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Small-Scale Community Based Management of Marine Resources vs. Large-Scale Industrial Aquaculture in Chile

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ABSTRACT

Chile has chosen different strategies to manage its rich marine resources while meeting the demands from domestic and increasing foreign markets. One strategy involves giving user (fishers, collectors of non-fish resources) organizations rights to manage and exploit certain target species in a public and limited area/volume of the sea in Management Areas for the Exploitation of Benthic Resources (MAEBR). This small-scale system coexists with large scale off shore fishing and coastal salmon aquaculture at industrial scale. These different production systems are affected differently by e. g. trade conditions, and are susceptible to disturbances such as diseases in different ways and to different extents. The present situation illustrates how the organization of the aquaculture sector itself may have contributed to the present precarious situation where the infectious salmon anemia virus has reduced salmon sizes and killed salmon at large scale. This has affected the Chilean economy, and new regulations and laws are now being implemented in order to make the salmon aquaculture sector less vulnerable. This paper discusses some issues under investigation in an ongoing project, where the Chilean system serves as one example of pulsing patterns in aquaculture and coastal resource extraction. The systems are discussed from a systems perspective, and some preliminary results from emergy assessments are presented.

INTRODUCTION

Wild capture fisheries peaked on a global scale in 1989 (FAO, 2002; 2009). As natural stocks are depleted, aquaculture is suggested by many as a crucial substitute for alleviating pressure on wild fish populations (Clausen & Clark, 2005; Naylor et al., 1998). This has given rise to a 'Blue Revolution' where rapid growth has been registered in many aquaculture sectors worldwide, as well as in state support for further expansion (Naylor et al., 1998). For example, fish farming is now growing at rates higher than any other kind of agricultural activity (Clausen and Clark, 2005). However, despite increasing market demands, growth has recently started to slow down in many places. This development may partly be explained by recurring environmental and social controversies associated with this industry. Lately, virus and disease outbreaks have negatively affected the aquaculture industry worldwide. Large-scale industrial salmon production is a particularly clear example of this trend, where overstocking has contributed to reduced salmon sizes and fish kills due to infectious salmon anaemia (ISA) (OECD, 2005). Although often described as circumstantial, globally many different types of aquaculture have followed similar trends (c. f. Gunawardena & Rowan, 2005; Bergquist, 2008). Thus it seems that aquaculture develops according to a "boom and bust" pattern, where exponential growth is followed by near or total collapse due to disease outbreaks and environmental problems.

There are however examples of more sustainable aquaculture, often coexisting geographically with their industrial and large scale counterparts. In Chile, small scale clam aquaculture, as well as artisanal fisheries management, share the coastal resources and environmental space with large scale and aquaculture production. This system includes user based management of coastal resources ranging from finfish to the Chilean abalone (*Concholepas concholepas*) and lately also a variety of kelp species (*Lessonia sp., Macrocystis sp. and Durvillaea sp*.).

Aim

The aim of this paper is to present and discuss some preliminary results from ongoing emergy assessments and experiences of two different yet interrelated systems of aquaculture and coastal resource extraction; (1) small-scale community based management of benthic resources and (2) large-scale industrial salmon aquaculture. However, the scope of the paper is limited in that it does not include complete emergy syntheses of these systems. Rather it aims to scrutinize the two cases from a systems perspective, while starting to identify general patterns in coastal socioecological systems, and providing empirical examples of the pulsing paradigm.

MATERIALS AND METHODS

A Systems Perspective on Aquaculture

One way to explain the boom and bust pattern of most aquaculture development may be found in systems ecology and general systems theory. Studies of many kinds of systems imply that pulsing is a general pattern in both human and ecological systems. Odum (1996) called this the pulsing paradigm, and stated that all systems include phases of expansion and collapse/reorganization. In the case of aquaculture, global demand as well as technological breakthroughs in production have allowed for rapid expansion (Naylor et al., 1998). However, after some time increased resource extraction and competition between companies may saturate markets, and/or push ecosystems to a state where cumulative and adverse effects slow down growth until another cycle develops (Bergquist, 2008).

Several studies (e.g. Naylor et al., 1998; Clausen & Clark, 2005; Buschmann et al., 2006; 2009; Bergquist, 2007; 2008) have earlier pointed to the fluctuating and destructive nature of large-scale industrial aquaculture. Increased reliance on fuels, capital intensive technology, feed, antibiotics and vaccines are just a few examples of external input dependency that decreases resilience and sustainability. Sustainability is significantly reduced especially due to dependence on nutrient rich feed pellets fed to cultured carnivorous species. Aquaculture feed is predominantly made by fishmeal and fish oil extracted from wild-caught and mostly pelagic fish species. The procurement of these inputs is associated with energy demanding and often destructive offshore fishing methods, as well as wasteful treatment of substantial bycatches (Clausen & Clark, 2005). Low energy input to output ratios are also common when wild caught fish is transformed into, e.g. Atlantic salmon. Naylor et al. (1998) estimated the inputs to fish pellets to volumes of two to four times that of yielded seafood outputs. This may not come as a surprise to those familiar with the second law of thermodynamics, which states that a part of the total energy input is always and unavoidably lost in any transformation process. However, the fact remains that of the five largest fisheries, three are today exclusively extracting pelagic fish for fish meal production (Clausen & Clark, 2005). Indeed, when viewed from a holistic energy efficiency perspective, using food products as feed for producing lesser quantity of luxury food may not make much sense at all (Odum & Arding, 1991).

Management of Marine Resources in Caleta Chigualoco

The Chilean government has granted user organizations tenure over marine areas since 1997. By this system of Management Areas for the Exploitation of Benthic Resources (MAEBR), users co-manage and extract specified target species in public and limited areas of the sea. The object of this approach was to conserve benthic resources and to promote the organization of artisanal fisheries and local coastal livelihoods based on these resources.

The exploitation of the Chilean abalone may be regarded as a driver for the implementation of the Chilean MAEBR system (Castilla & Gelcich, 2009). Increasing Asian market demand in combination with neo-liberal policies and generous credit programs resulted in landings peaking in 1980, followed by a deterioration of the resource (Keene Meltzoff et al., 2002; Gallardo, 2008; Castilla & Gelcich, 2009; OECD, 2009). Increasing demand for kelp species in combination with low prices on Chilean abalone is presently shifting pressure onto these algae ecosystems. Consequently, fisher's organisations (for example in Chigualoco) have lately embarked on a transition from mainly management and harvest of Chilean abalone to extraction of a variety of kelp species.

Representing the case of MAEBR, the research presented in this paper includes preliminary assessment of the conditions and experiences of the Sindicato de Pescadores Artesanales y Buzo Mariscadores Extractores de Productos del Mar Caléta Chigualoco, which is organising the extraction of benthic resources from three MAEBRs along the coast North of the village Los Vilos, in the region of Coquimbo. The emergy systems diagram is presented in figure 1. Forty six fishers and extractors are organised in the "sindicato". Target species regulated by landing quotas of the MAERB include Chilean abalone (*Concholepas concholepas*) and keyhole limpets (*Fisurella cumingi*, *F. latimarginata*, *F. maxima*). Moreover, the harvesting methods of the algae *Lessonia trabeculata* (huiro palo in Spanish), a kelp species, have been recently regulated by extraction criteria and quotas (Gobierno de Chile, 2008). The members of the Sindicato Chigualoco extract about thirty species of sea urchins, gastropods, clams, algae, crabs, and fish.

Salmon Aquaculture in the Region of Los Lagos

Salmon aquaculture in Chile mainly takes place in the Xth region of Los Lagos, with Puerto Montt as the regional capital. Throughout this region, Atlantic salmon (*Salmo salar*), which is non-native to Chile, is produced in highly specialized systems involving broodstock genetic programs, egg production, hatcheries where fry and fingerlings develop, smolt production in lakes and eventually outgrowth in salmon farms in coastal waters, harvest, and subsequent slaughter and processing in specialized facilities. The system in focus of this present study is presented in Figure 2.

The salmon aquaculture sector has been very successful making Chile the second largest salmon producer in the world. However, during recent years the salmon sector has experienced serious setbacks resulting from the infectious salmon anemia (ISA) virus. The virus decreases salmon growth

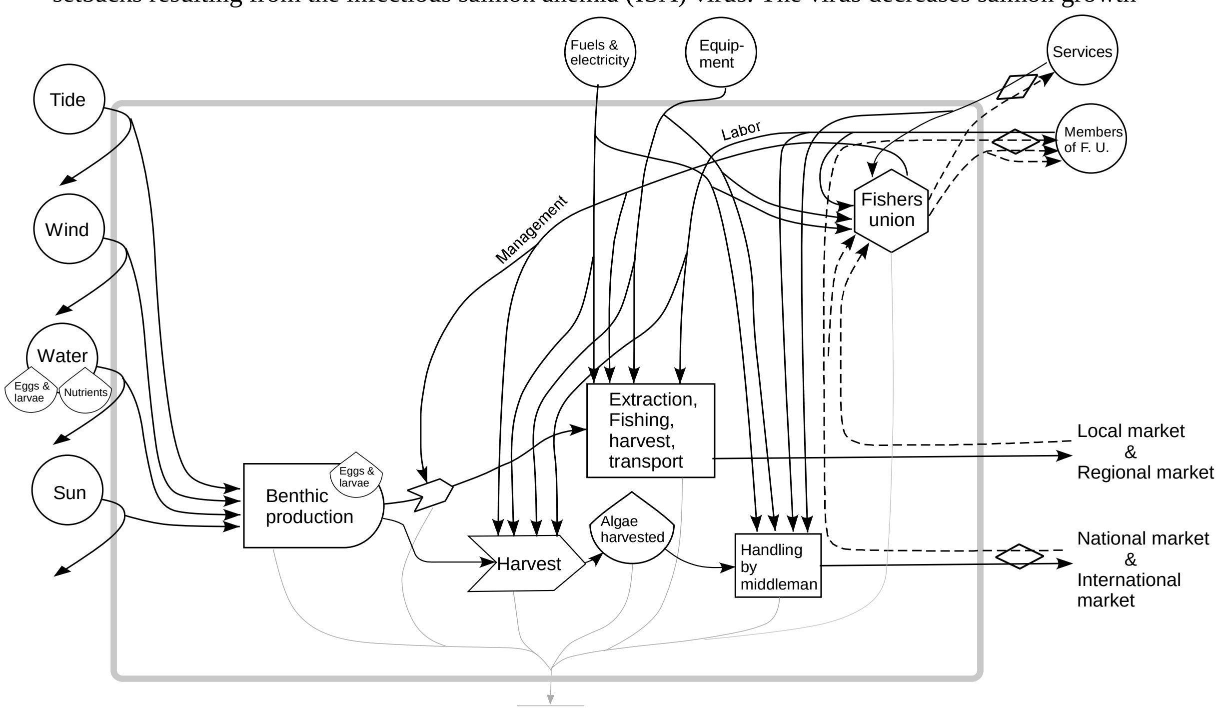

Figure 1. *Management areas of Chigualoco, Boca del Barco and Chepiquilla including seaside area and facilities used by the Fishers union of Chile, and its members.*

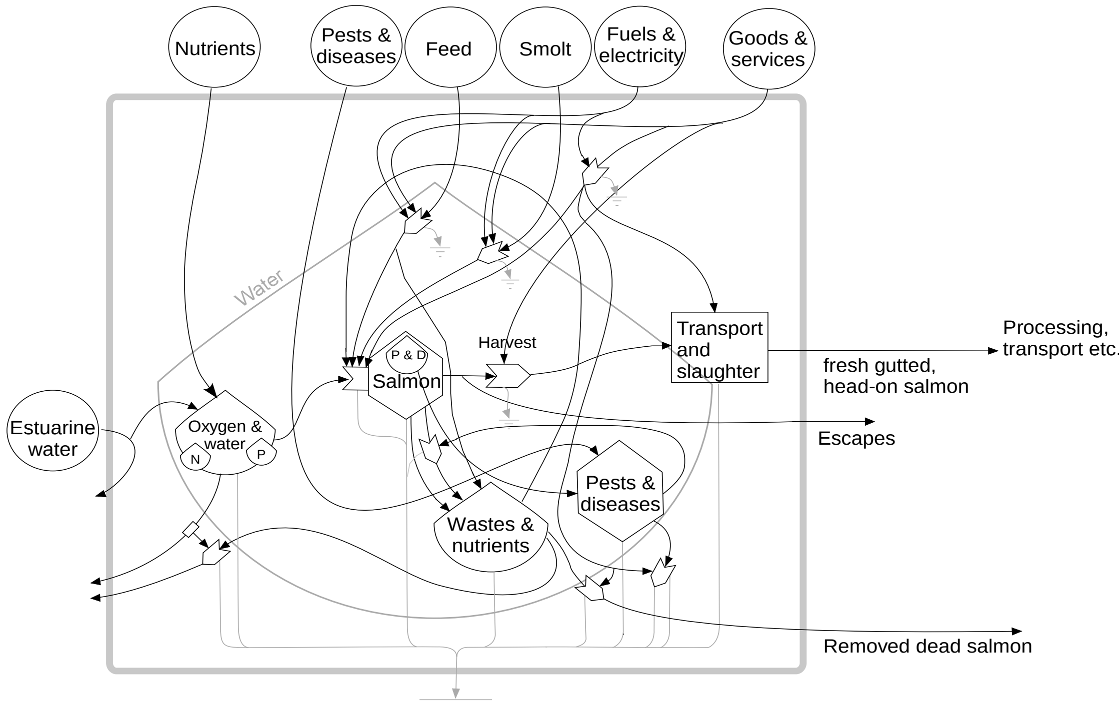

Figure 2. *Salmon production including harvesting, transportation and degutting in Chile. P&D = pests and diseases. N = nitrogen. P = phosphorous.*

rates and kills salmon. Tens of thousands of workers have lost their jobs and salmon facilities have been closed as a consequence of businesses struggling to survive. Ongoing initiatives by the government and industry aim at redirecting aquaculture systems to proactive measures instead of the previous reactive measures dominating the management (OECD, 2009).

RESULTS AND DISCUSSION

Figure 3 shows the preliminary emergy signature of low processed farmed salmon. Please observe that the estuarine support is estimated by the flushing of pens needed to dilute phosphorus released by salmon to background concentration (Odum, 2000). This procedure presupposes that neither crowding nor competition over estuarine services exists with other activities in the area, such as release of pollutants from industry or agriculture, cities or other salmon farms.

The preliminary emergy signature indicates about 50:50 dependence of local renewables and purchased external resources. However, the nonrenewable support is underestimated in this preliminary assessment since emergy of many materials are not yet included. Consequently the share of locally renewable support is overestimated in the emergy signature. Please note that electricity and fuels for feed are embedded in the emergy of purchased feed. The preliminary unit emergy was estimated to 4.3×10^{13} seJ/kg, including services, but will thus increase once the results are refined.

The assessment does not address environmental impacts of salmon escapes, disease transfer to wild fish, fish stocks and fish ecosystems for feed production etc. In fact, very little is known about the impacts of escapes, disease transfers, or systems inertia. Consequently the specific emergy is underestimated.

An interesting aspect of the activities in Caleta Chiguaoco is the current shift to algae extraction from previously focusing on management and harvest of Chilean abalone. Kelp forests are one type of marine ecosystem that has collapsed in several locations throughout the world, mainly due to overfishing and disruptions in trophic food webs and species interactions. Clausen & Clark (2005)

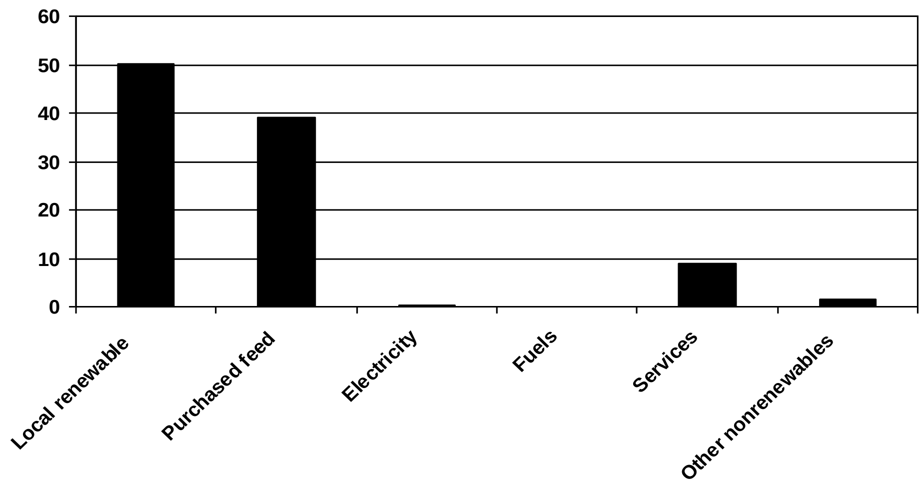

Figure 3*. Emergy signature of fresh gutted head-on salmon. Including harvesting, transportation and degutting in Chile. Numbers represent percentage of total emergy.*

pointed out that as traditional fish stocks are depleted, it is common for extractive fisheries to switch to previously unexploited species, often lower down the food chain. The transition currently underway in Chigualoco is a clear example of this trend. Initially, this strategy may appear successful since it enables continued growth of the fisheries system. However, switching from high-level species (i. e. finfish and Chilean abalone) to lower level benthic resources (i. e. algae) also implies a shift of extraction lower down the food chain. The risks associated with such strategies are substantial. By extracting kelp, the integral foundation of coastal ecosystems is potentially jeopardized, since it ultimately changes natural habitats and hence disrupts natural metabolic cycles and energy flow paths in the management areas. Hence, opportunities for ecosystem recovery, i. e. re-growth of fish and loco stocks, are potentially undermined, as are opportunities for subsistence fishing and other coastal livelihoods.

Our preliminary results indicate that both salmon aquaculture and artisanal fisheries in the MAEBRs have developed according to a pattern much similar to Odum's (1996) pulsing paradigm. In both cases, collapse in one system (i.e. capture fisheries) has triggered the reorganization of resources that in turn enabled starting a new growth cycle in another system (i.e. the aquaculture system and MAEBR system respectively). Furthermore, the transition to mainly algae extraction in Chigualoco implies that another pulse is approaching its peak. Applying this kind of systemic thinking to trends in fisheries and aquaculture, Clausen & Clark (2005) contended that it is this pattern, triggered by rapid declines in natural fish stocks, that has encouraged relocation of capital investments to aquaculture as a quick fix of natural resource depletion. Recently this strategy has started to spread also to the MAEBRs. For example, in an appraisal of the Chilean fisheries sector, the OECD (2009:15) contended that *"the recent decision to allow aquaculture activities within MAEBRs will help to make the scheme more flexible and attractive to coastal communities".* Clausen & Clark (2005) further argue that it is by such mechanisms that capital itself, through policy formulation and implementation, seeks to overcome limits to growth. However, this way of shifting extraction and production to new parts of the global economic system (i.e. iterating between growth phases in different peaking systems) does not mean that natural barriers are overcome in the indefinite future and on larger scales. Rather limits and destructive processes are re-distributed in new directions, as well as postponed.

Another aspect related to aquaculture that may be better understood from a system's perspective is how business operations in the oceans operate so as to merge local and imported resources for achieving economic growth. By importing fuels, fish fry and feed, these resources are combined with local coastal resources (e.g. water, currents, nutrients etc.), ultimately bringing high quality aquaculture products to the global market. In this way, aquaculture transforms national as well as imported natural and human capital into products that are internationally traded in exchange for money. As these products are exchanged, producers receive payment, but more importantly, become integrated and dependent on the global trade system. Consequently, local food systems are today more deeply connected to and dependent on global mechanisms and regulations of the international trade system than ever before. As pointed out by Clausen & Clark (2005), aquaculture and its environmental and socio-economic consequences need therefore to be analyzed relative to the economic system that is based on the capital accumulation (i.e. capitalism) in which it is embedded. As argued by Bergquist & Rydberg (2009), the main problem with integration of South producers and North consumers, is that the current trade system is based on ways of establishing value that underestimate the contribution by people and the environment, and hence more often results in unfair resource transfers than sustainable and fair accumulation of real wealth. As earlier argued by Odum & Odum (2001), the reason why most global trade results in unfair resource transfers is that the current economic system is organized according to hierarchical spatial patterns, where resources flow towards centers of concentration. As noted by Clausen & Clark (2005), this accumulation process reaffirms Marx's earlier observation that capitalist food systems always globalize, as they are ultimately dependent on importing resources extracted from distant places. The reason for this, Marx argued, (1978, pp. 200-203, cited in Clausen & Clark, 2005), is that capitalist operations will use any means necessary to decrease production time, so as to speed up the turnover time of capital, and hence, accumulation.

Several of the trends illustrated by the cases presented in this paper apply to fisheries and aquaculture at international levels. In terms of sustainability, most apparent is the increased reliance on imported fuels and resources. In the case of farming carnivorous species such as salmon, imported feeds contribute substantially to the production (Figure 3). Another important aspect is the increasing integration into global markets, due to which consumption takes place mainly in other countries than where marine resources are extracted/produced (Zeller et al., 2009). From a pure economic perspective, this is a feasible and effective strategy since locally declining catches may thus be buffered through such integration into global markets (Zeller et al., 2009). There is also a clear pulsing pattern in the extraction of marine resources, where depletion of one resource leads to reorganization and/or extraction of other species. In Chile e. g. the Chilean abalone peaked and collapsed in the 1980´s, as did the extraction of Gracilaria algae (Keene Meltzoff et al., 2002). Similarly, this pulsing pattern is apparent in aquaculture development. At present, the Chilean salmon industry is coming down after a strong pulse, with businesses collapsing and reorganisation of the sector. Put together, this trend forces fishers and aquaculturists to target species lower down the food webs. When a succession of species is exploited until the remaining species mix can no longer support the economic unit relying on the fishing (Zeller et al., 2009), the system will shift or pulse. Our results indicate that Chile is following this pattern for its benthic resources. The increase in extraction of kelp species may constitute an example of this.

Preliminary indices of head-on degutted Chilean salmon include an emergy investment ratio of 0.99 and an emergy yield ratio of about 2.0, both reflecting the 50:50 dependency on local renewable resources to purchased resources. The benefit to the buyer as shown by the preliminary emergy exchange ratio was about 9. This result seems to confirm that global trade in aquaculture products and marine resources follow a trend similar to the pulsing paradigm. This in turn results in asymmetric accumulation processes, where the "Global South" supports the "Global North" with low price resources and receives less emergy in exchange.

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