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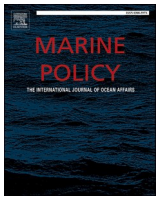

Delimiting coastal zones for integrated management: The case of the island and the sea of Chiloé (Chile)

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ABSTRACT

A delimitation of coastal areas based on an integrated approach has not yet been proposed in Chile. In response, the objective of this research is to propose a definition of coastal zones on a subregional scale, specifically in the archipelagic environment of the island and the sea of Chiloé, a highly unique geographic area where most globally observable coastal dilemmas converge. The methodology used, which is based on the Integrated Coastal Zone Management's (ICZM) principles, consisted of the analysis of multiple criteria grouped into five typologies: ecological, socioeconomic, cultural, political-administrative, and arbitrary. It is therefore the first delimitation of these characteristics proposed not just for the far south of Chile, but for the entire country. The coastal area that was delimited and mapped exceeds the conventional borders of the provincial district of Chiloé. The totality of islands and the inland sea has been included, in addition to other continental and open sea areas. The results have been divided into the four aspects of the field to achieve a more detailed justification of the suggested criteria. This example could serve as the study object for a future ICZM Program in Chiloé , an instrument that has not been developed to date. In addition, considering the territorial complexity that characterizes the archipelagic environment studied, the methodological proposal could be repeated in other coastal areas in the country.

1. Introduction

No initiative to promote coastal management at a subregional scale has been thus far established in Chile, due to the prevailing centralist state model. For this reason, the definition of coastal zones has been adjusted to the provisions of the National Policy for the Use of the Coastal Border (*Política Nacional de Uso de Borde Costero* - PNUBC), approved in 1994. To date, this government instrument has represented the greatest political-administrative advance in the country's coastal management [51].

The text of the PNUBC does not propose an explicit coastal delimitation that reflects its socio-ecological complexity from an integrated approach [6]. Conversely, the policy's object of regulation is exclusively focused on the concept of 'coastal edge,' which extends from the 12 miles of territorial sea to the 'beach land,' which extends 80 m inland from the high tide line [25,39]. Based on this definition, a zoning plan was established for coastal edge uses, without affecting adjacent privately owned lands. While this static definition offers a clear and precise delimitation, its reduced size in the terrestrial area has led to the degradation of its ecosystems. Therefore, the Chilean policy only protects maritime and intertidal coastal ecosystems, leaving out those beyond the beach zone. Consequently, real estate projects have been built on dune systems, beaches have progressively receded, water bodies have been polluted, the landscape has been artificially transformed and traditional economic activities have been displaced [35,48].

Recently, the "Integrated Coastal Zone Management" project run by the National Research Center for the Integrated Natural Disaster Management (*Centro de Investigación para la Gestión Integrada del Riesgo de Desastres* - CIGIDEN) warned of the need for a policy and law aimed at promoting ICZM in Chile [34,35,44]. Thus, based on the progress made by the CIGIDEN and other sectors of Chilean academia, the country's first draft Coastal Bill was presented. The proposal was submitted to the Climate Change and National Properties Committee of the Senate Environment on 28 November 2022, with the aim of protecting coastal ecosystems, promoting access and public use of the space, and safeguarding natural and cultural heritage. The new legislative proposal

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replaces the limited legal concept of 'coastal edge' with the scientific notion of 'coastal zone,' based on which the intention is to connect the physical, biological and anthropic elements that interact within the same territory [65].

It should be made clear that the focus of this research is based on the analysis of the coastal areas of the island and the sea of Chiloé, meaning that it moves away from the logic that accompanies the concept of 'coastal edge.' Chiloé is an eminently coastal archipelagic environment in the far south of Chile. The isolation that characterizes this place makes it a unique space and at the same time one that is vulnerable to globalization processes. The location and value of the natural resources offered by its coasts have contributed to the arrival of numerous extractive companies in the aquaculture, real estate, forestry and mining sectors [66]. Due to the transformations caused by the shift in the economic model, Chiloé's ecosystems began to suffer a growing degradation that has resulted in several environmental crises in the last decade [37].

Islands and archipelagos are usually considered easily delimitable locations, given that the terrestrial area corresponds to the total emerged surface in most cases. Therefore, an island usually constitutes a coastal environment in its entirety [12]. However, the Chiloé archipelago is located only a few miles from the mainland, which adds a level of complexity to the determination of the coastal zones' limits. Above all, it must be considered that most of the pressures, economic activities, and cultural interactions occur at sea. In this sense, the Chacao channel (to the north) and the inland sea (to the east) should not be interpreted as a physical separation between the island and mainland, but rather as a multidimensional connection space. Furthermore, the idea of managing land and sea environments as if they were sealed compartments must be overcome, as it generates fragmented governance that prevents coordination between the agencies responsible for managing the coast [20].

Briefly put, socio-ecological conflicts, the geographical uniqueness and the complexity involved in defining coastal zones in an archipelagic area close to the continent justify the choice of Chiloé as an area of study for this research. It is worth recalling that, until now, a delimitation of the archipelago's coastal zones had not been proposed. In the scientific literature, several studies on the Chiloé Interior Sea coast may be located, but they do not propose an explicit spatial delimitation [4,5,58].

Thus, the objective of this research is to delimit the coastal zones of the island and the sea of Chiloé, which could serve as the basis for a future implementation of an Integrated Coastal Zones Management (ICZM) program.

2. Study area

Chiloé is an archipelagic environment located in southern Chilean Patagonia (Fig. 1), which gives it a temperate oceanic climate with high annual rainfall. This is of 1500 to 3000 mm, with an average temperature of around 11 degrees.

The territory's geomorphology, which is vertebrates by an inland sea, has its origin in the altitudinal decrease experienced by the Chilean relief from north to south in its three morpho-structural units. First, the Chilean Coastal Range crosses the Greater Island of Chiloé until it disappears to the south of Quellón. Second, the Intermediate Depression sinks in this environment to form the Chiloé Sea, which is sparsely

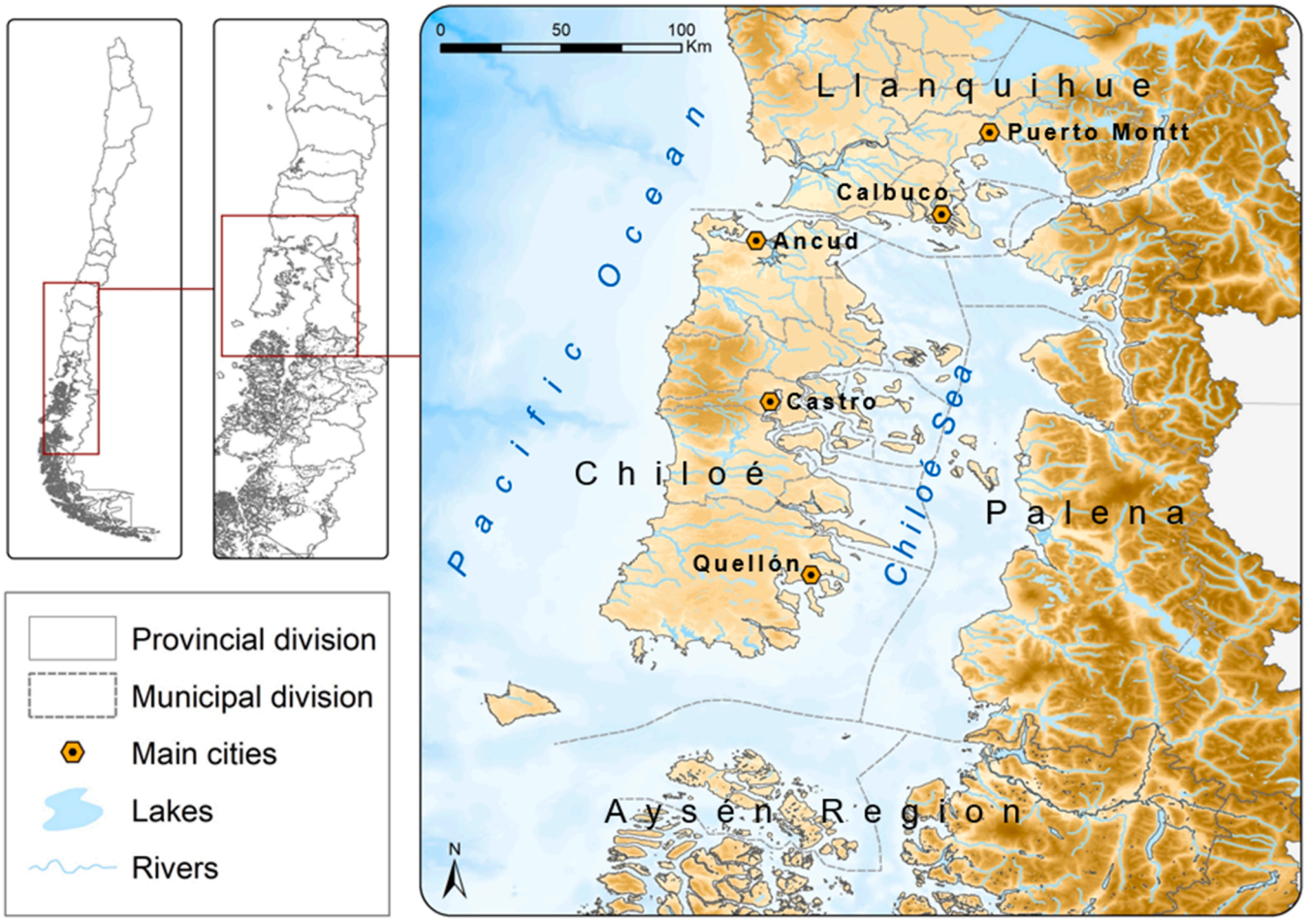

Fig. 1. Location of the area of study.
Source: own elaboration.

populated by small and low-lying islands. Finally, the Andes Range continues to prevail in this space until it vanishes at the southern end of the Southern Cone. The archipelago's modeling responds to the Quaternary glacial morphogenesis that occurred 12,000 years ago. This scenario developed the fjords, islands, and U-shaped valleys that extend along the eastern coast of Chiloé. Currently, the glacial hollows are occupied by lakes, such as the Huillinco and the fluvial currents, among which the Pudeto, Chepu, and Medina rivers are emphasized [24].

The isolation to which Chiloé is subjected is manifested in the lack of internal and external connectivity, and in the conservation of the local endemism and cultural singularities [30]. Chiloé's geographical peculiarities have conditioned its population so that the highest rates of demographic and urban growth are observed on the eastern slope and both sides of the Chacao Canal. Conversely, in the western zone, where the meteorological and oceanographic conditions are more hostile, there is only one small town in the Castro commune [15]. Since the 1980s, Chiloé was considered an attractive focus for immigration because of economic changes fundamentally linked to aquaculture industrialization and the emergence of salmon companies in the inland sea [43]. This in turn implied an improvement in the means of communication, an increase in local income, a reduction in unemployment, and an increase in exports. The main current conflicts and pressures began to simultaneously emerge [52].

The rural exodus and immigration led to an accelerated and disorderly urban expansion of the coast, which caused the landscape's homogenization and artificialization [66]. This alteration of the landscape is now beneficially visible in the sea. It is currently sparsely populated by salmon farms and other aquaculture facilities. Other activities were simultaneously developed. Some had existed from the past, such as forestry, and newer ones emerged. This is the case regarding tourism or mining associated with the exploitation of peat bogs, which is the main freshwater reservoir in Chiloé. In these ecosystems, the mosses of the *Sphagnum* genus, locally known as 'pompon,' emerged. Conversely, some of the traditional activities and customary uses, such as artisanal fishing and shore gathering, that characterize Chiloé have been reduced [14,46].

The environmental problems linked to the current extractive model quickly arose. A clear example of this is the red tide that occurred in 2017, among other factors of the salmon farming activity. This resulted in an unprecedented socio-environmental and economic crisis [16,37]. Climate change and its implications constitute another significantly influential variable in Chiloé, due to its archipelagic morphology and the intensification of summer water pressure [23,67]. These are complex conflicts that are locally familiar, but difficult to resolve, given that families in Chiloé depend on these economic sectors. All these challenges associated with aquaculture, forestry, mining, urban planning, tourism, and so on., must be contemplated in the future ICZM strategy.

Table 1 presents several indicators for the communes that constitute the study area.

3. Material and methods

3.1. Method and information sources

The coastal areas of the island and the sea of Chiloé's delimitation proposed in this article have been obtained from a consultation of bibliographic, normative, documentary, statistical, and cartographic sources. To commence, the scientific literature was reviewed to conduct a systemic diagnosis of the most significant challenges and conflicts that occurred in the study. These research works were found after consulting the *Scopus* and *Web of Science* databases. Most of the publications have been produced by Chilean researchers from the multidisciplinary team of the Center for Regional Development and Public Policy Research (*Centro de Estudios del Desarrollo Regional y de Políticas Públicas* - CEDER) at the Universidad de Los Lagos. Subsequently, cartographic information was collected through the country's Spatial Data Infrastructures (SDI), mainly from: the Ministry of the Environment, the Ministry of National Assets, the Ministry of Culture, Arts and Heritage, the Ministry of Public Works, the Undersecretary of Fisheries and Aquaculture, and the General Directorate of Water. Similarly, the Digital Elevation Models (DEM), provided by the *British Oceanographic Data Center* (BODC) were used to perform altimetric and bathymetric calculations of greater precision. Satellite images were also used to improve the boundaries' sharpness in the locations with the greatest information gaps.

Having understood the spatial reality of coastal conflicts in Chiloé, various proposals for the delimitation of coastal zones in different parts of the world were reviewed, especially from Ibero-American states (e.g., [56,57,41,9,47]). The fourth step consisted in selecting the delimitation criteria and grouping them into fisve categories: arbitrary, ecological and physical-morphological, socioeconomic, cultural and political-administrative. Some of the variables considered were obtained from consulting statistical sources and official databases published by public agencies. In addition, the layers of cartographic information had to be processed to calculate certain criteria. Lastly, the boundaries of the coastal zones in the island and the sea of Chiloé were digitized using ArcGIS software (Fig. 2).

3.2. Theory of the delimitation of coastal zones

The definition of the work areas' scope is the first step to follow for an ICZM strategy's construction [18,47]. Although numerous proposals for the delimitation of coastal zones may be determined, a common methodology has not yet been established [41]. Usually, these investigations are based on a single type of limit-determining criterion, or

Table 1
General indicators of the communes of the island and the sea of Chiloé.

Commune	Population	Population density (hab./km^2)	Average age	Rural population (%)	Population of native peoples (%)	Population/housing
Ancud	38.991	22,3	37,6	27,5	29	2,30
Calbuco	33.985	57,69	36,5	52,9	31	2,50
Castro	43.807	93,44	35,8	22,3	29	2,43
Chaitén	5.071	0,61	37,7	67,6	27	2,28
Chonchi	14.858	10,84	36,3	61,5	40	2,22
Curaco de Vélez	3.829	48,14	37,8	71,1	31	2,26
Dalcahue	13.762	11,16	35,7	47,7	29	2,43
Hualaihué	8.944	3,09	36,1	59,3	35	2,01
Maullín	14.216	17,57	40,1	53,4	22	2,14
Puqueldón	3.921	40,76	39,5	100	32	2,39
Queilén	5.385	16,26	37,6	56,9	52	2,20
Quellón	27.192	8,1	33	34,5	49	2,47
Quemchi	8.352	18,9	39,2	69,9	39	2,16
Quinchao	8.088	51,15	38,5	60,3	51	2,27
Total or average	230.401	28,57	37,24	56,06	35,43	2,34

Source: own elaboration based on the INE [28].

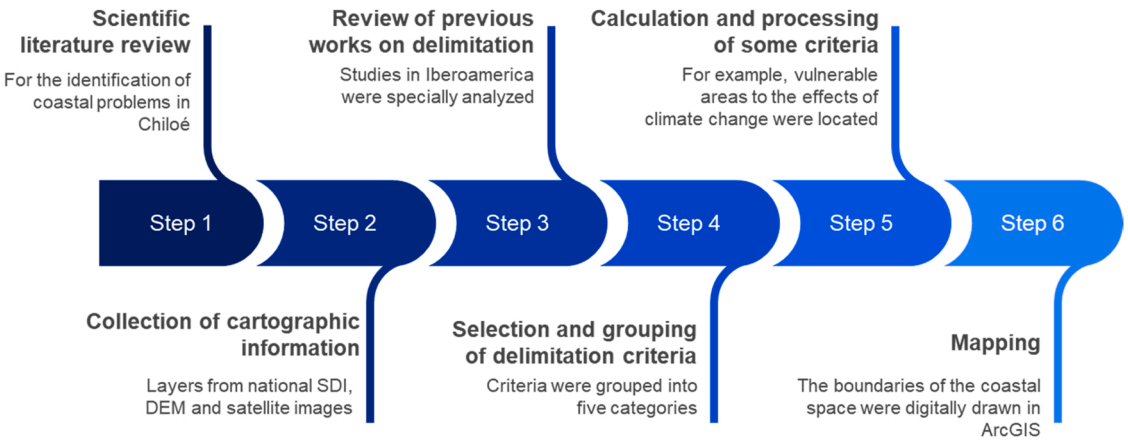

Fig. 2. Methodological framework.
Source: own elaboration.

they opt for using territorial jurisdictions already established by the Administration. Most coastal delimitations are aimed at correcting conflicts, especially for those that occur in land areas [8,57].

An effective delimitation requires a combination of different types of criteria that are following the pressures exerted on coastal-marine ecosystems [47]. For simplicity, sometimes it is possible to use a single criterion when working with a very specific issue. Conversely, if the goal is to propose an ICZM strategy, it is convenient to opt for the superposition of variables of a different nature [32]. Definitely, the criteria must be clear, mappable, and understandable for the local population. Although it is a subjective exercise, the resulting space must reflect the territorial context. The delimitation not only has an academic-scientific purpose, but it must also guarantee its applicability in the territory [1].

To mark a delimitation based on the ICZM model, various ways to classify the criteria have been proposed. For example, [10] suggests organizing them into three categories: geographic, operational, and arbitrary criteria. It is also possible to group the criteria into two classes, separating those associated with scientific variables from the operational or functional ones [49]. In this study, a classification close to that proposed by Milanés [40] is used, since it classifies the criteria into four types: 1) arbitrary, 2) physical-natural, 3) economic-organizational and 4) legal-administrative. Given the recognized patrimonial uniqueness of the field of study [64], a fifth criterion type has been considered, which is focused on aspects related to local culture.

The following subsection describes and analyzes the five groups of criteria that have been proposed for the delimitation of coastal areas in the island and the sea of Chiloé.

3.3. Definition of the criteria for delimitation

In many of the examples of coastal delimitation, there is a tendency to use arbitrary criteria, especially in the terrestrial environment since it is easier to map and measure. However, they do not conform to the natural boundaries of ecosystems, production zones, homogeneous cultural areas, or administrative divisions. These are fixed altitude, distance, or bathymetry measurements that do not adapt to the changing complexity of the coasts [29,40]. Therefore, when arbitrary indicators are applied for a delimitation, they must be combined with other criteria [60]. Although in this study the inclusion of arbitrary criteria as a delimitation category has been considered, they have been dispensed of in practice.

Contrary to what happens with the ones previously mentioned, the ecological and physical-morphological criteria are the most difficult to map. This is due to the lack of specialized information. A good delimitation must include the ecosystems, critical habitats, and typical coastal morphologies, upon which human activities and communities depend [32]. Therefore, to achieve human well-being, ecosystem services must be represented. In this manner, beaches, cliffs, dune deposits, coastal lagoons, marshes, peat bogs, coastal plains, and urban settlements have been incorporated within the limits. The epibenthic zone, the macroalgae meadows, and the coral ecosystems present in the sea have been identified in the continental fjords. In addition, the emblematic species' main feeding, breeding and transit areas, such as that of whales, dolphins, and sea lions, have been located.

From the physical-morphological perspective, the gulfs, bays, straits, channels, estuaries, islands, islets, fjords, and the inland sea have been considered as part of Chiloé's coastal areas. Conversely, coastal risk zones and the areas "exposed" to the climate change effects have been defined and understood as being a space less than 10 m above the average sea level [38]. The latter was formulated in the executive summary of the Ministry of Environment, called the "Determination of the risk of the impacts of climate change on the coasts of Chile." To achieve greater resolution and precision, this parameter has been recalculated for Chiloé.

As previously mentioned, coastal areas must be defined based on the issues that affect ecosystem services and, by extension, society. For this reason, in the delimitation proposed for Chiloé, populated spaces that share uses and activities with repercussions on the coast have been integrated. The inclusion of tourist attractions associated with the sea, boat traffic areas, and fishing grounds located mainly in the inland sea, has been proposed as socioeconomic criteria. Another unavoidable element in the delimitation layout corresponds with the areas suitable for the exercising of aquaculture. In Chiloé, this is mainly composed of three activities: salmon farming, mussel farming, and algaculture.

Demography is also a socioeconomic criterion that helps to mark the territory boundaries. This is due to two reasons: Uninhabited areas usually lack conflicts or environmental issues, given that no human activities occur therein. In addition, in Chiloé these territories are largely classified as protected areas, meaning that they can be excluded from the delimitation by forbidding their occupation. Conversely, the demography makes it possible to group localities with a similar population and eliminate those where the excessive volume of inhabitants may distort the research objective. Finally, highways and roads have been considered as another socioeconomic nature criterion, since in certain cases, they constitute a physical barrier that separates the coast from the mainland.

Considering the richness of the tangible and intangible cultural heritage of Chiloé, it was decided to separate the cultural criteria from the other categories [55]. Within this typology, the sense of belonging and identity of the *chilotes*, the island-dwelling, and their movements in the territory for economic, educational, health, artistic or ceremonial reasons have been studied [2,30,63]. A clear reflection of the identity

expansion is located in the architectural elements. The churches of the Chilota School and the fishing corrals are highlighted among these [54]. The non-approved Marine and Coastal Areas of Indigenous Peoples (*Espacios Costeros Marinos para Pueblos Originarios* - ECMPO) have been requested by local indigenous communities and have been used as a reference [7].

Political-administrative criteria facilitate the decision-making and are easy to map, with the availability of spatial data. However, they generate rigidity in the delimitation and cannot be used as a representation of socio-ecological limits. This is since territorial pressures do not explain conventional borders [32,57]. Moreover, the division of certain units already established by public policies should be avoided. This is especially regarding those aimed at conservation or the promotion of sustainable development. Thus, in this category of criteria, not only the regional, provincial or communal divisions have been examined, but also the protected spaces and areas subject to the sustainable management plans.

Table 2 summarizes and categorizes the criteria described above.

4. Results

A detailed justification of the limits is provided below, based on the four spatial units into which the territory has been divided: 'Chiloé in the open sea', 'Boca del Guafo', 'the inland sea coast' and 'Chacao Channel and Reloncaví Sound'.

4.1. Chiloé in the open sea

The delimitation on the western slope of Chiloé is the least complex, due to its scarce occupation. The greatest anthropic presence may be observed in the extreme north and around Cucao [62]. This is the only population center on the west coast. The demographic vacuum and the climate's hostility have made it difficult to implement certain productive activities, such as aquaculture. Thus, the only economic sectors that are being developed are artisanal fishing and ecotourism. This explains the optimal preservation of the values and idiosyncratic elements of the natural heritage of the western part of Chiloé [15].

The terrestrial limit of the western coast corresponds to that of the Greater Island of Chiloé, within which this zone's limits are exclusively marine. Various coastal ecosystems are visible, such as cliffs, some marshes, which are located around the riverbeds and coastal lagoons, and the beaches and dune ridges of Cucao. The rich landscape and the presence of endemic species justified the establishment of several protected areas, such as the Chiloé National Park and the Islotes de Puñihuil Natural Monument, which are in the Ancud commune. The latter constitutes the southernmost area of Chile, which houses a colony of Humboldt and Magellanic penguins.

Despite the minimal human development, in western Chiloé, certain socio-ecological conflicts that have been considered to encourage delimitation can be named. One of these disputes originated from a wind farm construction project near the islets of Puñihuil, which may have an impact on migratory birds, the movement of cetaceans, and artisanal fishing [21]. There is also a debate over the administration of

Table 2
Criteria for the delimitation of the coastal areas of the island and the sea of Chiloé.

Dimensions	Criteria	Elements of interest	Territory
Ecological and physical-morphological	Location of coastal ecosystems	• Beaches, cliffs and dune deposits • Coastal lagoons, marshes, peat bogs and coastal plains • Coastal settlements • Marine epibenthic zone • Coral ecosystems • Meadows of macroalgae • Places of feeding, breeding and transit of cetaceans	Marine and terrestrial
	Identification of coastal morphologies	• Gulfs, bays, straits, channels, estuaries, islands, islets and fjords • Inland Sea of Chiloé	Marine and terrestrial
	Determination of vulnerable areas to the repercussions associated with coastal risks and climate change	• Coastal area exposed to the effects of climate change • Physical elements exposed to adverse meteorological events and the mean sea level rise	Terrestrial
Socio-economic	Recognition of economic activities linked to the sea	• Operational aquaculture farms and areas suitable for the exercise of aquaculture • Fishing grounds • Tourist areas associated with the sea • Vessel traffic	Marine and terrestrial
	Use of physical infrastructures as limits	• Urban areas, ports, bridges and discharge areas • Highways and roads	Terrestrial
	Economic and demographic analysis of populated coastal areas	• Inclusion of anthropized territories that generate pressure on the coast	Terrestrial
Cultural	Recognition of island ways of life	• Sense of belonging • Interactions between the *Chilotes* and the sea	Marine and terrestrial
	Identification of marine spaces claimed by indigenous communities	• ECMPO requested without approval	Marine
	Location of heritage elements characteristic of Chiloé culture	• Vestiges of old fishing corrals • Churches of the Chilota School	Marine and terrestrial
Political-administrative	Use of conventionally defined territorial constituencies	• Regional, provincial and communal divisions • Inland waters	Marine and terrestrial
	Registration of protected spaces based on environmental conservation policies	• Categories of the National Service of State Protected Wilderness Areas (SNASPE): national parks, natural monuments and national reserves • Marine reserves • Nature sanctuaries • Biosphere reserves • Priority sites for conservation of biodiversity • Private parks	Marine and terrestrial
	Identification of areas subject to management plans for sustainable development	• ECMPO approved • AMERB approved	Marine
Arbitrary	Altitude, bathymetry and distances	This type of criterion has not been applied	

Source: own elaboration.

Management and Exploitation Areas for Benthic Resources (*Áreas de Manejo y Explotación de Recursos Bentónicos* - AMERB) in Cucao between the Mapuche communities, the local inhabitants and the fishermen's unions. In addition, to the south of Cucao, numerous requests for mining prospecting are being processed. This could lead to environmental issues and confrontations with the local fishermen [23].

Finally, the marine delimitation has been adjusted to the ECMPOs in a process that is distributed along almost the entire western strip. This will ensure that the customary uses claimed by the indigenous communities, the AMERB, and the fishing grounds, which are located a few miles from the coast, are included (Fig. 3).

4.2. Boca del Guafo

The southern limit of the territory in this study is marked by the Boca del Guafo, which connects Guafo Island, the Gulf of Corcovado, and the Tic Toc Bay. Similar to the western slope of Chiloé, human settlements and activities are scarcely developed in this area. The native forest covers more than 90% of the land surface, which explains the extent of the protected areas located in the south of the archipelago. Among them, the Tantauco Private Park is found, which occupies 15% of the Greater Island of Chiloé. Since its declaration in 2013, conflicts have arisen with the Huilliche communities that claim this territory and denounce the imposition of lucrative conservationism [45].

To the southeast of the study area, the Priority Site for the Conservation of the Biodiversity of the Tic Toc Bay has been used as the land boundary, due to the presence of coastal ecosystems, the economic interest it arouses, and its relationship with the marine biological communities. To avoid human pressure on the life cycles of several emblematic species in this location, a protected coastal marine area has been recently developed in the Tic Toc Bay [19]. The space proposed in this study has also been incorporated into the delimitation.

There are also attempts to occupy Guafo Island for aquaculture and coal extraction. Until now, it has remained completely unoccupied, which has allowed for the conservation of numerous species of birds, felines, and endemic reptiles. It has even been compared to the Galapagos. Likewise, it constitutes an area of ancestral connection between the indigenous peoples and nature. To preserve the tradition and

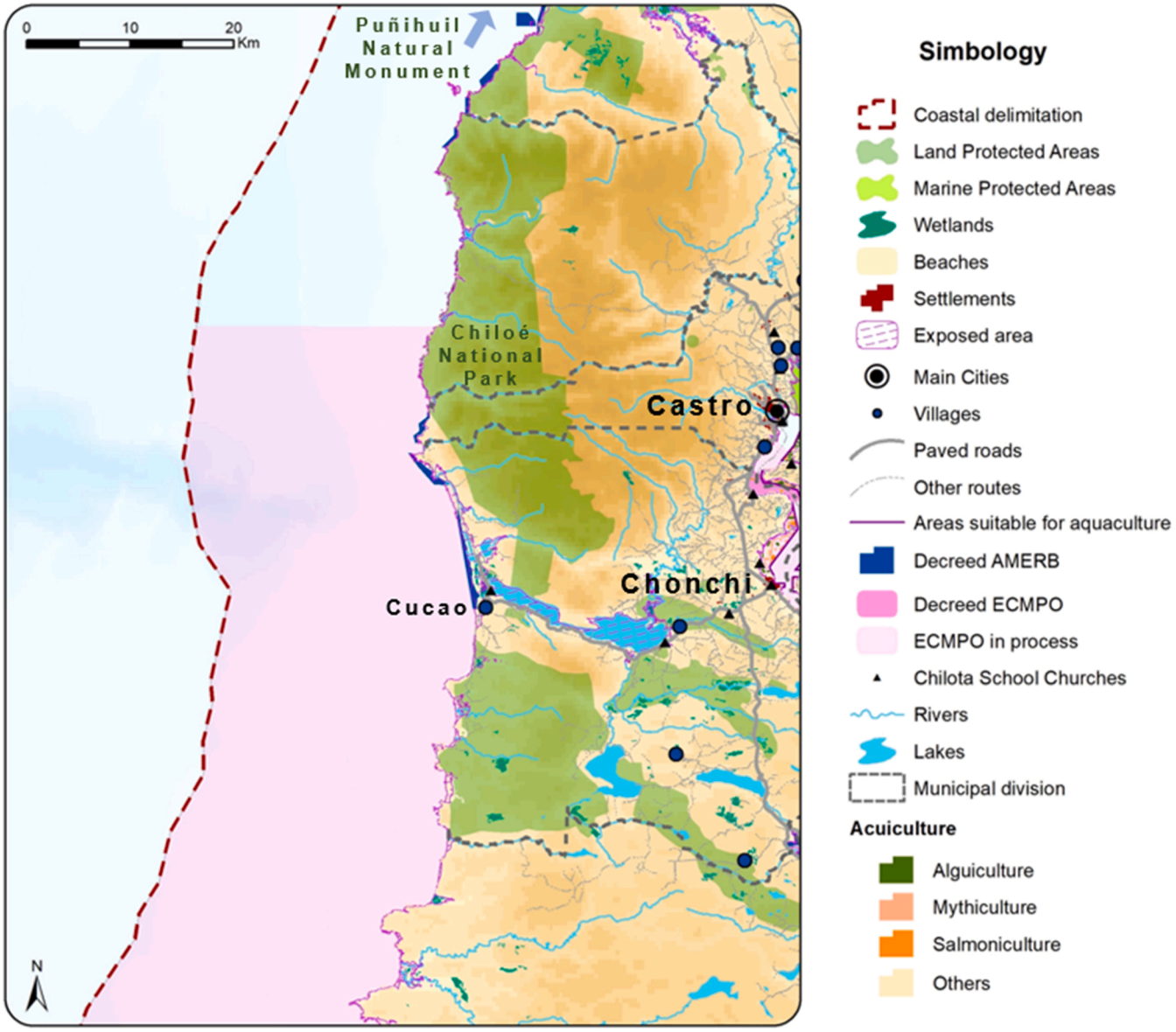

Fig. 3. Delimitation of the coastal zones of Chiloé in the open sea.
Source: own elaboration.

customary coastal uses, local communities are claiming the management of the Guafo Island [33]. These island dwellers between the waters surrounding the island and the Gulf of Corcovado have also been considered for the delimitation of the coastal zones.

The integration of the marine areas in the south of the archipelago is also necessary, due to their high ecological value. Boca del Guafo is configured as a place of passage, feeding, and breeding of cetaceans, among which the blue, humpback, and sea whales are highlighted. The *Cephalorhynchus eutropia*, which is an endemic dolphin from Chile is also highlighted. Many times, these populations conflict with trade and maritime transport, whose routes overlap with the circulation of marine mammals [27].

As a result of these criteria, the ECMPOs in the process and political-administrative boundary that separate the Los Lagos Region from the Aysén Region, have been used as a marine divide. Overcoming this border would imply greater complexity in management and would reduce the practicality in the decision-making. Although certain shared ecological and cultural patterns are noted, they are inadequate to include more spaces in the Aysén Region (Fig. 4).

4.3. The inland sea coast

The eastern slope of the delimitation is structured around the Inland Sea of Chiloé. It is the most dynamic space that best represents the Chiloé society. It is the main setting for conflicts and environmental issues in the area. Therefore, it was considered necessary to include the entire inland sea, combined with the islands and islets that sparsely populate it. Most of the urban centers are located on its waters' shores, including Castro, the capital of the Chiloé province. These are sheltered from the inclemencies of the humid winds from the west. Despite the cultural, economic, and ecological uniqueness that characterize these marine areas, they are hardly protected. Numerous ECMPOs covering almost its entire surface have been proposed, but none have been approved to date.

Most of the fishing grounds and AMERB frequented by artisanal fishermen are in the inland sea. Off the southern coast of the Chaitén commune, the presence of fishing exploitation areas is considerably reduced, however, greater development is expected in the future. These traditional activities have conflicted with other economic sectors, such as maritime transport and above all, salmon farming. Currently, about 80% of the inland sea coastline is classified as Adequate Areas for Aquaculture (AAA), which has caused controversy on several occasions with tourism employers and conservation groups [24]. The unsustainability of the salmon industry in Chiloé has led to eutrophication, a decrease in dissolved oxygen, and the loss of biodiversity in the inland sea. These factors ultimately caused the health crises, due to the proliferation of the infectious salmon anaemia virus among farmed salmon in 2007, and the Harmful Algal Blooms (HAB) in 2016 [16].

In the definition of the limits of Chiloé's coastal zones, the marine fjords of Comau and Reñihue, in the province of Palena, have been incorporated. These are the only places in the inland sea with the endemic coral formations of the *Desmophyllum dianthus* species [24]. These organisms and the biodiversity that characterizes this environment are threatened by 17 salmon farms. In the Comau fjord, a HAB occurred in April 2021, which led to a major mortality prevalence of salmon in nine production plants. Although other variables associated with climate change, drought, and the El Niño and La Niña cycles have also had an influence, researchers insist that the main cause of these environmental issues lies in the accumulation of feces, leftover food, and medicines used in salmon farming. In addition, the transfer of dead salmon also implies a risk for marine ecosystems, because of the increase in maritime traffic [59].

The continental area included in the delimitation has been greatly reduced, due to two reasons: the high altitude that the land reaches

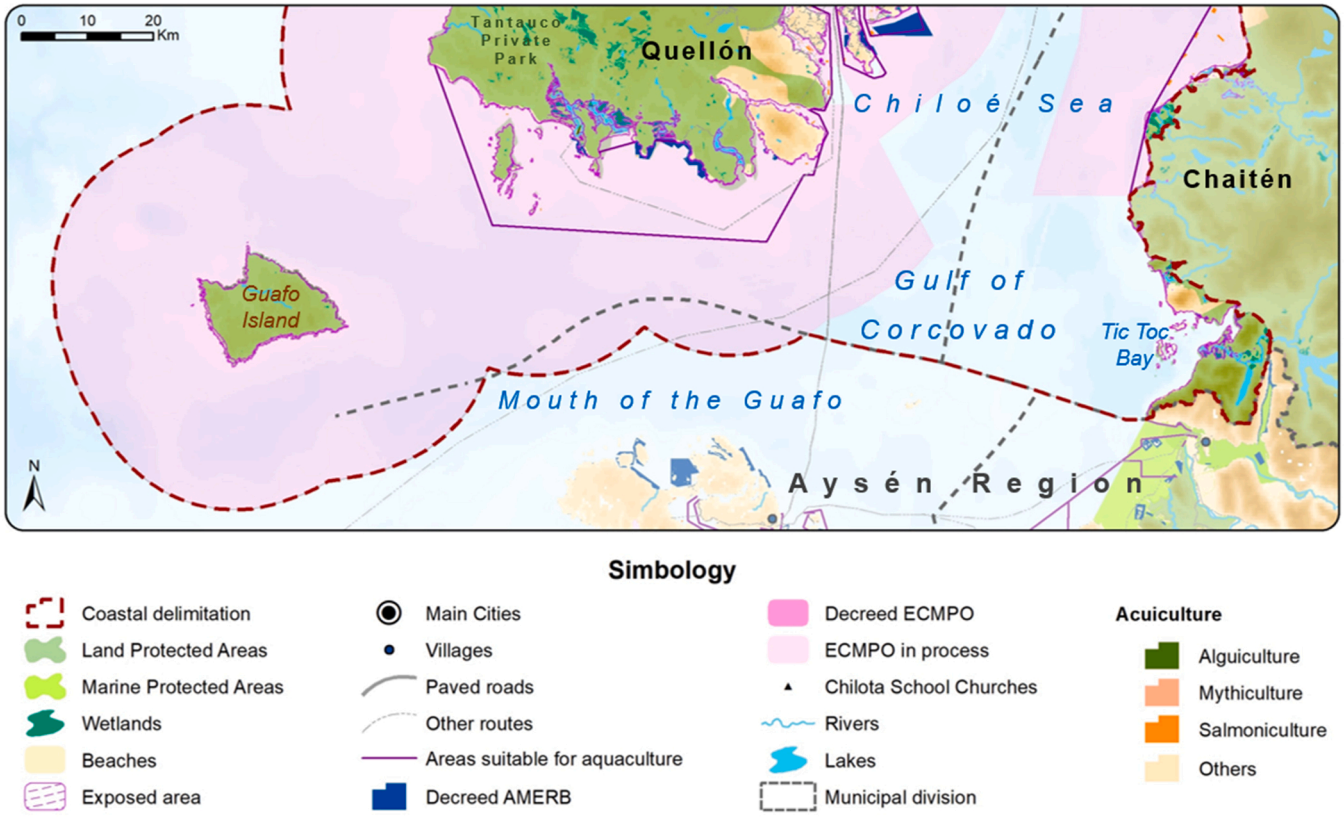

Fig. 4. Delimitation of coastal areas in Boca del Guafo.
Source: own elaboration.

which is a few meters from the sea, and the scarcity of settlements and human activities. It should be clarified that the province of Palena, to which this coastal strip belongs, accounts for multiple protection figures. The area exerts minimal pressure on the inland sea. Therefore, the continental limits include the few coastal populations, the fishermen's coves, and the aquaculture facilities of the Hualaihué and Chaitén communes. Similarly, in certain areas, the Carretera Austral has been used as the border of the area of study.

In less anthropized areas lacking settlements, infrastructure, and economic activities, the delimitation has been based on the inclusion of typically coastal ecosystems, such as marshes, beaches, dune deposits, and cliffs (Fig. 5).

4.4. Chacao Channel and Reloncaví Sound

The northern limit of the Chiloé archipelago is the most complex in the area, due to the level of the anthropization of the coast. It constitutes the largest focus of economic, demographic, and urban development in the study area. The city of Ancud is known for being the only municipal capital in the province of Chiloé that is not bathed by the inland sea. This commune contains various coastal environments, such as the beaches and marshes that border the mouth of the Pudeto River. The Pullinque Marine Reserve is also located here, which was founded in 2003 to protect the *Tiostrea chilensis* oyster ecosystem [24].

Efforts have been made to avoid the fragmentation of spaces destined for production or conservation that are defined by public policies. Thus, the marine delimitation to the northwest follows the same criteria used for the western slope, so that its layout coincides with the limits of the ECMPO in a process located off the western coast of the commune of Maullín. This territory is home to several AMERB and the Island of Doña Sebastiana. This is considered the northernmost limit of the Chiloé archipelagic unit. From an ecological perspective, the waters of the Gulf of Coronados are home to a great diversity of macroinfauna of commercial interest [24]. On land, the limit has been set from the secondary road that borders the west coast of Maullín. The incorporation of the mouth of the Maullín River has been eliminated since it is infrequently frequented by the inhabitants of the Chilote archipelago.

From the town of Carelmapu, in Maullín, to the Reloncaví Sound, the

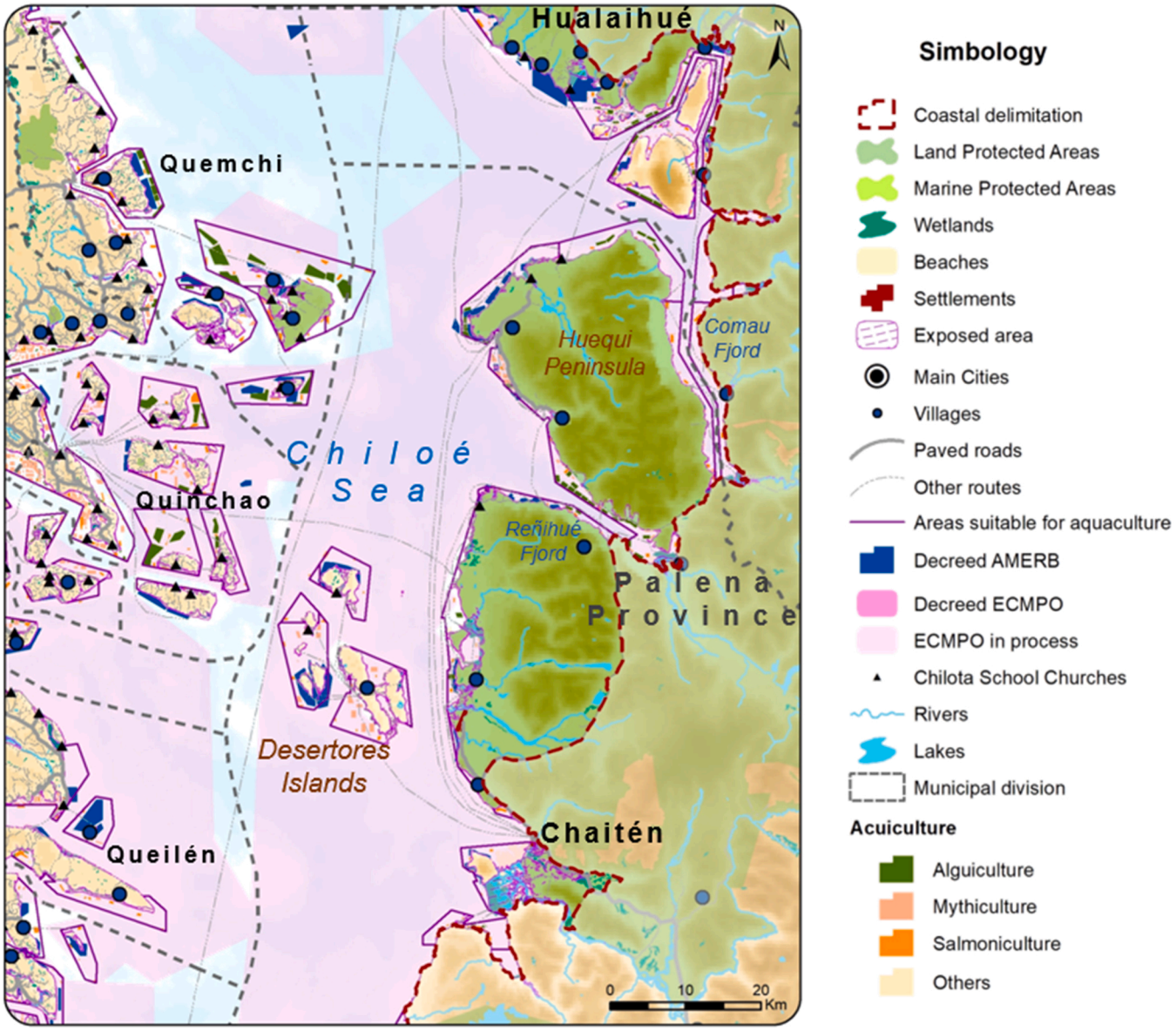

Fig. 5. Delimitation of the coastal zones of the Chiloé inland sea.
Source: own elaboration.

coastal boundaries have been largely adjusted to the path of Route 5. In certain sections, however, the delimitation has been extended to include some ecosystems and coastal settlements located to the north of this road. This includes the area exposed to the effects of climate change defined by the Ministry of the Environment. Thus, the Chacao Channel, the main point of communication between the province of Chiloé and the continent, by means of maritime ferries, is entirely part of the work scope. It is expected that by 2025, a bridge will be built on the Chacao Channel to reduce its geographic isolation and improve territorial articulation [5]. This strait must be represented in the research, not only because of its socioeconomic significance but also because it forms a transit point for southern dolphins [27].

The consideration of Calbuco as part of the coastal areas of the island and the sea of Chiloé is due to the similarities that this commune has with the Chiloé archipelago. The economic activities, the environmental issues, and the socio-ecological conflicts that characterize Calbuco are very similar to those observed in the rest of the inland sea. It should be highlighted that the low and dismembered terrain of this area makes it a potentially vulnerable place to coastal risks. In addition, it should be added that many of the buildings belonging to the Churches of the Chilota School are in the Calbuco commune.

Finally, in the extreme northeast, the Calbuco communal limit has been used as a delimitation criterion. The Reloncaví Sound may be described as a space with homogeneous economic, ecological, and cultural features. However, including its entire surface would imply considering Puerto Montt (capital of the region) as part of the coastal areas of the island and the sea of Chiloé. It has a population of 214,000 inhabitants [28]. This decision would divert attention from the archipelago and generate an excessive contrast between this city and the other population centers in economic and demographic terms (Fig. 6).

4.5. Final delimitation

Fig. 7 shows the study's delimitation of the coastal areas based on the application of the criteria described in the method. As indicated, the resulting demarcation encompasses the ten communes that constitute the Province of Chiloé: Ancud, Quemchi, Dalcahue, Castro, Curaco de Vélez, Puqueldón, Quinchao, Chonchi, Queilén, and Quellón. This has implied the inclusion of the Greater Island of Chiloé which, in its more than 8000 km^2, is a minimum of 25 km away from the coast [13]. From a geomorphological perspective, the group of islands that constitute the archipelago and that transcend political-administrative limits has also been integrated. In addition, certain continental areas that belong to the communes of Maullín, Calbuco, Hualaihué, and Chaitén, have been incorporated to the north and east of the territory. Therefore, not only is the Province of Chiloé represented in the delimitation, but it also includes Llanquihue and Palena.

Thus, a homogeneous space that houses Chiloé's characteristic diversity was obtained. All the populations that inhabit this territory share a series of traditional activities (such as artisanal fishing) and industrial activities (such as salmon farming). Likewise, they participate in common customary uses and maintain close cultural ties associated with their history, mythology, living conditions, and Chiloé mobility [3,5]. These similarities may also be appreciated in the most recent situations arising from the environmental, landscape, and sociocultural issues and transformations [43]. Such is the similarity that exists between the Chiloé archipelago and the continental areas bathed by the inland sea, that some authors refer to them as 'Insular Chiloé' and 'Continental Chiloé' [53]. Moreover, a precise spatial definition of these concepts has never been proposed.

Conversely, the delimitation includes the Inland Sea of Chiloé in all its extension, except for the northernmost sector of the Reloncaví Sound. The inland sea is the setting where most of Chiloé 's mobility, conflicts, and peculiarities materialize. For example, aquaculture is developed almost exclusively in this area. It is considered as the local economy's dominant activity and the determinant of many of the socio-ecological issues. It should be emphasized that 78% of the Chilean aquaculture production is generated in the Los Lagos Region, and from this, more than 80% originates in the inland sea. Although mussel farming stands out in the surface area and the number of concessions, salmon farming stands out for its productivity, which amounts to 75% of the regional aquaculture production [24].

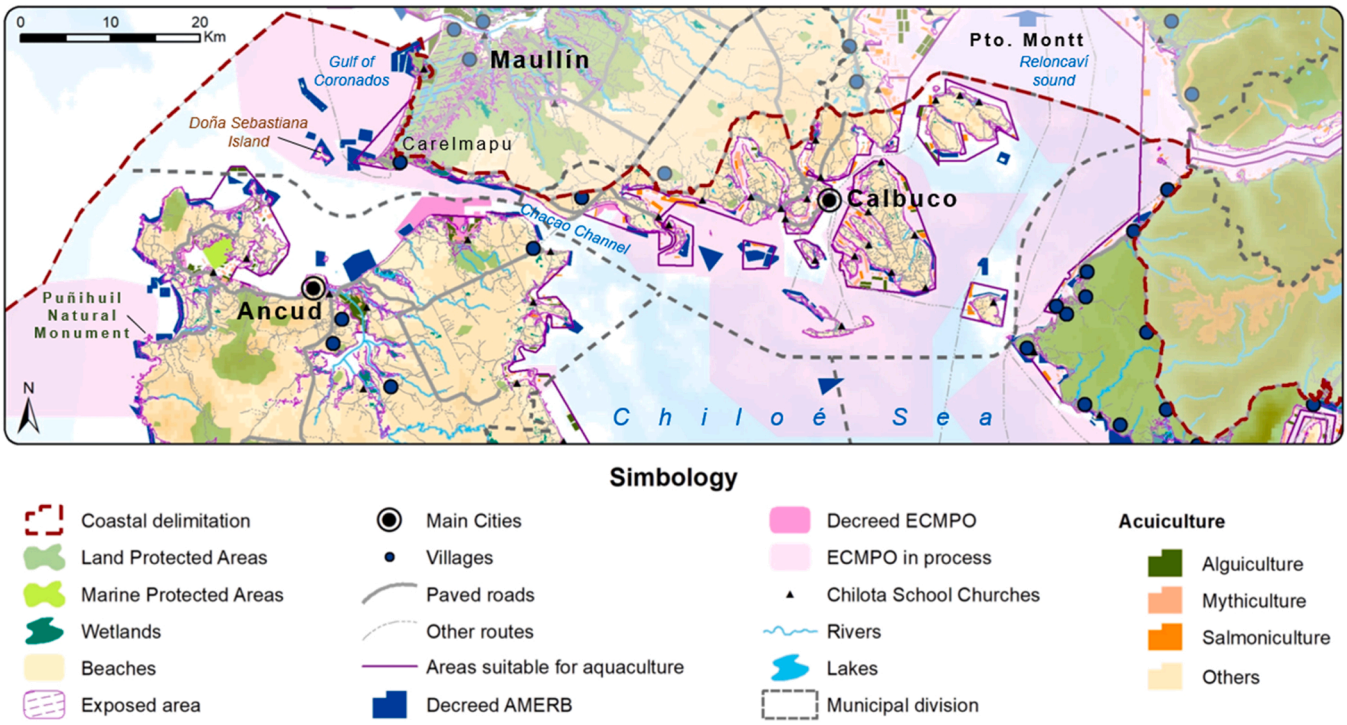

Fig. 6. Delimitation of the coastal zones of the Chacao Canal and the Reloncaví Sound.
Source: own elaboration.

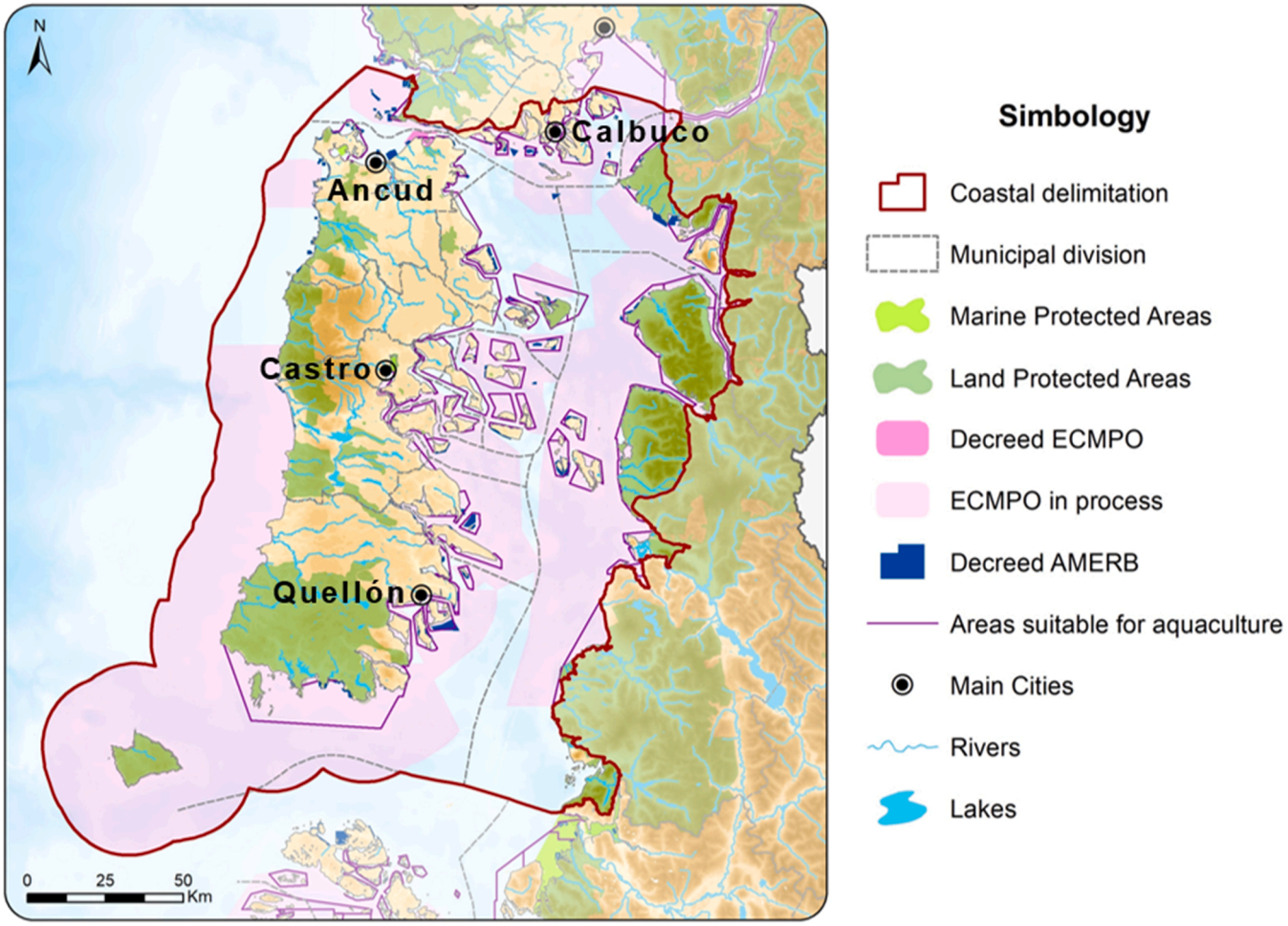

Fig. 7. Delimitation of the coastal zones of the island and the sea of Chiloé. Source: own elaboration.

In summary, the delimitation of the coastal areas of the island and the sea of Chiloé covers a total area of approximately 34,200 km^2, with 35% constituting land and 65% being marine areas. In addition, it should be noted that more than 40% of the land area is under some form of environmental protection. Regarding the marine areas, 75% of the waters are ECMPO approved or in the process of being thereby approved. The function of these spaces is to favor the conservation and management of customary uses through the administration plans prepared by the indigenous communities and approved by the Undersecretary of Fisheries and Aquaculture.

5. Discussion

5.1. A contribution to coastal management in Chile

An effective delimitation must be based on the recognition of the common characteristics that define a specific territory. The island and the sea of Chiloé 's coastal areas are configured as a diverse socio-ecological system with shared conflicts and environmental challenges. This result has been achieved by managing criteria based on different scientific research, from studies on biology, ecology, and climate change to those from social disciplines. These include geography, anthropology, and economics. These have been combined with the political-administrative dimension, given the public interest in the coast and the role it plays as a mediator between the social and ecological variables [10].

For the first time in research, this study proposes a delimitation of the coastal areas in Chiloé with the help of Geographic Information Systems. Indeed, no legal or academic project defining the limits of coastal areas in Chile has yet been published. However, the master's degree project presented by Pizarro Cisternas, [50] for the ICZM master's degree program at the University of Cadiz is worth mentioning, which presents a proposal for delimiting the coastal space of Chile's Valparaíso Region based on the application of geographical, ecological, socioeconomic and administrative criteria. Due to the orographic characteristics of the study area, Pizarro Cisternas, [50] pays greater attention to the influence that mining activity exerts on the coasts through river currents. Chiloé 's low-elevation archipelagic geography and its economic model based primarily on the exploitation of marine resources explain why the two proposals differ in the implementation of delimitation. The delimitation of the Valparaiso Region's coastal zones is expected to be published soon.

The above example shows that the spatial variability observed along the Chilean coast requires the application of different delimitation criteria adapted to the reality of each area. It must be stressed that it is not enough to establish a national delimitation, since territorial dysfunctions that occur in more specific areas would not be represented. On the other hand, nor does it suffice to examine the problems that occur in the closest environment, without paying attention to the negative implications caused by human activities located at a greater distance, in what is known as the coastal zone of influence. In short, it is considered that the ideal scale for defining coastal zones is the intermediate one, that covers anywhere from several municipalities to a region [10,32,42].

5.2. The coast according to current Chilean legislation

In Chile, the National Policy for the Use of the Coastal Border (PNUBC), approved in 1994 by the Supreme Decree, continues to be the main form of advancement in coastal management in the country. This is despite it being implemented for over 25 years without revision. The policy aims to develop national zoning for the management and mapping of the preferred uses of the coastline. Subsequently, through the Regional Commissions for the Use of the Coastal Border, a 'macro-zoning' should be proposed for each region. However, thus far it has only been approved in two of them [51].

The PNUBC bases its speech on the concept of 'coastal edge,' which states that "that the strip of territory that includes the fiscal beach land, the beach, bays, gulfs, straits and channels, interiors, and the territorial sea of the Republic, forms a geographical and physical unit of special importance for the comprehensive and harmonious development of the country" ([25]:4). To better understand the term's scope, it should be noted that according to the policy, the 'fiscal beach lands,' have an extension of 80 m inland from the high tide line, which only applies to environments free of urbanization. In other words, we can say that the PNUBC uses physiographic (bays, gulfs, etc.), political-administrative (12 miles of territorial sea), and arbitrary criteria (80 m of fiscal beaches) to delimit the coastline [49].

This mistaken definition of the coast gives rise to a broad marine space that contrasts with the small land area represented by the coastal edge. Martínez et al. [36] argue that introduction of this concept into the Policy is due to the lack of interdisciplinary work, where the variable nature of the coast, the country's seismicity or climate change were not considered. In addition, the 80 m of beach lands only apply when beaches are not adjacent to private properties, meaning that in many cases the 'coastal border' only extends to the high tide line and leaves out typically coastal ecosystems like dune systems.

The neoliberal logic on which the PNUBC is based was strengthened with the Coastal Border Management and Maritime Concessions Bill (2013). Therefore, a very narrow and rigid delimitation is generated, based on merely quantitative criteria, which are incompatible with the dynamics of the coast [22]. This definition is not adaptable to the Sustainable Development Goals, climate change nor to the risks derived from telluric movements, which are highly frequent in Chile [34]. Alongside the lack of the definition of the coastal zones, there are other obstacles caused by Chilean legislation. These include the prioritization of development over conservation, the scarce human and economic resources allocated to the coastal management, the absence of cooperation and coordination mechanisms, the insufficient involvement of indigenous groups in the decision-making, the ineffectiveness of the controls to prevent the formation of private beaches and ultimately, the lack of political will [17,35,51].

5.3. The promulgation of a Coastal Law in Chile

Due to the political situation in Chile, the National Research Center for the Integrated Natural Disaster Management (CIGIDEN) proposes to replace the concept of the 'coast border' with that of 'coastline.' This is, in other words, the maximum level reached by sea during the Holocene. In this manner, coastal ecosystems (wetlands, dune fields, marshes, etc.) previously invaded by the sea because of the last glaciation would be included [34]. Therefore, the CIGIDEN has recently coordinated the development of a white paper for the creation of a Coastal Law in Chile. In addition, other fields linked to coastal management are progressing, especially regarding land use planning, because of the enactment of Law 21,074 for Regionalization Strengthening (*Ley de Fortalecimiento de la Regionalización* - LFR) (2018), and Decree 469 that approves the National Territorial Planning Policy (2021). This has meant a greater transfer of powers to the Regional Governments [26].

The draft Coastal Bill submitted in late 2022 defines the coastal areas as "the dynamic space or interface of variable width depending on the geographical the geographical characteristics where land ecosystems interact with aquatic ones, be they marine or continental" ([65]: 5). This concept, supported by scientific knowledge, is better adjusted to the changing nature of the coast, the fragility of its ecosystems and climate change. The new legislation must also serve the purpose of delimiting public coastal space and the zoning uses that can be developed in both public and private properties. This will entail imposing restrictions on private parties that might affect coastal-marine resources or spaces, as the purpose of this area would be to protect ecosystems and public interest in the coast [11].

Meanwhile, regional coastal macro-zoning initiatives in Chile have so far been ineffective, as over 25 years since the PNUBC was enacted, they have only been approved in two regions. However, noteworthy progress has been made in coastal management in recent years that could improve the effectiveness of these instruments. On the one hand, following enactment of the LFR in 2018, macro-zoning instruments have become binding, since they must now adhere to the Regional Spatial Planning (*Planes Regionales de Ordenamiento Territorial* - PROT). On the other, replacing the rigid concept of 'coastal border' with that of 'coastal zone' in the draft legislation would also affect the exercise of rationalizing coastal uses, as it would be applied to a far larger area. Thus, the results of this article could be used to propose the 'macro-zoning of coastal zones' in the Los Lagos Region.

5.4. The establishment of a ICZM program in Chiloé

The construction of a new notion of coastal zone in Chiloé allows modifying the spatial context where Chilean policies, regulations and instruments are applied. The zoning of uses and activities in a broader environment than the one proposed by the PNUBC contributes protecting ecosystems that were not previously considered, such as dune systems or wetlands. In addition, the private properties located within the proposed demarcation would be subject to greater legal restrictions to defend public interest regarding the coast and the ecosystem services it offers. This would allow a transition toward a more sustainable development model in Chiloé . The regional macro-zoning of coastal uses should be accompanied by and serve as the basis for establishing a ICZM program for the coastal areas of the island and the sea of Chiloé . For implementation of this instrument to be effective, it would be advantageous to generate alliances between the Chilean state and international organizations like the Inter-American Development Bank (IADB). In addition, given the geographical uniqueness and biological wealth that characterize Chiloé , this place could take advantage of the opportunity to benefit from the economic funds offered by institutions such as the Global Environment Facility (GEF).

Still, the study's cartographic results should be contrasted with the vision of local actors based on participatory processes. In this regard, it is worth highlighting one of the exercises developed by [61] in their research project, consisting of the location of 'Maritime Geocultural Areas' in Chiloé (*Área Geocultural Costera Marítima* - AGCM). This is a zoning of the Chiloé Inland Sea based on [31] 'lived space'. This is based on the existing interactions between the local population and the environment. This perspective has been very useful for determining the marine cultural criteria of the coastal areas of the archipelago since it provides cartographic information on the island's inhabitation and the transformations it has experienced because of globalization.

The delimitation of the coastal areas of the island and the sea of Chiloé serves as a resource for decision-making in the public policy framework. In Chile, where coastal boundaries have not yet been defined on a subnational scale, this research could be used as a methodological example to be followed in other areas of the country. Certainly, the delimiting exercise must be adjusted to the territorial context of the location, the issues and conflicts that occur there, and the availability of its mappable information [8]. Moreover, the results must undergo a cyclical review, given the changing nature of coastal ecosystems, economic models, cultures, and policies.

6. Conclusions

The application of multiple criteria for the delimitation of coastal areas has caused a space that extends beyond the territory of the Chiloé Province. This incorporates some areas of the Palena and Llanquihue provinces, and the entire inland sea. As a result, the internal connections between the islands that constitute the archipelago and mainland are represented within this demarcation and allow the configuration of a work environment object of a ICZM program that pursues the establishment of a sustainable development model.

The consideration of criteria of a different nature enables it to separate from the legal borders that separate the city from the countryside and the land from the sea. The delimitation of the coastal areas of the island and the sea of Chiloé deviates from the continental and centralized logic on which the territorial planning in Chile has been based. Conversely, this approach is committed to a management method based on ecosystems, adjusted to political-administrative divisions, and is far from the definition of the 'coastal border' proposed by the PNUBC.

Based on this delimitation, the next task is to conduct an operational diagnosis of the coastal areas of the island and the sea of Chiloé to understand the nature and interrelationships between the socioeconomic, cultural, and ecological issues. Considering that territorial conflicts have their origin in political-administrative factors, it is essential to continue the investigation with a diagnosis of coastal governance to propose solutions.

Declaration of Competing Interest

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Data availability

No data was used for the research described in the article.

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