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Coevolutionary decoupling in artisanal fisher communities in the global south: a temporal perspective

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Abstract

The relationship between the exploitation and scarcity of fishery resources is a complex phenomenon that has been broadly examined by studies on fishing sustainability, the governance of the commons and ecology. This study furthers this line of inquiry using a systemic coevolutionary approach that enables the time perspective to be used to examine the negative effects on artisanal fishing. Through a qualitative methodology, document analysis and ethnographic approach, the research into the coevolution of artisanal fishing in Chile enables us to identify how the negative effects on the fishing communities are the outcome of the gradual increase in the decoupling of local socioecological systems which started in the mid-twentieth century and accelerated within the context of neoliberal capitalism. In this process, the value systems, knowledge, organisation, environment and technology change their ability to integrate with each other, leading to mismatches via successive multiple feedback incidents. From a temporal coupling-decoupling vantage point, a path of analysis opens up to understand the negative effects on the capitalist economic development in traditional fishing communities in the global South.

Keywords: neoliberal capitalism, smallscale fisheries, coupling-decoupling, systemic thinking.

Introduction

Since the mid-1990s, conditions of fishing practices and communities have attracted increasing interest from academia and policymakers, with a special emphasis on the challenges faced by artisanal fishing communities (Kooiman, Jan, & Bavinck, 2005) in a context of increasing ocean grabbing (Bennett, Govan, & Satterfield, 2015). Between 1960 and 1990, the worldwide extraction of 20 million tonnes of fishery resources quadrupled (FAO, 2018), radically altering marine ecosystems (Glaría, 2010).

Research on fishery sustainability relates scarcity to a social issue of resource management (Armitage et al., 2017; Armitage, Berkes, & Doubleday, 2007; Camus, Gayan, & Hidalgo Dattwyler, 2017; Camus, Hidalgo, & Muñoz, 2016; Kooiman, Jan, & Bavinck, 2005; Olson, 2011), overexploitation and ocean grabbing of fishing by big industry and, to a lesser extent, by small-scale fishing using techniques similar

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to monospecies extraction from the fishing industry (Beitl, 2015; Bennett et al., 2015), and focusing on unequal extraction power (Bennett et al., 2015). Complementary studies based on governance of the commons in fisheries address the problems by advocating the development of collaborative-participatory management and co-management among different public and private actors (Begossi, May, Lopes, Oliveira, & Silvano, 2011; Trimble & Berkes, 2013), with an emphasis on regulating resource extraction as a way of dealing with the power asymmetry of those with greater extractive technology (Acheson, 2018). Management practices like Payments for Ecosystem Services (PES) have enabled the impacts on overexploitation to be managed by means of associations and incentives for protected extraction, and have allowed the species and life of the ecosystems to be conserved (Bladon, Short, Mohammed, & Milner-Gulland, 2016). In this debate, artisanal activity is identified as important in contributing to feeding the population and balancing the species' reproductive cycles (Kooiman, Jan, & Bavinck, 2005), as well as being a potential alternative approach to neoliberal resource management, with both positive (Beitl, 2015; Mackenzie, 2001; Ocampo, 2017) and negative results (Begossi et al., 2011).

Co-management (Begossi et al., 2011) as an alternative fisheries practice has incorporated the participation of a wide range of local actors into its approach; however, it has been unable to deal seriously with the socioecological fishing crisis, given that although it does articulate the creation of interesting projects to reactivate traditional fishing through conservation, tourism or protected areas, in practice they seldom take root and achieve generational continuity. It clashes with dynamics of fishery dispossession (Malm & Esmailian, 2012), especially in the global South. It could be argued that because it is centred on resource management, co-management conveys values of economic development to the traditional activity through a neoclassical economic matrix, in which productivity-efficiency and competitiveness underlie the process of sustainable development. Mansfield (Mansfield, 2004) calls it 'another neoliberal project' in fisheries, as management becomes a restrictive norm (Schultz, 2015) and a rationalist (Percy & O'Riordan, 2020), calculating (Pinkerton & Davis, 2015) and individualist resource (Acheson, 2018; Olson, 2011).

The commons approach of Ostrom (1990) has also influenced the management of fisheries governance (Kooiman, Jan, & Bavinck, 2005) by addressing the impacts on resources and those who promote them, in which a variety of actors, the governance system, resource units and interactions-outcomes all come into play. However, this approach is limited to the empirical analysis of management within the governance of fishery resources, making it difficult to adapt it to more complex interpretations of the negative effects on fisheries, changes and transformations over time. Inspired by this interpretation, models like the Social Ecological System (SES) (Basurto, Gelcich, & Ostrom, 2013; McGinnis & Ostrom, 2014) consider the negative effects on fishery resources while ignoring other factors like the influence of the national economic context on the local one, the deterioration of ecosystems over time and the predominance of certain values in the culture and politics that make what happens in fisheries in the global South different, where the institutions are fragile and at times corrupt. The implementation of regulations controlling extraction via quotas, for example, has been criticised for being a rational tool agreed upon institutionally through regulations that restrict the traditional activity of fishers, distancing them from their culture and their tradition, which is based on spoken agreements (Blomley, 2016; Castree, 2008; Giordano, 2003).

Unlike governance and commons approaches, by observing affected networks and food chains, ecology focuses on biophysical-chemical properties that lower the availability of resources over time. From the

integral ecology approach (Chapin III, Matson, & Mooney, 2002; Grimm, Grove, Pickett, & Redman, 2008; Redman, Grove, & Kuby, 2004), Long Term Ecological Resources (LTER) (Kröncke et al., 2019; Lercari et al., 2018) and Local Ecological Knowledge (LEK) generate evolutionary models that provide explanations of the scarcity of fishery resources due to changes associated with variations in climate, ocean temperature, extraction practices and nutrients produces the food chain over time (Hanazaki, 2003; Santos Thykjaer, dos Santos Rodrigues, Haimovici, & Cardoso, 2019). Although they integrate the socioecological system and feedback on fishery ecosystems, these studies are limited to explanations of ecological patterns—nutrients, food chain and species—without fully integrating the relationship with social systems (Vrba & Znachor, 2016). These studies have conceptualised some social patterns but the social condition is ultimately not included. As Berkes and Folke (Armitage et al., 2007) and new critical currents (Bakker, 2010; Bresnihan, 2019) point out, the new context of effects on fishing —anchored in sustainability, resource management and FAO reports—requires a complex understanding of local socioecological interactions related to fisheries.

In this article we further the analysis by adapting Norgaard's coevolution model (Ekins & Norgaard, 2006; Gual & Norgaard, 2010) with a systemic lens to study the process of socioecological impacts of artisanal fisheries in two localities in Puchuncaví (Valparaíso, Chile), incorporating a time perspective. This co-evolutionary analysis helps us to recognise multiple incident factors of negative effects on the socioecological system over time, including not only the organisational aspect associated with management and governance but also the ecological patterns addressed by integral ecology. As such, the analysis carried out in this study provides analytical tools to understand the negative effects on fisheries over time by identifying the different interactions that have influenced a process of change and scarcity.

Coevolution as a systemic approach for understanding socioecological fishing affectations

The coevolution approach provides an understanding of fishery resources associated with various interdependent interactions in a more complex socioeconomic context, including technological management, applied wisdom and the values that coexist within the same ecosystem and local community (Armitage et al., 2007; Bresnihan, 2019). It allows us to understand the negative effects on fishery resources in a relational way and how these changes are produced, taking into consideration the local traditions of the place (Fournier et al., 2014). Moreover, the analysis of fishing coevolution is situated within the context of the ecological crisis of the Anthropocene (Ribot, 2017), where a new type of approach is urgent in order to build alternative development to the conventional sustainable one (Freire Vieira, 2012).

Coevolution emerged as a theory for studying the change and evolution of species like insects (Porter, 2006) and became a theory used by ecological studies to observe transformations in different ecosystems, especially agricultural ones, with the assumption that there are multiple influences in this change, from both social and ecological systems (Gual & Norgaard, 2010). This approach recognises the socioecological interdependences between the environment and human beings (Urquiza, 2018) and analyses the ecological problem, such as the use of pesticides in crop lands, in a complex way (Folke, et. al 2007), thus differing from other single-cause approaches (Berkes, 2008). In this case, it recognizes the influence of the industrial process as well as the social needs that lead to agricultural coevolution to depend on artificial chemicals and fertilizers.

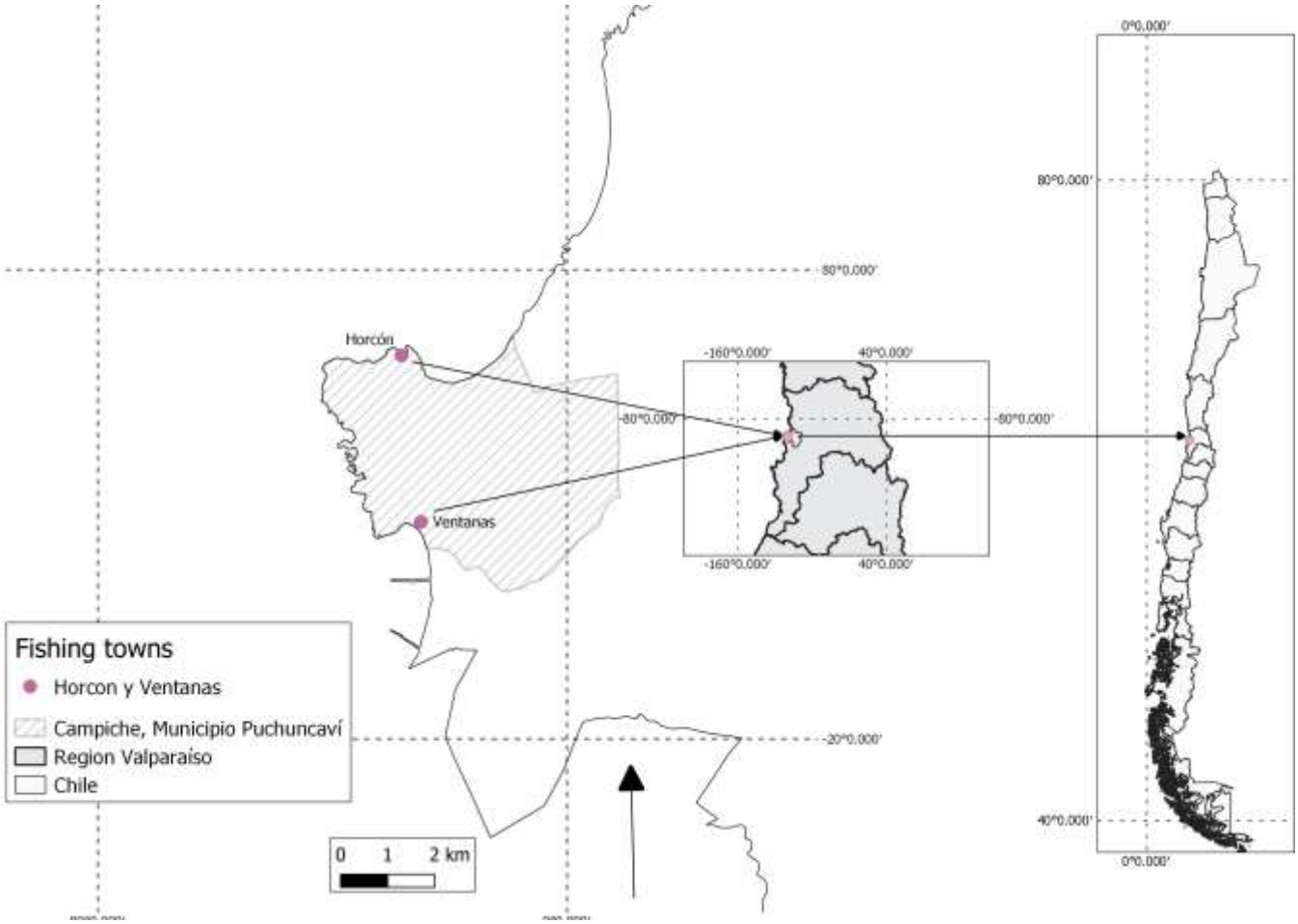
Coevolution from a systemic approach applied to studying traditional fishing is a research approach which enables us to make headway by addressing different kinds of interdependence feedback that influences a given resource or system over time, associating ecological patterns with social and institutions patterns in the same theoretical framework. The study of feedback (Ekins & Norgaard, 2006, p. 87), where society and nature are active agents of change and evolution, makes a systemic perspective with a focus on the local scale possible, as exemplified in studies on agricultural systems in the Brazilian Amazon and pests in the United States (Ekins & Norgaard, 2006; Norgaard, 1981). It does so by integrating the systems of organisation, environment, knowledge, values and technologies into its model of analysing the change process.

The relationship among systems enables the concept of systemic coupling or structural coupling proposed by Varela and Maturana (1984) to be adapted and incorporated, which means analysing the type of relationship among systems based on their own structures of local functioning (Maturana & Varela, 1984). This allows us to observe whether, based on the interaction caused by the fishery resource, the systems involved (environment, knowledge, organisation values and technologies) are coupled or not to cooperate with the life of the local ecosystem, and whether the coevolution or adaptability to a crisis changes the behaviour and cooperative nature of the local fishery ecosystem.

Methodology

The fishing localities of Puchuncavi experienced a socioecological resource crisis that dovetailed with the global weakening of traditional fishing activity starting in 1985 (Armitage et al., 2007; Beitl, 2015; Kooiman, Jan, & Bavinck, 2005). In Chile, fishing practices have evolved within the framework of the establishment of policies defined as sustainable, including fishing quotas, management areas, closed systems and aquaculture (Anbleyth-Evans et al., 2020; Ceballos Cardona & Ther Ríos, 2018; Glaría, 2010). Moreover, in this specific case, the process is linked not only to the global strategy of the privatisation of fishing (Bennett et al., 2015; Olson, 2011) but also exposure to industrial contamination with copper and arsenic residues in the localities (F. Sabatini & Mena, 1995; Francisco Sabatini, Mena, & Vergara, 1996), social-natural disasters (EM-DATA, 2018) and, more recently, the effects of climate change (INFODEP, 2016).

Figure 1 Fishing towns of Ventanas and Horcon in the commune of Puchuncavi, Valparaíso region, Chile



(Authors, 2020)

These are localities with stark social-ecological contrasts. On the one hand, they are rich in biodiversity—floral, fauna and native forest species like Quirilluca[4]—in addition to being unique geosites in Chile. On the other hand, the influence of the Puerto Ventana-Campiche industrial estate has caused ecological damage for decades (Sabatini & Mena, 1995; Sabatini, 1994; Sabatini, Mena, Vergara, 1996), which is coupled with the urban expansion on the coast due to second residences and seasonal tourism. This has earned it the name of 'sacrifice zone' given the impact of the country's development on the communities (Bolados, 2015; Fundación Superación Pobreza, 2015).

The qualitative research methodology includes document analyses, interviews with key actors—both experts and non-experts (Freeman, Phillips, & Sisodia, 2018)—and ethnographic work. The document analysis (Mackieson, Shlonsky, & Connolly, 2018) has enabled us to identify 10 relevant studies.[5] They were chosen based on the negative effects and outcomes over time. In the second phase, the field work (August-November 2019), 51 interviews—exploratory, in-depth and semi-structured with key actors (Kvale 2011)—were conducted (Table 1), accompanied by timelines and location maps (Scollon & Jones,

[4] Information provided by the NGO Chinchimen http://www.chinchimen.org/

[5] Calisto, O. (2014), Fernández (2017), González, J. (2006), Guajardo, A (2012) , Muñoz, T (2011) , Para el Desarrollo, CIA & González, E. (2001), Sabatini, F., & Mena, F. (1995), Sabatini, F., Mena, F., & Vergara, P. (1996), Verdejo Velásquez, K., & Bahamondes Parrao, M. (2014)

2011; Hanson & Creswell 2005), which enabled major milestones in relation to fishery resources over time to be identified.

Table 1 *Participants in the interviews and instruments applied*

Type of actor	Actors	Instrument	Participants
Experts in marine sciences	Regional institutes and universities	In-depth interview (timeline)	10
Fishing communities	Unions, federations, Independent fishers, families of fishers	Exploratory interviews In-depth interview (timeline)	22
Local community	Artisans, social movements, neighbourhood organisations	Semi-structured interviews	12
Civil society organisations	Partners from the communities	In-depth interviews (timeline)	2
Public sector	Sernapesca (National Secretary of Regional Fisheries), Regional government, Municipality	In-depth interviews (timeline)	5
			51

(Creation, participant observation, fieldwork 2019)

Coevolutionary processes in the transformation of fishing

Using multiple feedback analysis (Ekins & Norgaard, 2006; Grimm et al., 2008; Gual & Norgaard, 2010; Redman et al., 2004), we observed that the negative effects on fishery resources occurred throughout an extended time period. Of all the feedback and interdependent relations, we prioritised those that were more important qualitatively and quantitatively[6] (Figure 1), enabling us to identify five periods of change and transformation in Horcón and Ventanas: 1) subsistence (1930- 1959), 2) material progress (1960-1973), 3) neoliberal extraction (1974-1985), 4) neoliberal reflection (1986-2000) and 5) neoliberal post-reflection (2001- 2020).

Subsistence (1930-1959)

This period stands out for the balance and integrity among systems. The extraction of fishery resources was regulated by the reproductive cycles of nature, where the rich, mixed environment encouraged knowledge and values like the learning process and local subsistence based on the household economy. We call this systemic integration (see Figure 1, arrows and fading outline) because there was a hybridisation between the environment, knowledge, technology, values and local organisation. Fishing subsistence was associated with traditional values regarding the local socioecological context, which was also about agriculture, harvesting and reuse.

The *feedback with the greatest influence* in this period occurred between the environment and local organisation (Figure 1, orange arrows). The local ecosystems provided the development of *subsistence* in

[6] There are no arrows in the figure. This does not mean the lack of feedback but instead a decision to represent and prioritise the most influential feedback in the coevolutionary process.

the fishing extraction done by family economic units (women, men, children, relatives). Even though they were affected by the material poverty of their life system, they were fed by an abundant, complex agricultural-fishing system between the freshwater of the estuaries, springs and ocean water. The collection of seaweed, coastal and freshwater species, and benthic, pelagic and oceanic pelagic species coexisted alongside the cultivation of legumes, wheat and barley in the periods when fishing was impossible. The fishers, who were also farmers, gained astronomic knowledge of the Moon for crops and fishing, climate signs from birds that facilitate the activity and angles of fertile zones.[7] Fishing techniques passed down conveyed, like mending and crafting nets, freehand fishing, the use of sails to move from north to south and diving techniques with materials reused from the home and the natural world, including wax and "esperma" (sperm) and wooden rods for coastal fishing and fishing salinisation. The family economic unit *organised its subsistence* (orange arrow pointing to the environment) and supplied the local food, generating a symbiosis between fishing, harvesting and reuse: "**when the weather was bad in the winter, the entire family would go cut peas**" (Justiniano, 2019).

The environment guided the community *activity* (activity guide, arrow pointing towards organisation). The reproductive cycles of species marked the seasons and limited the extraction of resources. Activities were organised by seasons of the year, with the family participating and women playing an important role. "**I thought there was a balance between what we got and what reproduced, because nature didn't always let you work. There are heavy seas, winds and a natural closed season**."**There were women working on the shores. They took advantage of low tide on the beach and got shellfish there"** (Carlos, 2019).

Material progress (1960-1973)

The functions integrated into the systems within the socioecological system changed (see Figure 2, continuous outline), lowering their qualitative local complexity and interdependence and increasing the autonomy of their roles. The *environment* ceased to articulate and became an asset providing fishing *values* and *technology*. It fell under the control of the *technological* system, which became autonomous thanks to industrial processes, and a fishing *organisation* which instead of being part of the family ecology was shaped by unions and cooperatives which grew qualitatively and quantitatively thanks to the support of training centres. The activities of farming and harvesting were separated from fishing. The contaminating industrial action of the coal and cooper industrial estate affected the crop fields and the fertility of their soil. As an effect of the evolution of fishing organisations within the technological system (see Figure 1, black arrows), the most influential feedback was the *fishing organisation and technology* (orange arrows in two directions).

This feedback promoted *material wellbeing* for organisations (material wellbeing, arrow pointing towards the organisation) and influenced the handling of specialised fishing techniques: diving, the use of motors, the growth of vessels and the shift northward and southward on the country's coast, generating greater economic wellbeing. '…**Everyone made their houses. The way of life changed**. **Extreme poverty was exchanged for an organisation**. **The cooperative worked**. It defended the value**"** (Enrique, 2019). '... **with diving everyone bought their diving supplies and caught Chilean abalone'** (Robledo, 2019). On the other hand, the fishing organisation handled and controlled the technology and ocean better (handled

[7] These angles were projections of lines that the fishermen made from their vessel to the coastline when they were in a fertile zone, which they marked or memorised in accordance with the time of year and season.

and controlled, arrow pointing towards technology)—species, distances, identification of schools of fish—by viewing the sea as a 'workspace'. The fisher was guided by values that prioritise productivity. The result can be seen in the specialised extraction of species prized for their high economic value, working towards control and mastery of the medium. '**I was diving as far as [the far north of the country] for Chilean abalone. A Japanese company bought the abalone from us**' (Victor Robledo, 2019); '**we were going every which way, like in three months**' (María Eugenia, 2019).

Neoliberal extraction (1974-1985)

This phase established the extractive, exogenous development of fishery resources. The socioecological dynamic of local resources shifted towards exports, profiting economics outside the territory. This was done by different actors—artisanal, industrial and new agents—that fished without studies or knowledge of the availability and with the absence of technical guidance. Even though artisanal fishers continued to work and catch species, their relationship with the environment was impoverished, and they lost the handling and technological control of the environment framed within the model of neoliberal development of resources in Chile (Schurman, 2003). **'The structure that was imposed by the civic-military dictatorship in 1970… The way to generate currency was to exploit natural resources', in particular benthic resources** (Luis Ariz, 2019).

The feedback with the most influence in this period occurred in the value system and organisation (figure 1, orange arrows and outlines), which translated into *extractive* values in artisanal fishing and the advent of *new fishing agents*. The internal markets were weakened, the economic value of the species was devalued and the fishing organisation was weakened, leading to individual fishers: '…**they were atomised [the fishers]**, **and this happened all around the country**' (Luis Ariz, 2019). The extractive values (extractive, arrow pointing towards organisation) sought to maximise the amount of fish regardless of the technology used, jeopardising the safety of the fishers on the open sea: '(…) **there were no better motors or better diving equipment… Artisanal fishing began to die in around the 1970s and 1980s**' (Roberto, 2019). The tendency to monospecies fishing started because of its economic sale value but were caught at greater risk, which materialised in accidents at sea.

In turn, *new agents* appeared (new fishing agents, arrow pointing towards values), who introduced values of fishing competitiveness between peers and industrialists: '**the cooperative was declining and had practically failed**' (Gloria Nuñez, NGO, 2019).The new agents were not from the territory and used vessels with an industrial extraction capacity (blue arrow). This introduction and reconversion of others towards fishing bolstered individualism, the value of money, social atomisation, mistrust among peers, practices of corruption like fishing piracy, in addition to indebtedness via loans to enlarge or change vessels. '(…) There came **larger fishers, and it was no longer a little boat, the old man and the sea; it was a 12-metre vessel**' (Roberto, 2019); '… they gave us like five years to pay for the motor [debt], so there we were' (Robledo, 2019).

Neoliberal reflection (1986-2000)

Fishing extractivism continued during this period. The fishers went back and forth from northern zones in search of resources. Sustainable development was legitimised as a narrative and practice for handling and managing fishery resources, generating awareness and reflexivity on the scarceness and exploitation

occurring globally (Kooiman, Jan, & Bavinck, 2005). Fishers, universities and the state joined forces within a discursive and practical framework via strategies for handling resources, associations and legislation.

Among the feedback with the most influence was *knowledge-technology* (orange arrows, see Figure 1). In one direction, knowledge came as *wisdom* and *scientific knowledge*. A mix between the local knowledge of the communities and the formal support of engineering and marine biology gave answers and solutions to the crisis in fishery resources. In another direction, we see the implementation of technological responses as a set of *fishing restitution strategies*, where knowledge was applied and the management of fishery resources was standardised as institutional regulatory *control* (see Figure 1).

The influence of *wisdom* and *scientific knowledge* accumulated over time was activated. The scarcity of resources spurred artisanal fishing organisations (black arrow). Local wisdom emerged (wisdom and scientific knowledge, arrow pointing towards technology), gaining awareness of the decimated situation of the schools of fish and shellfish, which enabled progress to be made with the self-management of technological solutions long before regulations appeared in the country. This dynamic of knowledge-technology was accompanied by the *scientific* knowledge of regional universities, along with NGOs and regional civil society.[8]

In relation to the *fishing restitution strategies* (strategy for fishing recovery and control), shared artisanal handling areas were established, a type of organisation created among different towns and a system of prohibitions according to the reproductive cycle. The fishers returned to the sea as aquaculturists. The torches of crops of Portuguese oysters, Japanese oysters and brown seaweed enabled economic sustenance based on reflection and dialogue. '… **The professor taught us how to make knots**. We laid nets and made strings(…) **then we managed to have a shared plot of all the coves, Horcón island**' (Carlos Vegas, 2019). The restitution of the resource was transformed into *control* (strategy for fishing recovery and control, arrow pointing towards knowledge). The best example is the 1991 enactment of the General Fishing and Agricultural Law (Law 18892), which regulated the registry of vessels, the fishery handling areas and the fish extraction quotas, among others. This set restrictions in the displacement capacity to fish in other regions and fish extraction quotas that limited the amount to be extracted. The activity was standardised, the sailing organisation was institutionalised by assigning responsibilities in each vessel that in the past came from customary agreements, which prompted discontent among artisanal fishers. 'The control brought discontent to the traditional artisanal fishers. The state responded by purges with clientele support' (Luis Ariz, 2019).

Neoliberal post-reflection (2001- 2020)

In this stage, the coordinated management of resources of the fishing organisations was weakened. A post-reflection phase got underway where agreements and trust in the restitution of species were abandoned. Regulatory control over fisheries management became a restriction for local artisanal fishers, while allowing for the development and evolution of economic, political and industrial stakeholders, who expanded not only in fishing but also in the Ventanas industrial estate and the urban development of the coastline.

[8] Universidad Católica y Santa María, NGOs like OCAC, funds from the Canadian Embassy, regional episcopate, feminist groups like 'estelar', etc.

The most important feedback includes the *technological-organisational* system. On the one hand, the influence of technology as a *control* strategy over the handling of fishery resources evolved to a *selective* phase (selective control, arrow pointing towards organisation, see Figure 1), increasing the power of fishery management's control over artisanal fishing while also offering compensatory instruments. Periods of prohibitions, an individual fishing quota system and fishing registry regulated by law restricted fishing activity in exchange for vouchers given to the families during periods of inactivity. '**Even grandma is registered, because if I'm going to get a voucher [monetary subsidy], they're all registered. That's the fault of the state**' (Exequiel González, 2019). The benthic resources handling and exploitation areas[9] (abbreviated AMERB) were consolidated as a management tool, but this promoted corruption due to competition among the fishers themselves, who stole and seized resources. '…**then came the fines [for violating displacements among regions] and you have to pay them. In the past we were free**' (María Eugenia, 2019).

On the other hand, the groups which were strengthened alongside the weakening in artisanal fishing interacted in an *expansive logic of industrial technological development* (expansive logic, arrow pointing to technology). While the fishers obeyed the prohibited times, the industrial actors took advantage of their lifting to engage in trawling, altering the base reproduction of the trophic chains in species which were growing or spawning. The power of other non-fishing organisations grew—Melón, Gasmar and COPEC—and groups with political and economic clout— Blumar, Itata and Golfo —expanded the *industrial technological development* in the territory (see Figure 1, arrow pointing to technology). The expansion of these groups involved the local public administration in a 'friendly' logic with the community via subsidies, grants and direct sources of financing to support development initiatives. Private agents with interests and a presence in the territory like AES Gener, OXIQUIM and COPEC spurred the expansion and part of the selective control: '…AES Gener **gave us coveralls. The neighbourhood board was given other things. And so they lived off trickery**' (Carlos Vegas, 2019).

The fishing organisations were weakened, and the fishers migrated in search of jobs outside and inside the towns. Those who stayed cleaned the contamination on the beaches and worked in other trades (plumbing, landscaping). *Mussels*, *sea squirts*, *limpets* and *sea urchins* were fished, along with rockfish, and they supplied scientific study consultancies, which purchased tonnes of species for different types of analyses, or local restaurants associated with tourism. There were also experiments with cultivating seaweed to capture heavy metals like arsenic, which enabled a form of ocean remediation to develop. The impact on the ocean was aggravated by climate change, with oceanic 'tropicalisation' tides which raised the temperature and attracted invasive species, which displaced others.

Discussion and conclusion

The case study of Horcon and Ventanas illustrates the complexity of the negative effects on fishery resources over time. These effects are identified via the interaction of different kinds of feedback which highlight interdependent relations (Castree, 2008, pp. 109–123) that coevolved over the periods (Ekins & Norgaard, 2006; Norgaard, 1981, 1988), showing different negative factors resulting from feedback from

[9] In Spanish AMERB means Áreas de Manejo y Explotación de Recursos Bentónicos; they are areas institutionalised by the Under-Secretary of Fisheries to manage and handle oceanic resources in Chile. Source: http://www.subpesca.cl/portal/619/w3-article-79853.html

structural coupling and decoupling which are relevant in identifying negative effects and actions which have been implemented in response in local socioecological contexts.

The analysis of the feedback identifies that each change that occurred (Znachor et al., 2016) was multicausal, rendering it impossible to isolate the interactions between the fishery resources and the social system in processes with negative effects. In this, we observe the incidence of the technological dominance of industrial fishing—i.e., ocean grabbing (Beitl, 2015; Bennett et al., 2015; Camus et al., 2016); industrial externalities that pollute the ecosystems (Francisco Sabatini, 1994, 1997; Francisco Sabatini et al., 1996); and negative effects from the development of the urban coastline (Sanchez & Cardenas, 2000). Thus, the scarcity of resources was part of a broader process in which non-exclusive contradictions coexisted. The organisation of local fishing was activated and evolved (black arrows, see Figure 1) from the previous period, becoming cohesive and aware of the ecosystems—something favourable—yet at the same time it incorporated extractive values observed in mono-species catches—unfavourable for the resources.

Even though the approach from the government of the commons (Armitage et al., 2017, 2007; Kooiman, Jan, & Bavinck, 2005; Olson, 2011) identifies scarcity and negative effects as an organisation and industrial problem (Begossi et al., 2011; Silvano, Nora, Andreoli, Lopes, & Begossi, 2017), our analysis reveals that in addition to the mutability of long-term ecological patterns (Redman et al., 2004) on the ocean (Kröncke et al., 2019), there is a complex system of relations—feedback—that accumulates over time. The scarcity of freshwater and coastal resources, for example, is not only because of the incidence of industrial technology or trophic alterations that impact the ocean (Lercari et al., 2018) but also to meeting the subsistence needs of fishing organisations and the local population, which evolved and thereby changed expectations and the way they did their everyday activity. They became more organised agents, which entails an improvement in their material wellbeing yet also has a negative impact on the availability of fishery resources—*feedback between values, organisation, knowledge*.

On the other hand, the feedback on structural coupling shows a local socioecological system where the type of relationship among the systems is cooperative. In the subsistence period identified in the study, the environment contributed to the everyday functioning of the communities, yet in this feedback the reproduction time needed for the development of their reproductive cycle was also respected. Maturana and Varela (1984) view structural coupling as the stability generated in a life system that consists in *integrating their own structures of functioning*. Berkes (Berkes, 2008) views this integration as an inquiry into endogenous socioecological properties, which some geographers view as the internal properties of the territory (Blomley, 2016; Giordano, 2003; Moss, 2014).

Our analysis reveals that local artisanal fishing promotes the existence of structural coupling resulting from the interdependence and contribution of each of the systems. This contribution is integrated within the local socioecological context, as occurs in *environment and knowledge*. Initially, the *environment* provides resources which are used as a means of life; however, the environment is not only used and affected but also articulates work times, family economic organisation, values and technology. In turn, *knowledge* provides the technological knowledge to fish, yet it also involves continuous learning through local technological experimentation with the environment. This means the existence of coupling, that is, the integration of cooperative structures of functioning, given that instead of one system dominating the other, the mutual contribution of all the existing systems in a local socioecological context predominates.

Even though it maintains the dependence among systems in time, coevolution moves towards local *socioecological decoupling* within neoliberal economic development in which the environment ceases to articulate, limit and promote and instead becomes an entity that is subject to domination and control—by either the organisational or the technological system. On the other hand, knowledge is no longer integrated as learning along with the technological, environmental and value system and becomes applied, stripped of local wisdom. We interpret this *socioecological* decoupling (neoliberal *extraction, reflection* and *post-reflection*) as a weakening in the reciprocal, integrated and cooperative relations among systems. Thus, from the period of subsistence (1930-1959) onward, systems' functions became autonomous from the local context, the environment lost its qualitative capacity for articulation and a process of simplified relations got underway in which the functioning of each system did not entail mutual local socioecological influence but the operation of extracting, producing and selling in an interaction in which the exogenous came to bear through exports. The interaction among systems was not enriched, contributing to the weakening of the development of local life in an environment under *organisational-technological* domination. The exploitation of resources focused on monospecies extraction, impoverishing the diversity of the ecosystems, while the artisanal identity mutated to an industrial identity (Percy & O'Riordan, 2020), weakening the bonds with the territory, quality of life and generational knowledge and exchange.

The decoupling observed is part of an advanced phase of neoliberal development for fisheries (Bresnihan, 2019; Oestreich et al., 2019), which is magnified in traditional fishing in the global South. Nature (Bakker, 2010) or the environment is extracted from the territory under sustainability criteria which abide by the national regulations yet produce violent impacts in the localities. This sustainability and management of fishery resources entails dynamics—roll out, roll back (Bresnihan, 2019; Mansfield, 2004)—in which the state promotes a kind of handling that fulfils the regulations (Schultz, 2015), yet private and industrial agents are favoured. There is an assumption of neoclassical values which other studies have also identified in Canada, Ecuador and Peru (Acheson, 2018; Mackenzie, 2001; Mitchell, 1997), characterised by calculation, rationality and order aimed at managing traditional fishing through catch areas, fishing records, transferable individual quotas and other measures which turn the ocean into a fragmented, exogenous place for traditional local activity.

The violent nature of this advanced neoliberal phase of development (Guerrero Valdebenito & Alarcón Rodríguez, 2018; Schurman, 2003) is not only expressed in the negative effects on employment and artisanal fishing activity. Through slow decoupling, cooperative capacity is weakened, that is, the capacity for the systems as a whole to promote life and wellbeing in coherence with the local territory. By abandoning local fishery organisation, the internal connection with the environment and the memory of handling knowledge and traditional technologies, the content that gives meaning and coherence to local life is lost. The organisations and communities interact with clientele-based instruments (Kue & Son, 2019, Malm & Esmailian, 2012), are subsidised by companies, work in other trades, receive monetary compensation in prohibited months, receive scholarships for their children to study, etc. This dispossession is also affecting Mexico (Altamirano-Jiménez, 2017), Egypt and Cambodia (Malm & Esmailian, 2012). The expulsion is over the complex biophysical-cultural practice, and it acts on the local socioecological coupling capacity.

On the other hand, in the *subsistence* period, the cooperative feedback 'integrated the structures of functioning' of the systems. The fishing activity not only caught a certain amount of fish but also produced an additional intangible transmission which involved the other systems, including lessons on using

technology or climate and ocean signals, among others. This entailed the maintenance of a complex local socioecological cooperative given that each system (technological, organisational, etc.) worked by cooperating with the others, contributing to and relying on them for its own functioning. Coastal fishing illustrates this idea of systemic integration and cooperation, as it allows the environment to sustain a reproductive system by being a local activity and therefore without the need for transport based on fossil fuels, and it supplies the local economic circuit, which spurs constant learning about multiple species, their behaviour and the technology used to fish them.

The possibilities that systems structurally couple appears as an interactive property in time that emerges as a *local capacity*. The traditional local ecology (Berkes, 2008) views it as the incidence of the endogenous in an ecological system with complex relations (Armitage et al., 2007). This is also associated with biocultural memory (Toledo & Barrera-Bassols, 2015), given that it remains latent in territories, with the capacity to emerge. In our case, the capacity for *self-management* (1986-2000) of fishery organisations emerged because of not only the support of civil society today but also the systemic activation of fishers through memory. This is not only a memory of the fishery organisation but a way of interacting accumulated over time, which involves the cooperative *structures of functioning* of the local socioecological system. The capacity to establish handling and prohibition areas entails an interactive memory; while the fisher learns from the reproductive cycle of the benthic species, the environment is treated as an active system that sets a limit to fishing activity. What emerges is not only the memory of the artisanal fishery organisation but a multiple, interactive 'remembering' which is updated as action and capacity for fishery self-management. This capacity is associated with the invisible dimensions what are found in power as part of alternative economies (Fournier et al., 2014).

The systemic principle of coupling-decoupling observed in Chile can be associated with what has happened in other traditional fisheries in the global South. Self-management as an example of the capacity for coupling can be seen in other types of practices, such as the *custodias* in Ecuador and prawn and mangrove aquaculture in Mexico and Peru (Beitl, 2015; Mackenzie, 2001; Ocampo, 2017). These communities changed their fishery practices to protect the resources, a bottom-up response that in Horcón and Ventanas was done by moving along the coastline to delay extraction due to the depletion of resources (Beitl, 2015), similar to practices in protected areas in the Canadian arctic (Bennett et al., 2015), where extraction is halted one or two days (Armitage et al., 2017). Generally speaking, the literature has examined these cases for their governance capacity (Armitage et al., 2017) and co-management of common resources. However, unlike this view (Ostrom, 1990; Pérez, 2014), structural coupling offers an approach which exposes the value of cooperative interaction between the environment and society.

Thus, fishery resources viewed as 'communal' cannot be established solely by property regimes (Mansfield, 2004), which is clearly a classic economic definition, but instead by the type of interaction and functions among systems, where important feedback is given for the development of local life. There, human beings and fishers are involved in all their existential dimensions (Max Neef, 2010) along with the environment and the other systems, without exercising domination, where they not only extract (have) but also experience a more complex way of being and doing. Instead of fulfilled agreements, good examples of co-management obey a process of socioecological coupling activated from memory which goes unnoticed by experts. This is significant because it makes the structures of functioning of all the systems involved for the communities cooperative in nature. The description of the difficulties of fishery co-management (Begossi et al., 2011; Silvano et al., 2017), where the communities often feel excluded, has

not considered this aspect of structural coupling as part of that awareness (Aillaud et al., 2001, p. 61) involved in the history of a local socioecological system. The studies have concentrated on changes in the ownership of resources (Bakker, 2010) and associations that manage resources as a pre-existing category, ignoring what Cottereau (in Aillaud, 2001) points to as existential complexes of an ecological awareness in the territory. He criticises what geographers mention as the encapsulation of resources in abstract categories (Blomley, 2016; Castree, 2008; Giordano, 2003).

The Anthropocene, the global ecological crisis and climate change are requiring systemic approaches to understand problems like the negative effects and scarcity of fishery resources, which have generally been examined from one discipline, through the productive-economic dilemma or as a management and associative problem from governance and the commons. The adaptation of Norgaard's coevolution to the study of local fisheries moves in a systemic, interdisciplinary direction.

Coupling and decoupling open a possibility to further our analysis of and intervention in contexts of change. This approach enables the feedback from cooperative, integrated and interdependent interactions among the technology, knowledge, organisation, values and environment systems in the territory to be explored from a temporal perspective. This opens up a new perspective when studying the effects of neoliberal fishing by focusing the analysis on local coupling through complex feedback, which may enable us to identify a local cooperative systemic capacity for adaptation in the face of the crisis of the Anthropocene.

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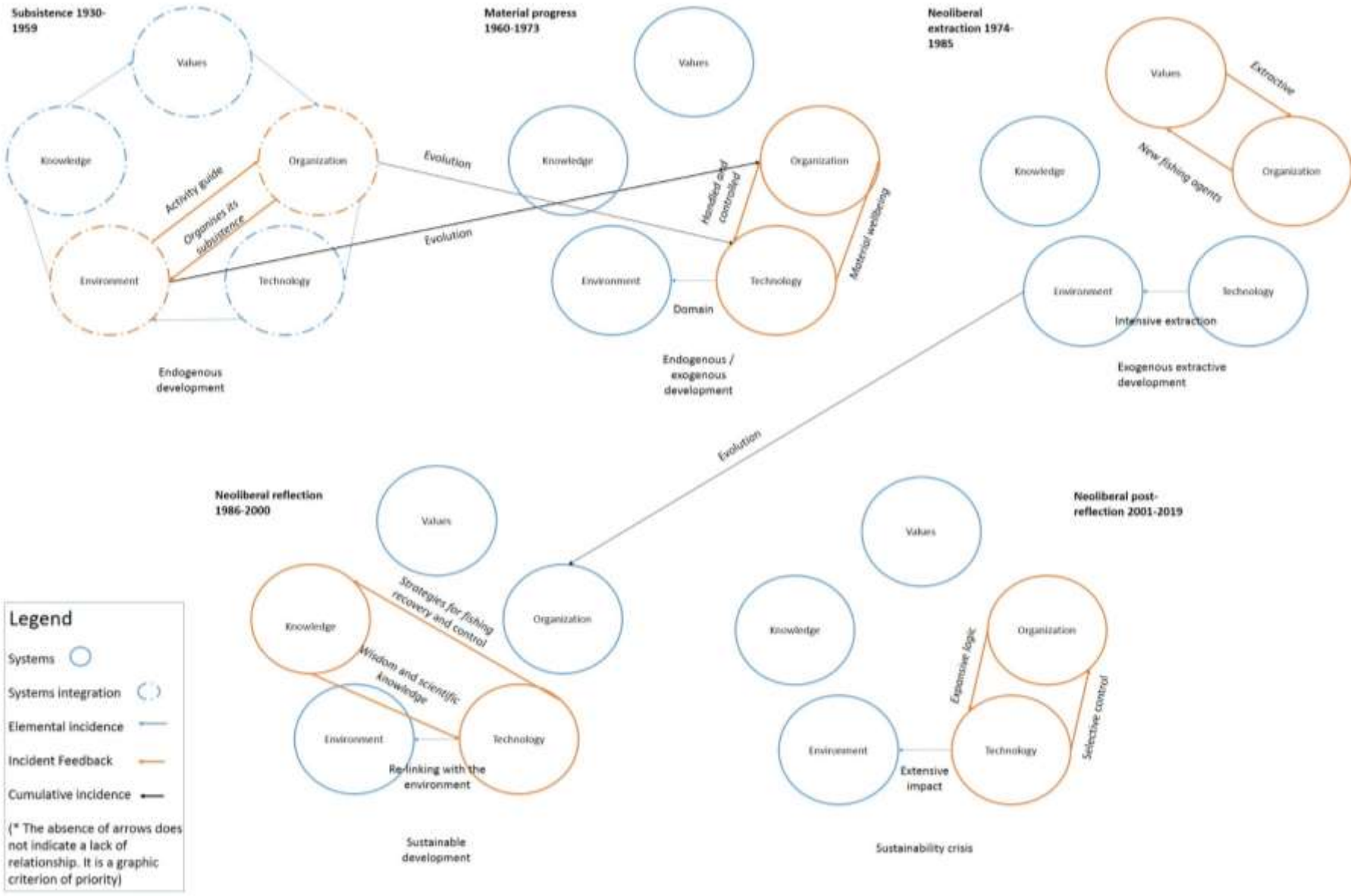
Figure 1 Coevolutionary process through the five periods in Horcón and Ventanas (1930-2019)



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