ENVIRONMENTAL IMPACT STATEMENT (EIS) FOR A NEW EXPERIMENTAL STATION FOR AQUACULTURE RESEARCH NEAR PALMAR (PROVINCE OF GUAYAS, ECUADOR)

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Introduction

Global shrimp farming increased steadily since the 1970s with main cultivated species *Litopenaeus chinensis*, *Litopenaeus monodon*, and *Litopenaeus vannamei*. In Ecuador, the aquaculture industry largely consists of *Litopenaeus vannamei* monoculture. Unfortunately, due to several disease outbreaks in the last 15 years, it has experienced substantial damage. In addition, several negative environmental consequences have been identified that compromise further expansion of the industry both in Ecuador and other shrimp farming nations. Hence, there is a growing need for scientific solutions to solve the existing problems and improve the practices and efficiency of today's shrimp farming activities.

Over the years, the Ecuadorian laboratory for aquaculture and marine research (CENAIM) experienced the need to confirm in the field some of its laboratory findings. In December 2002, the CENAIM-ESPOL foundation therefore bought the shrimp farm COFIMAR, about 12 km south of its main activities in San Pedro in the province of Guayas in Ecuador. The foundation is constructing a new 25 ha experimental station for aquaculture research at this site that will be largely focused on shrimp farming.

The rationale for the current study was to produce an Environmental Impact Statement (EIS) for this project with two primary goals: (1) the identification of potential impacts on the total environmental; and (2) the elaboration of a monitoring and mitigation plan to reduce the predicted negative impacts. In short, fieldwork of the study involved gathering information on the existing (total) environment and the project, verification of best management practices for shrimp farming (BMP's), a soil and water quality analysis and an environmental impact assessment. In addition, mitigative measures were proposed for all potential negative impacts and a tailor-made monitoring plan was elaborated.

Study area

The project

The selected site for the experimental station was an existing shrimp farm with four ponds ranging in size from 3.7 ha to 8.5 ha (Pond 1 = 3.72 ha; Pond 2 = 5.90 ha; Pond 3 = 5.70 ha; and Pond 4 = 8.50 ha). To convert it to an experimental station some restructuring of the ponds and the construction of additional civil infrastructure are necessary.

The complementary civil infrastructures for the experimental station include: (1) a base camp with offices, a meeting room, a kitchen, dormitories and a small laboratory; (2) dormitories with recreational installations; (3) sanitary installations (including septic tanks); (4) storage rooms for equipment and sampling materials; (5) an area for fuel storage tanks, an ice machine, an electrical station (including generators) and warehouses for food supplies; (6) an area for the assemblage and the storage of plastics and mobile aerators; and (7) a transit zone at the entrance of the research station for security (gate control), a wet laboratory for handling the harvest, a storage room and a freshwater reservoir.

The pond design of the experimental research station also requires some adaptations from the original lay-out. First of all, a high number of small ponds are required to allow for simultaneous trials of different treatments at minimal costs where extrapolation of the results to commercial pond size should still be possible. Secondly, there is a need for a variety of pond sizes depending on the type of trials and the type of organisms cultivated. And finally, relatively large ponds have to be provided for demonstration of research results under simulated commercial production systems.

The area of the influence

The experimental station is located at the northeast end of Palmar (02°01'37''S; 80°43'52"W); west of the coastal road that connects Santa Elena with Puerto Lopez. Palmar belongs to the canton of Santa Elena, 32 km away from the cantonal headquarters, in the province of Guayas in South-West Ecuador. The site is surrounded on the northern and eastern sides by other shrimp farms, most of them small (between 5 and 25 ha) and performing the traditional semi-intensive culture.

The area of influence is highly characterized by the climatic conditions and the geomorphology of the coast. There are two distinct seasons: a dry season from June to December and a wet season from January to March. The coastal area north and south of Palmar contains rocky bulges forming a small bay that connects to an estuary with a small area of mangrove. This 36 ha mangrove at approximately 1 km west of the site, is the most important biological feature in the area with typical associations of fauna and flora.

The mangrove of Palmar mainly consists of *Rhizophora mangle*, *Conocarpus erectus* and *Laguncularia racemosa* stands with associated vegetation, predominantly small and branched shrubs and herbs from different families including Amaranthaceae, Eleocarpaceae, Fabaceae, Malvaceae, and Poaceae. Several bird species nest in the mangrove and it is a nursery and breeding ground for many aquatic species. It provides several benefits to the local community including treatment of effluents from agriculture and aquaculture, support of economic important fish and crustacean species, tourism and the harvest of mangrove crabs.

Methodology

The field data were obtained in Ecuador from August to December 2003 and processing of the information and further analysis was done in Belgium from January to May 2004.

The description of the planning, design and operation of the experimental station was largely based on information received from CENAIM. Description of the environment was based on available literature, studies performed in the area and own observations during regular site visits. Several online databases were used to verify species nomenclature and status including the Fishbase database, the Interagency Taxonomic Information System (ITIS) database, the 2003 IUCN Red List of Threatened Species™ database and search engines from the Missouri Botanical Garden (W3TROPICO™), Purdue University (NewCrop™) and de Royal Botanical Garden Kew (SEPASAL™).

All aspects of the project were evaluated against the recommended Best Management Practices (BMP) for shrimp farming from the Global Aquaculture Alliance (GAA). The BMP's from the GAA were chosen because they are well established and because they are accepted by the members of the Ecuadorian *Camara Nacional de Acuacultura*.

Soil samples were collected using a tailor-made soil sampler in October 2003 from a total of 4 existing ponds. Samples were dried for 4 days at 50° C, crushed and then stored in a freezer (Ecuador). Upon arrival in Belgium, samples were freeze-dried for 24h with an end temperature set to -55°C, to remove traces of moist prior to chemical analyses.

All water samples were collected during a single day on the 28th of November 2003, from 7:00 am until 7:00 pm at several locations in the vicinity of the construction site. Sampling consisted of a 12-h sampling campaign at 1 location (intake canal) and sampling at different canals and location in the area of the construction site. Samples were collected for later BOD analysis and additional water was filtered with pre-weighed glass fiber filters for chlorophyll *a* and Total Suspended Solids (TSS) determination (twice 300 ml). Approximately 600 ml of the filtered water was kept for later Total Nitrogen (TN), Total Ammonia Nitrogen (TAN) and Total Phosphorus (TP) analysis. Additionally, 500 ml was kept for later determination of trace element composition and organic compounds. During sampling, salinity was measured with a standard refractometer, temperature and dissolved oxygen with an online detector and the pH with a pH-meter. Samples for trace elements analysis were spiked with 3 ml of concentrated HNO_3 for every 100 ml of water and transferred to acid washed plastic bottles, stored in a freezer for transport to Belgium and kept in a freezer until analysis.

Total dissolved solids (gravimetry), total phosphorus (persulfate digestion in acidic conditions and ascorbic acid finish), total nitrogen (persulfate digestion in basic conditions, cadmium reduction and diazotization), and 5-day biochemical oxygen demand (BOD5) were measured according to the protocols presented by the American Public Health Association *et al.* (1998). Between 100 and 500 ml of water were filtered through a Whatman glass fiber GF/C filter (1.2 μn nominal pore size) and chlorophyll a concentration was measured after hot extraction with a 5:1 acetone-methanol solution (Pechar, 1987).

Acid extractable metal fraction procedure for soil and sediments (also called pseudo total metal fraction) was done as described by Ryssen *et al.* (1999) with a HCl/HNO3 digestion using 0.5 g of soil per sample in digestion bombs with 2 ml HNO_3 (70% Merck) and 6 ml HCl (37% Merck).

Both the prepared soil extracts (filtrates) and water samples were analyzed for presence of trace elements using Inductively Coupled Plasma Atomic Emission Spectrometer – ICP-AES in Belgium in the Laboratory of Ecophysiology, Biochemistry and Toxicology (University of Antwerp). The soil samples were extracted using the acid extractable metal fraction procedure as described above. The observed values were then compared with normal background concentrations, toxicity levels and with specific threshold values for different environmental media (Fergusson, 1990; Pinet, 1992; Sadiq, 1992; Boyd and Tucker, 1998; Buchman, 1999).

Both the pre-treated (crushed, dried and freeze-dried) soil samples (filtrates) and water samples were screened for the presence of organic compounds at the department of toxicology of UIA (University of Antwerp). Selected soil samples were also subjected to a quantitative analysis of targeted pesticides. General methodology encompassed extraction and cleanup, gas-chromatography and mass spectrometric determination using a Hewlett Packard (Palo Alto, CA, USA) 6890 GC coupled with a HP 5973 mass spectrometer equipped with a 30m x 0.25mm x 0.25μm DB-1 (J&W Scientific) capillary column. Helium was used as carrier gas at a constant flow of 1.0 ml/min.

Potential impacts were identified using conventional EIA techniques based on site visits, field surveys, interviews, sampling and measurement of important parameters. Gathered information was then used to (1) compile an environmental impact matrix showing potential impacts due to projected activities executed both during the construction phase and during the operational phase; and (2) compile a level of risk matrix based on the qualitative risk assessment of potential negative impacts that were identified. The environmental impact matrix was based on a similar environmental impact assessment for a shrimp farming project in Tanzania (Boyd and Associates, 1997) and adapted to the specific circumstances of the present project. The qualitative risk assessment resulting in level of risk matrices was based on the 1999 edition of the joint Australian and New Zealand Standard for Risk Management (Australian and New Zealand Standards, 1999) as described by Crawford (2003). The standard was selected because of its simplicity and because it was already successfully used for qualitative risk assessment of aquacultural activities to support governmental decisions in the past (Crawford, 2003).

Results and discussion

Primary results

Analysis of soil samples taken on the construction site revealed that in general, the observed trace element content was within expected ranges of background values found in the literature with some exceptions. Copper concentrations were relatively high with values ranging from 4.96 μg/g to 66.34 μg/g and an average of 36.31 μg/g. Normal copper backgrounds in soil are around 17 μg/g but they can vary enormously. The observed copper concentrations could be due to the fact that copper (as copper sulphate) is regularly used in shrimp farming for algal control or as a fish disease treatment. Probably it has been used by the former shrimp farm owner. Exceptionally high levels of boron were observed, and further investigation is needed to determine the cause. No organic toxicants or pesticides could be detected, except for hexachlorobenzene (HCB), a common pesticide. The concentrations of HCB however, are considered to be below acceptable limits.

Water samples, taken in the estuary, water reservoir and several effluent canals in the vicinity of the construction site during a 12-h sampling campaign, revealed an expected change of major water quality parameters in the estuary from high tide to high tide. Most common water quality parameters, nutrient levels and trace element concentrations at all water sampling sites seem to be normal with some exceptions: Total Suspended Solid (TSS) load was on the high side, but not uncommon for Ecuadorian estuarine water; and boron concentrations were above normal, although further investigation is needed to determine the cause. The highest levels of trace elements and the poorest water quality parameters were generally observed for the effluent canals in the area. No detectable amounts of pesticides or other screened organic contaminants were found.

Screening of the socio-economic conditions of the area of influence revealed that the main economic activities of the Palmar community are tourism, artisanal fishing and shrimp farming. Basic services and infrastructure is present but limited. They include two clinics (one public), primary and secondary education facilities, limited sanitary infrastructure (no sewer system), public services for electricity and freshwater, decent roads and some transport facilities (mainly buses). The community is used to the presence of aquaculture and no major objections against the construction and operation of the experimental station were observed as long as the health of the mangrove is not compromised.

Impact assessment

Several potentially negative impacts, associated with the construction and operation of the experimental station, were identified. For the construction phase, noise pollution and the pollution of air and water by oil spills and dust particles pose the highest risk to the total environment. Potential sources for these negative effects are the use of heavy machinery and earthworks. For the operation phase, the following effects pose the highest risk to the total environment (in decreasing order of risk level): (1) disposal of feed bags; (2) reduced access to pristine seawater; (3) dispersal of pathogens; (4) accidental oil and fuel spills; and (5) social conflicts. Possible causes for these negative impacts include (respectively); the accumulation of used feed bags; clogging of the mouth of the estuary; accidental water release and effluent discharge containing pathogens; the operation of power equipment; and theft.

Due to the amount of feed that will be used when the experimental station is fully operational, CENAIM-ESPOL believes that the accumulation of used feed bags poses considerable concern. Since burning or burying them at the station is to be avoided, a deal with the producer or distributor for proper disposal should be negotiated. Theft is also a cause of concern, especially because it might interfere with research results and needs to be limited by security measures and good community relations.

However, aside from potential negative impacts, there are also several positive consequences and benefits associated with the project. The most important are employment opportunities, scientific research opportunities, prestige for the local and national community, increased aesthetic value of the area, increased monitoring of the Palmar mangrove health and the support and stimulation of local community projects.

In addition, former land use of the site, a small shrimp farming operation, was unsustainable due to viral outbreaks and poor management and infrastructure. The existing shrimp farm's alternative value is limited: (1) it is unattractive for tourism; (2) it has a low aesthetic value; and (3) a comparable shrimp farm would yield little extra work for villagers and marginal contribution to society. Although shrimp farms can be quite destructive for the environment when not properly managed, there's nothing worse than an abandoned shrimp farm as it leaves behind an ecological and social abyss that is not easily rehabilitated.

Impact mitigation and monitoring

Much of the mitigation for this project can be done with relative simple procedures and the implementation of good management practices during construction and operation of the experimental station. During construction these include: compaction of levees and pond bottoms, cut and fill operations, safe storage and disposal of oil, diesel and other wastes, use of local labour force with decent wages, open communication with neighbouring communities and use of planted mangrove and salt tolerant grasses around the station. During operation these include: proper handling and processing of used feed bags, use of a constructed wetland, careful monitoring, avoid intensive (high density) production, no use of non-food chemicals or antibiotics, use of proper safety constructions, practice an open communication policy, participation in community projects and the use of high quality feed.

One of the most important mitigative measures that will be implemented during operation of the station is the use of a constructed wetland. In an attempt to minimize the impact of operation on the fragile mangrove ecosystem and insure good water quality of the estuary over the years, all pond effluents will be retained in this wetland for a minimum period of 10 days to allow sedimentation of the suspended solids and removal of excessive nutrients. The total water treatment area is roughly 4 ha divided into two non-interconnected wetlands with a water column of minimum 2.5 m allowing for an aerobic layer where nitrification could occur and an anaerobic layer where sedimentation and denitrification will take place. In addition, it is also the intention of CENAIM- ESPOL to plant more than 1,000 seedlings in the wetlands and reservoir.

We believe that when all proposed mitigation measures are properly implemented, the suggested project can run a socially and environmentally responsible operation. Nevertheless, a monitoring program is needed to provide feedback on the environmental and social protection measures, and to suggest mechanisms to adjust the management plan for any unanticipated impact that might be revealed during monitoring.

Implementation of a monitoring plan will allow correcting unanticipated adverse effects before they cause any serious negative impacts. The monitoring will reveal if the environmental assessment was correct and the mitigation plan adequate. To meet the aims of the monitoring plan, local data on water quality, geology, fisheries and marine environment, mangrove vegetation, wildlife and socioeconomic conditions will be collected regularly over a long period of time.

Final Recommendations and Conclusions

The project of CENAIM-ESPOL to construct and operate an experimental station near Palmar provides a valuable alternative for the actual land use. The operation can offer a wide range of benefits without compromising the health of the total environment, provided that best management procedures, the proposed mitigative measures, the monitoring plan, and recommendations highlighted in this document are rigorously followed. Mistakes that are identified by monitoring should be corrected as the project develops and operates. We believe that this study presents an important step towards a successful project. However, it provides no guarantees as the final outcome is influenced by many factors and CENAIM-ESPOL Foundation might still deviate from the conditions and recommendations stated in this EIS.

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