Methodology for Comparing the Environmental and Socio-Economical Impacts of the Fishery and aquaculture Supply Chains: from wild fish in the water to protein on the consumer plate

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The debate is ragging between tenants of fisheries and tenants of aquaculture regarding global food-security in future. This debate is exacerbated by the recent concern about environmental and economical sustainability of these activities. Fisheries defenders claim that despite the relative conversion efficiency of many aquaculture systems cycling fishmeal and oil through other species is not as effective a means of providing highly nutritious animal protein to humans than the direct human consumption (DHC) of fresh forage fish. In addition, substantial energy inputs are required throughout the meal / oil mediated supply chain when inputs to fish harvesting, reduction, transport etc. are accounted for (Pelletier, 2008; Pelletier *et al*., 2009). Aquaculture defenders claim that the overall ‘‘fish - in to fish - out’’ (FI / FO) ratio for fed species was reduced from 1.05 in 1995 to 0.65 in 2007 (Naylor *et al*., 2009), and expected “progress” in genetics, physiology and feeding practices will likely continue to reduce this ratio into the future. The counter-argument is that greater use of alternative protein sources like soya meal also has an environmental impact linked to agricultural practices and related emissions (e.g. mechanical traction, production of fertilizers and pesticides, deforestation). Another claim of aquaculture defender is that in the wild, the equivalent of FI / FO ratio for carnivorous fish species is always higher than in fish farming, due in part to the higher metabolic energy demands associated with the foraging behaviour of wild fish in contrast with the industrial energy inputs to supply feed to farmed fish. The counter-argument of fishery defenders is that energy flows in marine ecosystems occurs within a complex food web with many different trophic levels and that the benefit of aquaculture versus fishery is not so obvious.

It appears that without a proper quantification of the numerous sources of environmental and socio-economical impacts, one must be cautious before pointing to supposedly bad practices (e.g. Pelletier and Tyedmers, in press). Rather than pitting aquaculture against fisheries, we consider that both activities urgently need further research for integrated management and sustainable development. A proper

integrated, quantitative and comparative study of food supply chains founded on forage fish is needed. Indeed a fishery is one of the nodes of a larger network that includes up and downstream processes or activities such as fluxes of energy and biomass in marine (and terrestrial) ecosystems, boat and gear construction, fuel provision, fish processing, marketing and transport, aquaculture uses and impacts, etc. Often impacts of these other activities are easily overlooked.

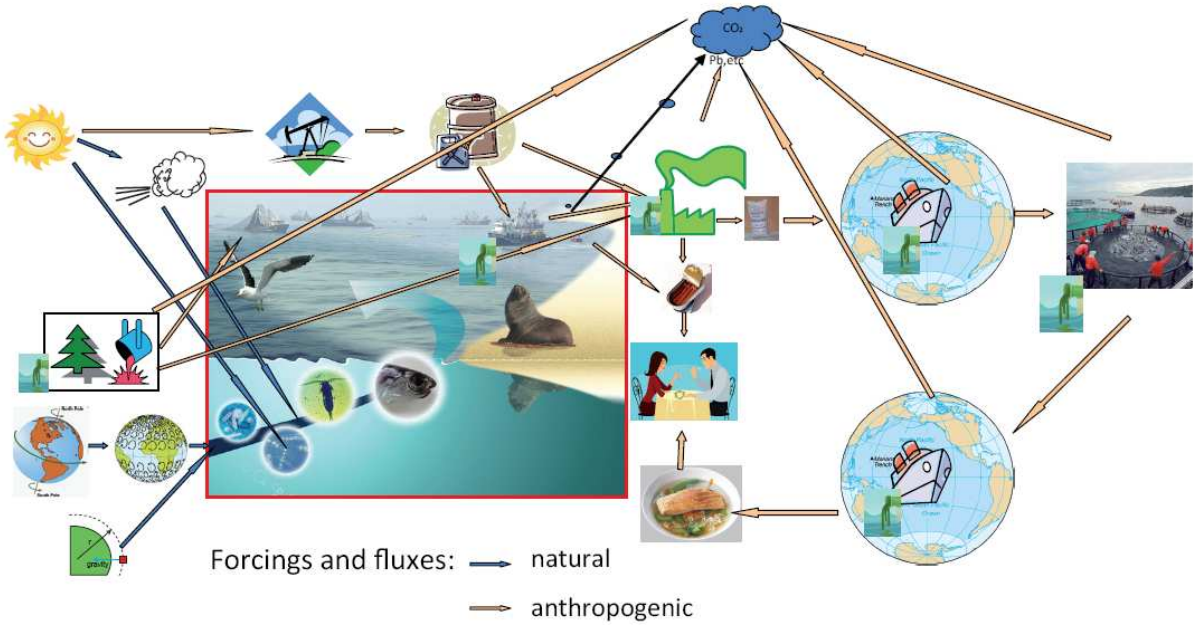

Figure 1: Simplified diagram of the functioning and environmental impact of the Peruvian anchoveta supply chain. The large composite image with a red frame in the diagram represents the Peruvian Marine ecosystem whereas items surrounding it in the far left and upper parts of the diagram represent natural forcing (sunlight, wind, Coriolis and gravity forces) and "exosomatic" input such as construction materials (wood, mineral) and domesticated energies (fuels). Items on the right hand side of the diagram represent transformation of anchoveta for direct or indirect human consumption, for instance through carnivorous fish cultivated in Asia.

A new research project on environmental and socio - economical impacts of the Peruvian anchoveta supply chains was launched at the end of 2009 by IRD (French Institute of Research for Development) and IMARPE (Instituto del Mar del Peru), within the framework of the International laboratory DISCOH (Dynamics of the Humboldt Current system) and with the input of external experts in various fields. The aim of the study is to quantify and compare the environmental and socio - economical impacts of the Peruvian anchoveta supply chains for direct and indirect human consumption, from end to end (Fig. 2).

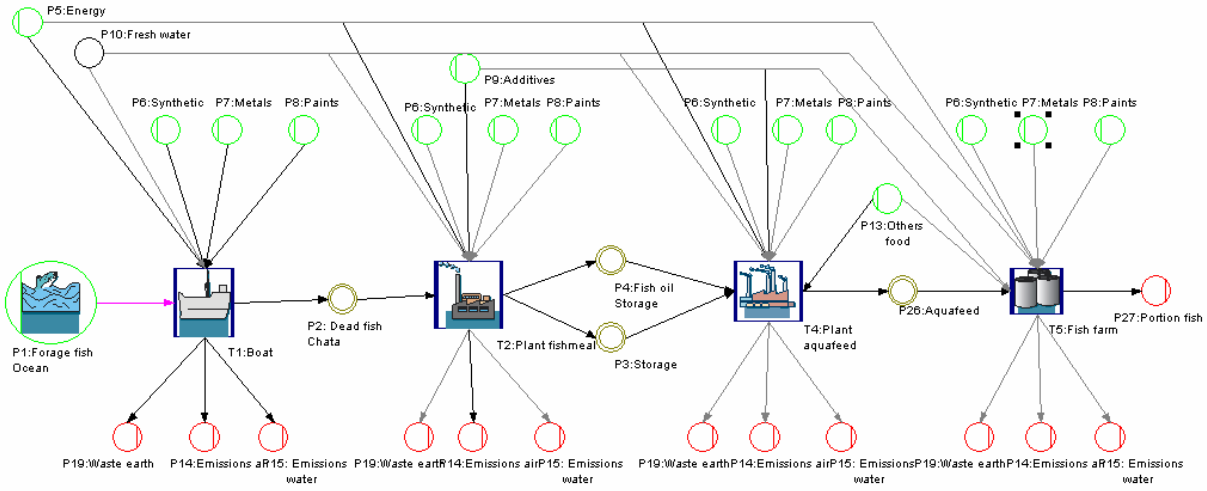

Figure 2: Simplified Petri diagram of the flow of energy and materials in a forage fish supply chain. For simplification, transport is not explicitly represented, nor the marine trophic flows. Green circles represent inputs, red circles outputs.

The first step will be a comparison of impacts resulting from the extraction phase according to the type and size of boat. Life cycle assessments of the extraction phase will be performed, along with analyses of employment (direct and indirect) and economical rent in order to provide decision makers with a broader and multidimensional understanding of this complex sector. A similar study will be undertaken for the transformation phase (fishmeal and fish oil production, canned fish, frozen fish, fresh fish and cured fish) both locally in Peru and abroad (for example in Asia). This will help to identify sustainable fishery systems that better align with policies aimed at addressing climate change (Driscoll and Tyedmers, in press) and social welfare (Pelletier et al., 2007). This type of analysis is especially important at this juncture, where over - exploitation and collapse of several fish stocks (FAO, 2007), increasing fuel prices, concerns over greenhouse emission contributions to climate change and ocean acidification and related issues have combined to increase consumer concern regarding how and where their food is produced (Deere, 1999; Jacquet and Pauly, 2007). This project should help in the definition of criteria and good practices for certification of pelagic fisheries and supply chains in order to promote incentives for a more environmental friendly exploitation of natural resources.

Life Cycle Assessment (LCA) is a tool which provides a useful framework to identify potential contributions to a wide range of global scale environmental concerns that result from various production systems. It will be used to inventory the physical inputs, production materials, energy requirements along with the resulting emissions (to air, land, fresh water and oceans) associated with each stage of each production chain: from anchovy capture through production, transport, use and disposal. The process will be facilitated by the use of the SimaPro software package by Pre Consultants that allows various indices of environmental impacts to be derived. Material Flow Analysis and conventional micro - economics approaches will be used to complement LCA and study rents and employment (but not environmental costs). The Umberto software will facilitate this approach.

This study will provide direction on how to best support people dependent on fisheries as it will assess and compare the socio - economic implications of each stage of the anchovy production system in terms of indirect and direct jobs, and use of the rent and wealth redistribution. Together with other studies of the whole artisanal and industrial fisheries undertaken by IMARPE and IRD, this work will provide indications on the vulnerability of Peruvian fisheries to global changes such as climate change, globalisation of the markets, human population growth, global economical growth and the associated increasing demand for animal proteins. Quantifying natural resource use, together with the social and environmental factors of the industry represent a novel approach which could lead to improvements of the management and a more environmentally and socio - economic sustainable anchovy industry. It aims at providing stakeholders and policy makers with a basis upon which to jointly decide further research and development perspectives in the sector and generate the necessary information to inform consumers about the aggregated environmental impacts of each anchovy derived product, in addition to socio - economics aspects.

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