. For this purpose, the Chilean government has invested around USD 120 million in aquaculture research and development, reaching an average public expenditure of USD 14 million per year. The main areas served were farming technologies, productivity, and product quality.

In El Salvador, the government has developed the Project for the Development of Mollusk Aquaculture, with the support of the Japanese government, through the Japan International Cooperation Agency (JICA). The objective is to improve the quality-of-life model mainly through mollusk aquaculture activities, based on the awareness of natural resource management. The Project conducted trials to establish artificial seed production technology, the technique of the intermediate culture, and the culture for fattening shellfish (*A. tuberculosa*) obtained from the Guide for the Production of Anadara spp [45].

In Ecuador, experiences have also been developed in which international cooperation has improved the production and marketing system of *A. tuberculosa* [46]. Likewise, through the Public Institute for Aquaculture and Fisheries Research, the Ecuadorian government publishes reports to determine the fishing exploitation of the shellfish resource in the mangrove ecosystem and generate management recommendations for its sustainability [47]. Additionally, through the Ministry of the Environment, the Socio Bosque Incentives Program, Mangrove Social Chapter has delivered monetary incentives to more than 70 community organizations dedicated to the restoration and sustainable management of the mangrove ecosystem [48].

For their part, Ecuadorian universities also carry out actions in favor of the hydrobiological resource *A. tuberculosa,* through investigations that have served to diagnose the exploitation of the resource and propose project improvement actions. Such is the case of the Technical University of Machala and the Luis Vargas Torres de Esmeraldas Technical University, which have published more than 200 studies related to *A. tuberculosa*.

Finally, the Ecuadorian private business sector is also making its contributions to the development of this value chain. Such is the case of El Pailón company, which made the first export of 50 kilograms of black shells on May 18, 2021, to the United States of America and expects to export one ton per week [49].

Based on these experiences and the challenges and strategic objectives to be achieved, creating a national coordination body in Ecuador is necessary to integrate the interested parties in mangrove restoration and strengthen the *A. tuberculosa* value chain (Figure 4).

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**Figure 4**. National association model for strengthening the *Anadara tuberculosa* value chain
Source: Authors

This coordination body could represent shellfish collectors, universities, private companies, and enterprises dedicated to the commercialization and preparation of the shellfish, the government, and international cooperation. The aim is to coordinate actions' innovations to strengthen the value chain of the concha prieta and the restoration of the mangrove forest. Among the main strategic objectives of this challenge are:

- Coordination at the national, provincial, and municipal levels to fulfill the challenges and strategic objectives set.
- Seek and allocate the necessary resources in an optimized way to develop actions that are planned jointly or individually.
- Explore financing mechanisms to fulfill its purposes, either nationally, internationally, or through the value chain itself, establishing a contribution by the economic actors involved.
- Prepare the national business development plan for the concha prieta in correspondence with the preservation and restoration of the mangrove ecosystem.
- Present semiannual reports on the progress of their actions and the business situation of the CP.
- Generate new knowledge through basic and applied studies on biological, technical, productive, social, economic, and market aspects necessary to comply with the elaborated planning.

## 5. Conclusions and recommendations

Based on the objectives of this research, the following conclusions and recommendations are presented.

- The value chain of the *A. tuberculosa* is composed of links between shellfish collectors, shellfish association managers, traders, and restaurants-cevicherías, presents a moderate to good performance based on the diagnosis made of its three dimensions, competitiveness, productivity, and quality-of-life.
- Competitiveness was evaluated through the cost, quality, and market segment subdimensions. Productivity was analyzed through the physical productivity and economic productivity subdimensions. Finally, the quality-of-life dimension was based on the infrastructure, overcrowding, and schooling subdimensions. It should be noted

that the competitiveness dimension was the one that achieved the best performance when compared with the productivity dimension that registered an intermediate performance level and the quality-of-life dimension, which obtained the lowest performance level. The main strength of the black shell business lies in the unique characteristics that make it an appealing product in high demand. Still, it is threatened by different factors, which could be appropriately managed if progress is made in meeting the challenges raised in this research.

- Diagnosed performance and observation of the *A. tuberculosa* value chain allowed identifying the main challenges for its strengthening and for mangrove preservation, which are the following: 1) Restoration of the mangrove ecosystem; 2) Introduction of good production practices of the *A. tuberculosa*, both of natural populations and new populations derived from low-intensity aquaculture techniques; 3) Implementation of good practices for manipulation and purification of the *A. tuberculosa*; 4) Promotion of ventures with a value creation approach; 5) Strengthening of shellfish organizations and Mangrove Custody and Sustainable Use Agreements, and lastly; 6) Development of an institutional support system that, based on innovation, contributes to the advancement of the challenges mentioned above.
- For each of the challenges and strategic objectives, it is recommended to perform research and generate master documents that help clarify the optimal way for their application in the Ecuadorian context and serve as a guide for the rest of the countries that produce and commercialize the *A. tuberculosa*.

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