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Toward marine democracy in Chile: Examining aquaculture ecological impacts through common property local ecological knowledge☆

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ABSTRACT

The preferential treatment of the aquaculture industry over fisheries and marine protected areas in Chile through the demarcation of the Areas Appropriate for Aquaculture has set it on a collision course with conservation, artisanal fishing and coastal communities. This article shows how marine democratic governance can evolve through the inclusion of artisanal fisher local ecological knowledge. Artisanal fishing communities elicit how contamination from industrial aquaculture is causing natural shellfish banks, fish populations and endangered cold corals to diminish. While fisheries and aquaculture governance are nominally governed by the same body, the ideological concerns of decision makers have not left space for the original users or ecological health. The right to good water quality and ecological health of artisanal fisher, original people and the broader coastal community are highlighted. Using semi structured interviews, participatory cartography and Geographic Information Systems fishers explain how the contamination footprint has expanded across benthic habitats. Diving in the contaminated areas confirmed the impacts using comparison with control sites. The article shows how new laws are need to assess nutrient loading, antibiotics and invasive species introduction. It links these impacts to literature in other countries where harmful algal blooms result from eutrophication from aquaculture contamination. It shows how the privatisation of space has left marine governance unable to take adequate enforcement. Artisanal and indigenous common properties can lead toward participation in marine planning for ecological health, whilst governmental institutions need realignment so that marine ecological planning for conservation can evolve.

1. Introduction

There has been simultaneous local and international contestation brought on by the radical transformation of the Southern Chile marinescape during the last two decades; brought on by private marine property rights for industrial aquaculture [1,2,101,108]. Species including *Onchorhynchus* spp., *Salmo salar, Crassostrea gigas*, *Haliotis rufencens* have been introduced making Chile, behind Norway, the 2nd largest salmon, trout and mussel producer in the world [3,109]. The ecological impacts of the rapid development of aquaculture in Chile have not been studied [4]. Significantly, the protests have been focused against the designation of the majority of coastal space across Chilean regions as areas appropriate for aquaculture (AAA) without local participation [5,6].

In Chile, successful marine governance is limited by the hegemony of neoliberal thought and property rights [7]. Environmental policy, institutions and participation have been shaped by the legacy of a right-wing dictatorship (1973–1989). Rigby et al. [8] highlighted the conflict of interest between regulator's responsibility between protecting the environment and supporting aquaculture in Canada, something this article explores in the Chilean context. In Chile, it appears the associated orthodox interpretation of neoliberalism for the marine environment is inimical to sustainability [9]. The government has instituted across ecosystems; a legal regime that works to enable corporate resource extraction, whilst limiting the regulation ecological impacts [10]. The neoliberal reforms resulted in a marine private property system, where the rights of private concessions for aquaculture supersedes other rights [2]. These include artisanal fishers, indigenous rights and conservation. This has been without consideration of the ecological baselines, appearing to be a case of shifting baseline

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Acronyms

HAB	Harmful Algal bloom
FAA	General Fisheries and Aquaculture Act 1991 (Based on Spanish acronym)
AMERB	Areas de Manejo de Recursos Benticos (Benthic Management Resource Area)
ECMPO	Espacios Costeros Marinos Pueblos Originarios (Indigenous Peoples Marine Spaces)
AAA	Areas Apt for Aquaculture
GIS	Geographic Information Systems

syndrome [11]. As there has not been a move away from this top down power structure, there is no mechanism of participation in coastal decisions. Nor to scientifically assess the impacts or carry out adaptive management to the threats. Approximately 80% of Southern Chile's coastal zone have been zoned to industrial aquaculture, with opportunities for further private concessions [6]. Subsequently, the industry has grown by 800% since 1990 [12].

There has been new fisheries legislation, based on the General Law on Fisheries and Aquaculture 1991, which proposed the first categories of management and marine conservation [13], and the INFA, which requires consultants paid for aquaculture to test in the concessions. However, there is no public oversight of this process [14]. There has been no change from the original push for marine privatisation, nor a concomitant strategy to integrate marine protected areas (MPAs) to offset the exploitation and collapse of marine ecosystems [15–17].

Ecological disruption of extensive aquaculture is expressed in different ways: 1) salmon escapees from the pens in rivers and coastal waters of southern Chile, which may exceed 4.4 million individuals each year [18]; 2) the unregulated use of chemical compounds, such as antibiotics used to prevent infections due to widespread piscirickettsia sea lice [19]. Additionally, the use of Emamectin benzoate for sea lice has resulted in levels found in sediments exceeding expectation around farms even if regulated which are thought to influence the entire ecosystem [20,21]. Additionally, copper used as antifouling [22] and litter [23]; and 3) the loading of nutrients from aquaculture into the interior sea and lakes and 4) nutrients from large scale mussel farms. The controversial explosion of the Marea Roja (Red Tide) Harmful Algal Bloom (HAB) in Southern Chile pulsated to international attention in 2016 after small scale fishers and the Chiloe islanders developed a new social movement with substantial protests [5]. The local community has linked the increasing Marea Roja HAB events to contaminating anthropogenic factors, that can be related to the lack of democratic governance of aquaculture and fisheries.

Muslow et al. [24] explained how soft-bottom ecological assemblages have been collapsing in two fiords of Chilean Patagonia from industrial aquaculture through contamination including nitrates, phosphates and ammonia, resulting in reduced oxygen conditions and a dark crust on the seabed. This supports a wide-ranging literature from other parts of the world that organic waste from industrial aquaculture creates impact on benthic sediments seeing biodiversity decrease and physio-chemical properties change [25–27,110]. In eutrophic conditions authors such [28] describe the spread of a white crust of Beggiatoa bacteria on this black anoxic crust, and on gorgonian species in the Comau fiord (Hausmann et al., 2013). Internationally, literature links nutrient loading, eutrophication and HABs (North America [29,30]; Europe [31]; Korea [32]; and Japan; [33]. However, in Chile, many studies downplay the role of nutrient overloading and ecological change from industrial aquaculture supporting HABs finding global climate change to be the more significant driver [34–37].

The connection between representation and power contributes to a sociological concept of scale, in which different levels of an organizational hierarchy respond and act at particular spatial and temporal scales [38]. How institutions can evolve to adapt to integrate local ecological knowledge (LEK), ecological indicators and more equalized power relations is discussed in the context of adaptive co-management. That is, linking different experimental and experiential learning of ecological change or LEK with participatory governance [39]. While adaptive and ecosystem forms of management have gained attention [39], point out that over emphasis has led to the domination of natural science, making translation into the socio-political arena difficult.

Spatial rights for low impact forms of artisanal fishing were first recognised in Chile with the developed of the AMERB *Áreas de Manejo y Explotación Bentónicos* (Benthic Management Resource Area) system [40] also called Territorial Use Rights [41]. These are common properties as they are common pool resources owned in common [42]. Artisanal fishing includes diving, rod and lining, potting, set netting and hand lining. AMERBs are the most common property right with 296 syndicates operating in “Los Lagos” district and 30,000 artisanal fishers [112]. Nevertheless, there are several challenges still for AMERBs to perform as units, underpinning an ecosystem approach and integrating LEK into governance [43]. Another form of common spatial property right to be compared with AMERBs in the results are “*Espacios Costeros Marinos Pueblos Originarios* (ECMPOs)”, which aim to protect ecosystems and indigenous cultures [44]. How these two different common properties can support the evolution of ecological health through association with the socio-ecological interests of the wider coastal community and multi scalar interests in conservation needs further research.

This article examines how fisher LEK through fisher common properties, the AMERBs and ECMPOs in southern Chile is evidencing contamination from aquaculture and the loss of natural shellfish banks, other habitats and associated biodiversity. Overharvesting while also important; is discussed elsewhere. It describes a mechanism of participation through fisher common properties, integrating fisher LEK through participatory cartography and Geographic Information Systems (GIS) [45]. Furthermore, a legal regime that requires the testing of these pollutants to support existing democratic local institutions is described [33]. These observations are invaluable for future conservation given the ecological disruption caused by industrial aquaculture and other impacts from development. Complex adaptive systems can benefit from the combination of different knowledge systems [39]. It is important to note that involving fishers in this way can develop feedback between fisher local ecological knowledge and scientific epistemologies to build bridges for biodiversity [113].

Furthermore, a bottom up and democratic approach to territorial and ecological planning through common properties can solve the current conflictive political situation and could limit the environmental deterioration in coastal western southern South America.

2. Methods

2.1. Case studies: introducing Maullin, Dalcahue and Mañihueico - Huinay

Case studies are useful here to compare the repeated instances of a particular phenomenon across different places [114]. They are based on interviews and focus groups with community stakeholders, fishers and marine governance from Dalcahue in Chiloe, in Maullin in south west Los Lagos Region and Mañihueico - Huinay in the northern-most fiords of Chilean Patagonia. Other cases studied included Yaldad, Quellon, Compu and Calbuco however there was no space to discuss these results beyond a table of biodiversity change. Chiloe is characterised by a vibrant culture which a mix of Indigenous Mapuche-Huichille and Spanish. The area possesses a Chilote identity separate from Los Lagos, and was in the past, independent from the regional capital, Puerto Montt. This is noteworthy as the city is the location of many of the headquarters of the industrial aquaculture businesses which this article considers. To balance this, research was carried out outside of Chiloe in Maullin, and in Mañihueico – Huinay.

2.2. Participant observation – diving impact assessment

In the austral region, scuba diving observation took place in different locations to better understand the contamination impacts from industrial aquaculture. These were in the areas where the participatory cartography was produced. It was important to observe the spread of the contamination footprint to comprehend the extent of the ecological change. This formed a form of, before/after impact assessment, as diving also took place in a similar control habitat to understand the natural conditions of the ecosystem were like, in areas without the aquaculture footprint [46]. The first control habitat where observations took place was the Isla Tabon, one of the few areas outside the AAA, and Caleta Condor, inside an MPA where no industrial aquaculture has been developed in proximity as can be seen in Fig. 1 below. These are referred to in the map below. Furthermore, participant observation of this form of fishing, specifically took place in the Chiloe archipelago. Fishing with Huichille-Mapuche groups using nets and lines also took place in ECMPOs. Participant observation relates to the sharing of the activities of the group studied, in this case, the process of fishing and its evaluation of fish stocks [115].

2.3. Semi-structured interviews

Sampling using a snowballing interview technique lead to 20 semi-structured interviews with those working in different governmental institutions, NGOs and aquaculture related businesses (Miles and Huberman 1994). Interview data was ordered through an inductive approach to thematic analysis supported by the software NVivo 10 [116]. The meta themes that were used during interviews were: Access to decision making and participation, how the system could be improved, the impact and pollution in the marine environment, how this relates to seabed habitats and biodiversity. Questions were specifically asked regarding the last time the fish species listed in the biodiversity Table 1 below were seen, and how this related to habitat impacts from aquaculture. The semi structured interviews were framed according Fraser's [47] conceptualization of realising parity of participation.

Table 1
Showing species perceived to have been lost through contamination and the year last reported by fishers in the case study geographical areas.

	Corvina	Pejerrey	Robalo	Mero	Jurel	Navajuela	Tumbao
Dalcahue	1998	1995	2001	2003	2002	2001	1997
Maullin	2002	2001	2003	2005	2002	2006	2001
Compu	1990	1992	1995	1993	1991	1989	1991
Quellon	1998	2001	2003	2004	1999	2000	2000
Quillien	2000	2005	2003	2006	2001	2002	2000
Calbuco	1999	2002	2001	2004	2006	2008	2002
Puerto Montt	2002	2011	2007	2001	2003	2004	2001

Those interviewed will be referred to in the text by their local community, and the number corresponds to the order of those interviewed.

2.4. Participatory cartography and focus group

During the focus groups participatory cartography took place to better comprehend the contamination spread and the influence on natural bank ecosystems. Counter-mapping refers to attempts to map against dominant power structures, to further seemingly progressive goals [48]. Those involved in the generation of Public Participation in Geographical Information Systems have worked to decentralise power of from the hands of the cartographic elite to support marginalised knowledges [49]. This research found participatory sketch maps were more accessible as a way to share LEK in the first instance, before consolidating the maps using computer software. This cartography was shared with an adaptive learning group. These are thought to be better for ecosystem-based approaches as they allow for exploration and experimentation [117]. This approach allowed for the agency of coastal champions such as fishers who have the knowledge if not the formal background to engage in institutional experimentation [50]. In the Maullin focus group, there were 15 people representing six fishing and seaweed farm unions at the confederation meeting and took approximately 3 h. In Dalcahue, 10 fishers from 4 unions who came together at

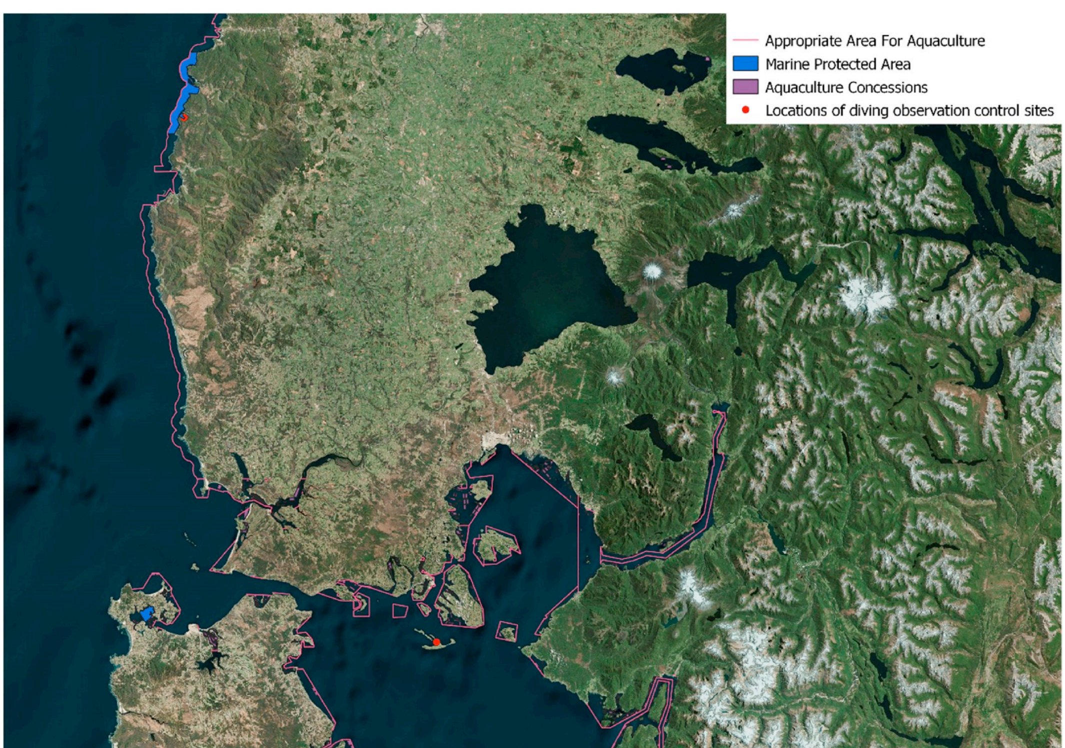

Fig. 1. Locations of dive observation control sites. Caleta Condor in Lafkenmapu Lahuel MPA and Isla Tabon, outside the AAA.

the municipal meeting, which took over 4 h. In Mañihueico Huinay 12 leaders from 12 different indigenous communities at the ECMPO management meeting which took over 4 h. The overarching questions discussed included the impact and pollution in the marine environment from aquaculture and other sources, where historical habitats were, where they are now and if they have died, and how this is perceived to relate to continuing biodiversity.

3. Results

3.1. Observation of biodiversity decrease

Across the Chilean south since the introduction of aquaculture in 1980, different fishers have reported a continued decrease of pelagic and benthic fish species including “Corvina” (*Cilus gilberti*), “Pejerrey” (*Odontesthes regia*), “Robalo (*Eleginops maclovinus*) Mero” (*Dissostichus eleginoides*), “Jurel” (*Trachurus Murphyi*), “Navajuela” (*Tagelus dombeii*), “Tumbao” (*Semele solida*), reportedly from the aquaculture as seen in Table 1 below. It is also important to note that overfishing may have been occurring contributing to the loss.

3.2. Maullin estuarine fishing community

Maullin is a municipality situated in the central western part of “Los Lagos” district, on the mainland north of Chiloe as can be seen in Fig. 2, the map resulting from the participatory cartography. It is an estuarine ecosystem which is firstly of interest because it is not an intensive site of production for aquaculture. Despite this, their experiences with aquaculture made them highly motivated to develop a participatory marine plan through the cartography. The rich natural providence of the area means they are able to harvest a number of species from Jaiva *Cancer* sp., (crabs), *Piure Piura chilensis* (ascidian), a large seaquirt, to a variety of bivalves including almejas (Clams) *Venus antiqua*, machas (Razor Clams) *Mesodesma donacium*, choritos (Mussels) *Mytilus chilensis* and picorocos (Giant barnacle) *Austromegabalanus psittacus* from the benthos. Where these benthic resources are gathered is predominantly in open access areas, on what are called natural banks. These are sometimes called biogenic reefs in the literature to signify living structures that enhance biodiversity [51]. However, the conceptualization of the natural bank and its subsequent recognition is contested between fishers and the defining governing body, Sernapesca. A fisher from

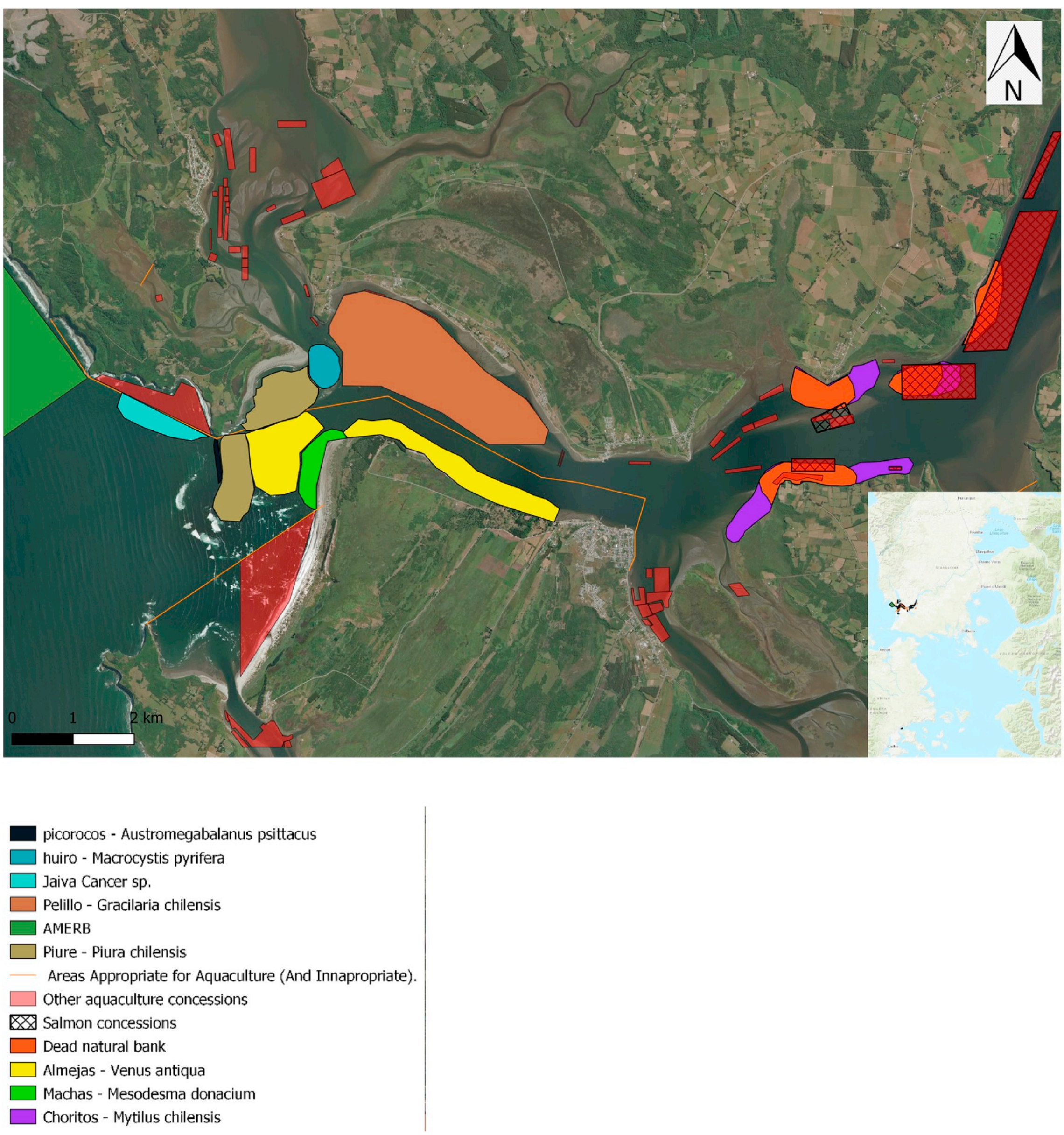

Fig. 2. Ecological municipal plan Maullin.

Maullin explained:

They don't recognise our natural banks. We have them right next to the salmon farms. They came and measured it in 2012, and said it wasn't healthy enough. But it has degraded since the early 90s when they put the salmon farm there (Maullin 1).

Sernapesca created a definition for what can constitute a natural bank in 2012 under Ley N° 20.434. This definition required a certain level of species abundance and richness to be present when the measuring began in 2012 [52]. Fishers around "Los Lagos" felt this was environmentally unjust as the measurement of the natural bank

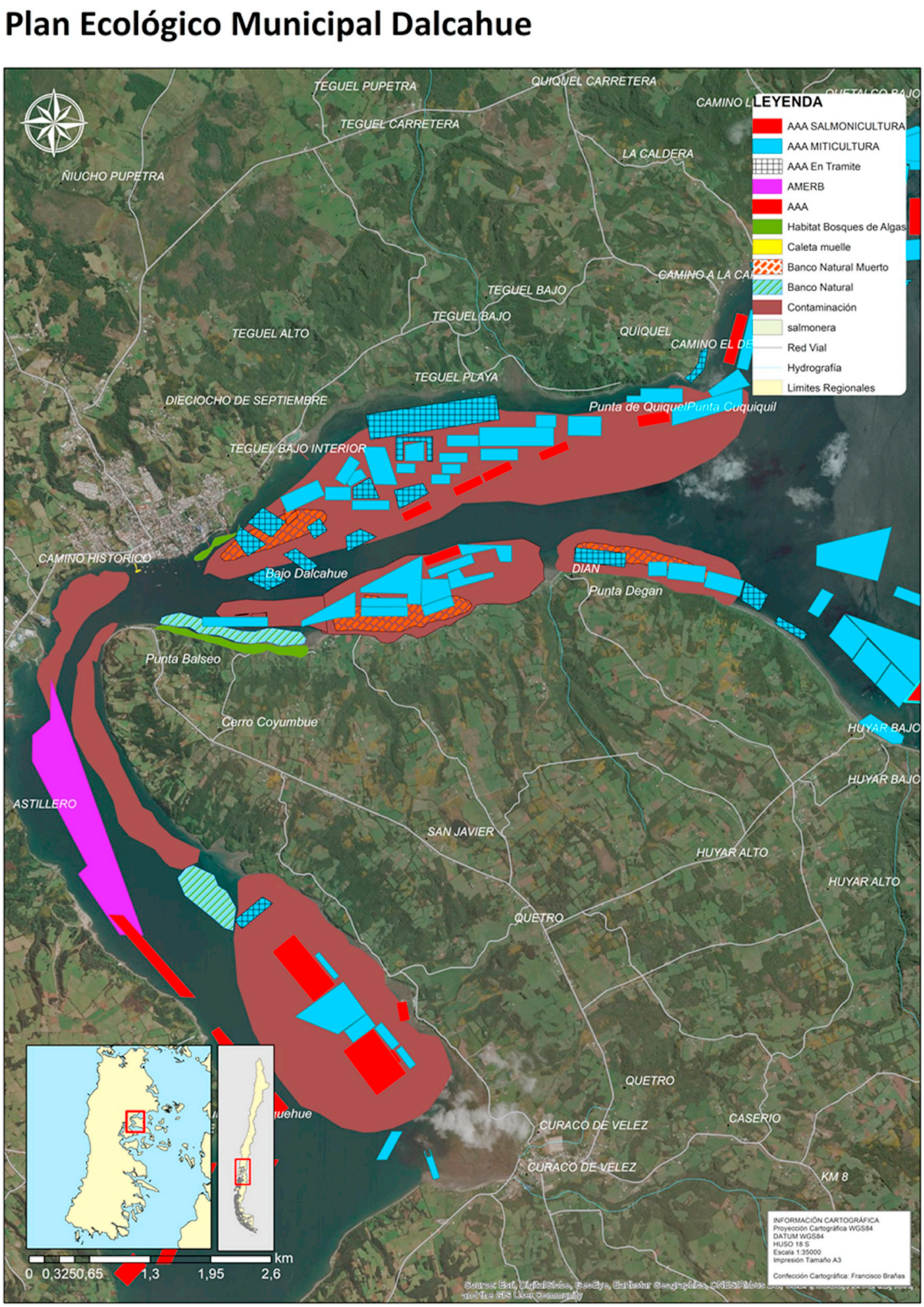

Fig. 3. Ecological plan for Dalcahue municipal showing contamination impact from aquaculture concessions and artisanal fishing AMERB.

baseline began in 2012, nearly forty years after the first salmon farm was established. Having a snapshot in time after the damage has been done meant the continued debilitation of the ecosystem, an example of the shifting baseline syndrome where measures are taken after the period of good ecological health [53,54,124]. To achieve environmental justice, it is important to have a conceptualization of natural banks as ecosystems that were healthy in the past, as well as incorporate the communities' future vision of the ecosystems return to health. Nevertheless, there remains an opportunity through the participatory marine plan developed below to protect the remaining areas. As can be seen many of these resources were mapped to establish rights before new aquaculture concessions were given through the AAA. The fishers established that the natural banks were particularly debilitated around the salmon and mussel farm concessions. There was no environmental impact identified around the seaweed farms.

3.3. Dalcahue municipality, the AMERB and the open access area

Dalcahue is a municipality and port town, a gateway to the islands of the interior sea of Chiloe which can be seen in Fig. 3, the map resulting from the participatory cartography.

In Dalcahue there are 60 active registered fishing boats, and 170 registered divers. Dalcahue saw one of the first salmon industrial aquaculture concessions in 1980. Since then it has seen further 6 salmon concessions and 30 more mussel farms (Mytilus) and other concessions. It has been defined as an area of high production by Subpesca. The community was never given any opportunity to comment on whether these aquaculture concessions should be given permission by Subpesca and Directemar. Despite this the municipality as a democratically elected council is highly interested in having some responsibility over its marine area for those that live and work there such as the fishers and their intergenerational families, and those in the tourist industry. Differently, the majority of the skilled salmon aquaculture workers are migratory, whose managers headquarters and owners are situated elsewhere [55]. Furthermore, spill-over benefits have not occurred as the businesses only pay taxes to the central government in Santiago rather than provincial government (Irarrazaval and Barton [56]. It is worth noting that many of the mussel farms are owned and managed locally. Because of the environmental degradation, the fishers involved in the municipality were interested to share the extent of habitat and biodiversity loss over time through participatory mapping. A group of ten fishers set to work to develop a map which demonstrates the spread of the contamination from the salmon and mussel farms visible whilst diving, as well as observed using fishing gear including pots and long lines. A diving fisher Morris from Dalcahue introduced.

The contamination does not stop, because there are still more salmon farms. In these salmon farms, there are salmon fecaes mountains that produce pollution. Sometimes in the black barrows, you can see the white crust growing. They say it is linked to eutrophication.

The fishers and those working for the municipal from a fisheries background worked to show the extent of the contamination footprint, coloured brown, and how this linked to the aquaculture coloured red for salmon and blue for mussels. They drew on the map where historic shellfish banks, a mix of “almejas” (*Venus antiqua*) and “choritos” (*Mytilus chilensis*) in this case, had significantly decreased as result in orange (Fig. 2). They explained they had observed this while diving historically for shellfish inside the AMERB highlighted in pink to the west, and outside in traditional open access areas such as the lost natural banks. They agreed there was too much of both types of aquaculture, and that the in-combination impact was to blame, suggesting that the natural bank areas should be protected from contamination in the future through a buffer zone from the aquaculture. They highlighted that as a semi enclosed area, the contamination footprint is more concentrated than it would have been if outside in an open sea zone as seen on the map Fig. 3 [26]. This map shows that it is unsuitable to be an area of high production as designated by Subpesca. It has also seen a continued decrease of fish species since the late 1990s, as described in Table 1 below. The AMERB is very small in comparison to the open access area and thus it is difficult to imagine a spatial management plan without a new form of designation to control contamination.

3.4. Mañihueico - Huinay ECMPO, aquaculture contamination and cold-water corals

Mañihueico - Huinay ECMPO is a much larger area than the AMERB cases before. As it is an ECMPO, it is managed by the Huilliche-Mapuche indigenous community. It includes the Seno Reloncavi bay, and various fiords such as Quintupeu and Comau. It has not yet had its management plan approved by Subpesca, but this will be soon. Differently to the private parcelling action of aquaculture concessions, the Huilliche ideology expresses its vision of territory as a shared common space, with different management practices for different seasons. Some of the users maintain the old religion which holds nature as sacred [57]. Its complex network of fiords and islands has made it popular with industrial aquaculture. The area in the fiords have significant reefs of cold-water corals with *Desmophyllm dianthis* being the matrix species, the solitary cosmopolitan deep-water scleractinian coral which occurs in unusually shallow waters in the area, a situation unique in the world [58].

According to the ECMPO stakeholder's fisher LEK, certain locations are unsuitable for aquaculture as the nutrients and other contaminants do not flush out, as the circulatory regime is too slow, such as the area in the south of Comau fiord. This has meant that some of the cold-water coral reefs, some only discovered about 15 years ago have died since the aquaculture contamination has increased [58].

Yes, we have seen the areas where the cold corals. We have also seen where they have died off recently near the aquaculture from the contamination. It is too much, the natural shellfish banks have died off too, the AAA zone makes no reference to them (Mañihueico 1).

This dive fisher described her experiences diving in the fiord and seeing the endangered cold corals. She described seeing them die off through the contamination in the areas near the aquaculture. Similarly, in 2012 [58], described a mass die off of Desmophyllum banks along at least 15 km of shoreline, probably through the combination of a low oxygen event after a strong algae bloom (caused through eutrophication) in combination with highly active cold seeps present in the fjord. There has been at least a doubling of primary production in the fjord during 20 years has been associated to the growing salmon farming industry [119]. Simultaneously, their records show algae blooms have increased in frequency and intensity [58]. There is a highly endangered octocoral species unique to the area, *Swiftia comauensis*, only found to the north of the Comau fiord [59]; Chilean Red List). However, it may be possible to develop adaptive co-management of the increasing nutrient loading to protect these species in the future. An ECMPO leader explained further their plans for the ECMPO.

We want to develop the management plan so we can limit the amount of contamination impacting the corals and the fish. There is an area around Liliguapi where I think they found a new coral species which we can protect. It is early still, we haven't had the plan approved yet by Subpesca, but we will calculate the carrying capacity for different areas, then we can limit the contamination in those areas and preserve the corals (Mañihueico, 2).

The group is explicitly planning to set up areas of conservation to limit the impacts of aquaculture contamination. This is the early stages of an adaptive co-management plan [39], where the community group can limit aquaculture expansion and destructive fishing to stop the species loss through buffer zones. They are looking to collaborate with the local marine ecological research station at Huinay in the future.

4. Discussion

4.1. Fisher LEK identification of ecological impacts and the need for new co-monitoring laws

Substantial species, biodiversity and habitat loss arising from industrial aquaculture impacts are reported by fishers in AMERBs and in ECMPOs around Southern Chile. The black crust described by Muslow et al. [24] matched the spatial footprint described by the fishers. Additionally, there were lower levels of diversity observed in the contaminated area, influencing the fishing and biodiversity in general. In a context where there is a lack of enforcement through institutional inadequacy and the privatisation of sea spaces, artisanal fisher LEK can provide an invaluable role through the production of evidence through monitoring contamination. This can be achieved by calculating nutrient loading for each municipal marine landscape area, or ECMPO equivalent sized ecosystem. However, a locally situated and democratically responsive monitoring programme needs to consider the impacts of individual sites alongside, in combination and cumulative impacts at different spatial scales [22]. This can interface with the marine licensing programme, which established limits maximising annual biomass by "barrio", but it does not consider the other users in the common property and municipal, such as fisheries tourism and conservation interests.

In both AMERBs or ECMPOs there is no law for the enforcement of water quality standards, or to protect habitats and biodiversity of the natural banks. Significantly in regard to the problem of HABs and the Marea Roja, there is no legal requirement for the testing of nutrient loading, of ammonia, nitrate and phosphate levels, the main feed for vegetative dinoflagellates under the law No: 3612, 2009 ([14,120]. While there is a regulation for private aquaculture companies to provide temperature, PH and dissolved oxygen levels, it leaves a significant data gap. Another important gap is the need to test phytoplankton and Cyano-bacteria ecology dynamic balance [60] which is changed in Chile through eutrophication from aquaculture [61]. The changing food webs include loss of shellfish, Gobler et al. [121] and smaller species. In combination chemical change from aquaculture contamination and its eutrophication has been proven to cause HABs to flourish in many parts of the world [29–33]. However, in Chile, such impacts causing ecological changes and HABs such as *Pseudochattonella verruculosa* [62] and *Alexandrium Catenella* [63] through aquaculture impacts before and after installation need further research. This area has perhaps received less attention because of the close links of many Chilean scientists who are funded or linked to the financially important aquaculture industry.

Thus, given that as [64] highlight that given climate change influences virtually all mitigation strategies, the only locally controllable mechanism is setting nutrient input reduction targets and establishing nutrient-bloom thresholds for impacted waters. Furthermore, the law preventing the right to kill salmon, as an invasive predator [65], species needs updating. These enforcement issues are left to Sernapesca, who indicated during interviews that they lack their own vessels, and easy access to the data, which is sent to the department of environmental testing (SEA), in the Ministry of the Environment, whilst being the policy responsibility of Subpesca.

4.2. Common property rights compared to private property rights considering ecological health

The current AAA zone needs reconsideration, as the more than 80% designated lacked consideration of both community need, ecological or oceanographic characteristics. It is odd that the natural shellfish banks, so important for fishing communities are not acknowledged, such as through ongoing baseline assessments. Similarly, it surprising is that the habitat of the globally rare shallow cold-water coral reefs, such as the endemic *Swiftia comauensis*, have been designated appropriate for industrial aquaculture, making it apparent that the AAA needs to be changed. Each coastal municipal may have different aspirations; however, these rural, coastal communities depend on natural resources differently to urban central government and multinational aquaculture corporations. The law giving private property rights to aquaculture needs modernising, recognizing the collective right of the coastal commons to healthy marine ecosystems and participation is an ecosystem approach [66]. With private property returned as public [122], or common property, these concessions can be re-established as leases from the municipals or ECMPOs giving democratic oversight over the marine area.

AMERBs and ECMPOs can be compatible with ecological health and biodiversity given micro zonification, buffer zones for water quality and creating no take areas across ecosystems [25]. However, it worth noting that outside of the smaller AMERBs, in the open access areas, the fishers lack historic spatial property rights. This has seen 80% of the area of the 5 nm area guaranteed for aquaculture concessions [6]. It is worth noting that while fishers were previously able to move to fish elsewhere, after the 2012 update of the Fisheries Law their licenses have become specifically associated with areas. Likewise, the Subpesca designation for the natural shellfish banks needs reconsideration given they only recognise those which were in pristine health by 2012. The Sernapesca decision to not include historic natural banks which have been debilitated by aquaculture and overfishing before 2012, which could recover is also environmentally unjust. For example, 75% of the abundance of species was lost from the Comau fiord over 10 years since the installation of aquaculture [111]. For coastal communities, the recognition of the former ecological health in the past, as well as their future improvement needed need support. Mapping can result in targeted ecological rehabilitation with hatcheries for ecological restocking, reduced contamination and artificial reefs.

The concession system developed, has made access to aquaculture and their surrounds private. However, the seas' fluid nature, as an open system means that these private rights ensure that the impacts are felt in common [123]. Today not even the public monitoring institutions (IFOP or Sernapesca) are allowed to test within the private rectangles water column or test the benthos below and surrounding area, without asking permission [6]. These unregulated impacts from nutrient loading, antibiotics and heavy metals require new laws to stipulate and control safe operating levels, with the government empowered to test them in a transparent fashion.

4.3. Developing a mechanism of participation

The holistic inclusion of multiple stakeholder perspectives needs mechanisms for conflict resolution and involvement in decision making [67]. The literature indicates both bottom-up and top-down approaches are necessary for achieving sustainability [68]. Here, the top down is in tension with the democratically elected perspectives of the municipals representing the artisanal fishers in AMERBs and those in the ECMPO community wishing to conserve natural resources. AMERB and ECMPO common properties can lead the democratisation of knowledge. While it is reported by Directemar, the ultimate marine authority that it is impossible for the Coastal Edge Plans to have updates, they acknowledge that these plans could be affected by 'third-party actions or environmental effects'. As it is vital for Coastal Edge Plans to have updates, so that ecological health and participation can be increased, it is important to clarify why this is so, so it can evolve. Fisher LEK through AMERBs and ECMPO common properties can begin this.

As the interior sea of Chiloe has only been profiled on a crude scale by the Hydrographic Service of the Navy (SHOA), the only profiling accessible is from the fisher LEK experience of bathymetry. There is also a lack of habitat baseline mapping, or species records, making it necessary to use fisher LEK to fill the gaps that science cannot reach [53,69]. While a strategic plan has been developed on land, the regional government has not included activities in the sea (Gobierno [70]. However, they have been systematically marginalised from marine planning. Thus, a Foucauldian reflection on power relations in planning is necessary to explain their exclusion [71]. As well as being framed through legislation, power is exercised through communication characterised by non-rational rhetoric and maintenance of interests, rather than by freedom from domination and consensus-seeking. Validity is established via the type of communication, such as reports released by Subpesca, using dependency relations between participants [71]. Where these power relationships are creating crisis of sustainability [50], highlight the potential for institutional innovation, such as in this case where power needs to be re-localised, to enhance a more socio ecologically resilient system through common properties [72]. Micro-zonification of habitats, features and uses can scale up through AMERBs and ECMPOs integrating fisher LEK and secondly in the open access areas, as described in Fig. 4 below.

To pass the screen of living democracy, Vandana Shiva (2006) argued that localization of decision making must be made closest to where the impact is felt. Relevant is the concept of inclusive development, in which Araos, and Ther (2017) consider that its key contribution is the relational element.

Fig. 5 Shows the new process integrating fisher LEK leading toward participatory ecological plans.

This participatory ecological baseline assessment can be supported by full bathymetric mapping and profiling. Thus, zones where aquaculture has a higher likelihood of contamination, eutrophication and HABs, such as shallow areas, and low currents can be more formally recognised and mapped. Similarly, where the case studies showed that there is too much congestion and contamination from aquaculture overdevelopment, reduction and re-localisation can take place, supported by fisher LEK. As industrial aquaculture producers today move around cages without assessment, GPS tracking devices are needed to monitor their location. With the continuous location visible of industrial aquaculture made visible, this can lead to macro zonification, and the exploration of integrated coastal zone management with stakeholders. This form of participatory marine planning can be supported by dispersal models to support the influence of oceanography on impacts through GIS [73] This can be integrated with other coastal pressures such as construction of ports, power stations and sewerage pipes, given that an ecosystem approach to area management is used for planning worldwide [12].

If marine licensing and planning officers from Directemar and Subpesca were inserted into the offices of coastal municipals, in proximity to activities and democratic processes, it would be easier for stakeholders to bridge knowledge systems through face to face dialogue. Thus, when a new application for an aquaculture farm or other development occurs, the coastal community can be consulted, through a notice advertised in a local paper and in the municipality, with formal representations made by email and letter. Working with Directemar to achieve this is possible, and its possible successors in the construction ministry if privatisation of the foreshore goes ahead. Common property can co-produce integrated coastal zone management with the coastal community including fishers, aquaculture farmers, conservationists and other stakeholders to determine how to re-establish ecological health and biodiversity. This can benefit the maximum amount of people and highest levels of ecological health rather than lowest.

Some key recommendations:

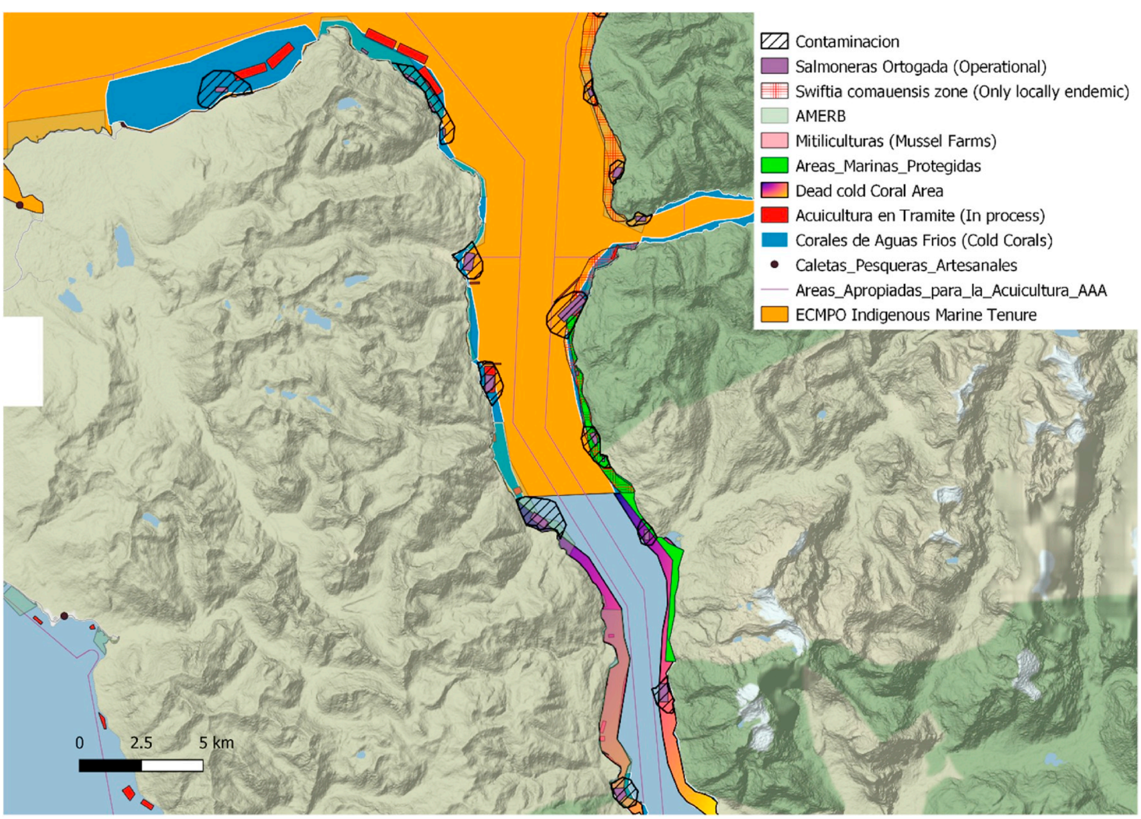

Fig. 4. Mañihueico - Huinay ECMPO in orange: includes areas where several types of so-called "marine animal forests" are present with critically endangered cold-water corals species, brachiopod banks, gorgonian meadows, bryozoan and barnacle aggregations. These species are at risk with aquaculture concessions and contamination situated upon them or in proximity. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

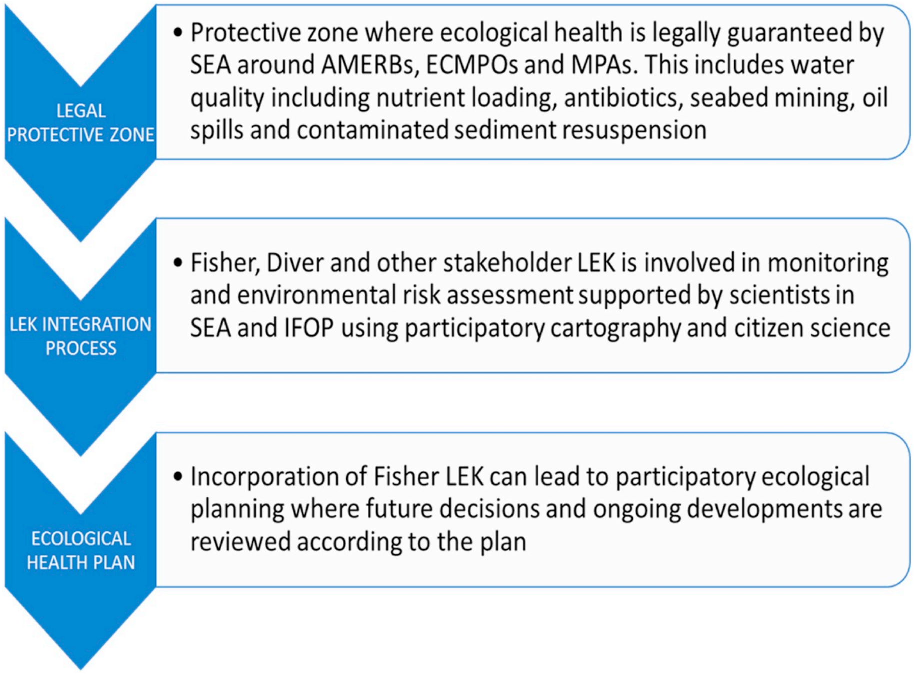

Fig. 5. Shows the new process integrating fisher LEK leading toward participatory ecological plans

Environmental legislation	Enforcement	Democratic governance
1.There needs to be laws regulating nutrient loading causing eutrophication and algal blooms that can produce cascading effects on the trophic web. (E.g. FAA).	1.The marine agency Sernapesca needs boats, or ways to scientifically test or enforce crimes to the marine environment.	1.A buffer zone is needed for AMERBs and ECMPOs from aquaculture contamination to achieve ecological health
2.There needs to be a law to monitor and improve good ecological status, including monitoring phytoplankton ecosystems, escapee invasive species, macrofauna, meiofauna, infauna or flora habitats or ecosystems.	2.Monitoring can be supported with video cameras and Wifi streaming footage of cages and workers to reduce salmon escapees, rubbish dumping, nutrient and antibiotic loading	2.The monitoring would be recorded so that the public could access it if it is asked for
3.Private property rights need to be changed to temporary leases so monitoring can occur effectively	3.Currently Sernapesca and IFOP has to ask permission to enter	3.Permanent private property rights can be turned into leases, allowing for local legal oversight
4.Licensing and monitoring regulations developed during the mid-1990s, need to consider in combination impacts of multiple sites	4.A limitation of nutrient loading would be enforced according to the oceanographic, geographic and social characteristics	4.Marine micro zonification can start with AMERBs and ECMPOs eventually scaling up to the municipal level
5.The 80% designated area for the AAA for aquaculture needs to be democratically reassessed from the community scale (E.g. AMERBS, ECMPOs, municipals).	5.Limitation of use of sea space according to ecological health and socio/cultural needs	5.Participatory planning led by common properties and eventually municipals
6.Decentralised monitoring programs and licensing procedures are needed to consider community and ecological differences	6.The decentralised mechanism can integrate fisher LEK and other stakeholder LEK supported by scientists	6.Participation in marine governance is a democratic right, not a privilege

5. Conclusion

If questions of socio ecological equity are to be satisfactorily addressed, the groups most vulnerable to the negative effects of industrial aquaculture need to participate in the formulation of environmental impact assessment. Coastal zones should be delineated for fisheries, aquaculture, tourism and other uses equitably, through the process of integrated coastal zone management Primavera, (2006) ecosystem services (Outerio et al. [74] and marine democracy [124]. Stakeholder theory developed by Ref. [75] to analyse corporations demonstrated that different classes of stakeholder that are not normally recognised by managers need to be listened to. In the case of marine management, the concept of “stakeholder” could imply that other users (including fisher, conservationists and scientists) have a valid reason to have their consultation listened to. Including normative claims such as traditional or customary rights (designing appropriate structures and procedures) can improve economic efficiency. There are opportunities for the AMERBs and ECMPOs to learn from international experiences, such as the system of Inshore Fisheries and Conservation Authorities (IFCAs) in England, whose customary rights to marine ecosystems allow them to create local by-laws through LEK to protect the overexploitation of the ecosystem [125]. Nevertheless, as explained by Anbleyth-Evans [124], to achieve marine democracy, the local stakeholder LEK needs to be integrated into the multi-scalar decision making over the licensing of other activities, from seabed mining to aquaculture.

While Anbleyth-Evans [124] highlight that certain types of scientific knowledge, dominate decision making in the UK environmental policy, in Chile, there remains significant marine knowledge gaps because of the governmental prioritisation of the expansion of neoliberal aquaculture markets. Ultimately this research brings into sharp attention the need to develop a democratic system for marine governance Chile, where fisher and other LEK can be involved in monitoring baselines and observing risks to ecological health. A system where uncertainty can be investigated, and local marine narratives can be heard more clearly and potentially validated, alongside the importance of habitats and biodiversity, cold water corals, different marinescapes, other marine sites of cultural importance such as corrals, as well as birds and cetacean feeding areas. In these case studies in south Chile, the findings can be generalised across the Austral or Patagonian region. Given that no ecological baseline investigation was taken before the installation of industrial aquaculture, nor democratic processes to consult communities, this article shows fisher LEK can help fill ecological knowledge gaps, in pre-assessment ongoing impact evaluation and habitat mapping. AMERB and ECMPO common property rights, can enhance the democratisation of environmental knowledge, but need urgent simultaneous legislative support and regulation to achieve ecological health.

Terminology

Marea Roja – Red Tide.

Common Property – an area of the sea owned by the community under local harvesting and conservation rules. These include AMERBs and ECMPOs.

Declaration of interest

The authors have no financial interests to declare. The authors did not work with other people or organizations that could inappropriately bias the work.

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