Mitigating water pollution in Vietnamese aquaculture production and processing industry

The case of pangasius and shrimp

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Mitigating water pollution in Vietnamese aquaculture production and processing industry

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Pham Thi Anh

Thesis

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Abbreviations

AFA	An Giang Fisheries Association
AGRIFISH	An Giang Fisheries Import Export Joint Stock Company
AGU	An Giang Unviersity
APFIC	Asia-Pacific fishery Commission
APHA	American Public Health Association
APPU	An Giang Pure Pangasius Union
BATs	Best Available Technologies
BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
BQF	Block Quick Frozen
CDM	Clean Development Mechanism
CENTEMA	Center for Environmental Technology and Management
CERs	Certified Emission Reductions
CoC	Code of Conduct for Responsible Fisheries
COD	Chemical Oxygen Demand
CoP	Code of Practice
DARD	Department of Agriculture and Rural Development of province
DO	Dissolved Oxygen
DONRE	Department of Natural Resource and Environment
eFCR	Economic Feed Conversion Ratio
EPA	Environmental Protection Agency
ESA	Environmental System Analysis
FAO	Food and Agriculture Organization
FCR	Feed Conversion Ratio
FFER	Fish Feed Equivalence Ratio
GAP	Good Aquaculture Practices
GDP	Gross Domestic Product
GSC	Global Steering Committee
HACCP	Hazard Analysis and Critical Control Points
HCMC	Ho Chi Minh City
IE	Industrial Ecology
IPCC	Intergovernmental Panel on Climate Change
IQF	Individual Quick Frozen
ISO	International Organization for Standard
MARD	Ministry of Agriculture and Rural Development
MOFI	Ministry of Fishery
MONRE	Ministry of Natural Resource and Environment
MRC	Mekong River Commission
NACA	Network of Aquaculture Centres in Asia-Pacific

NAVIQAVED	National Fisheries Quality Assurance and Veterinary Directorate
N-NH_3	Nitrogen ammonia
PAD	Pangasius Aquaculture Dialogue
PFG	Process Facilitation Group
QCVN	National Technical Regulation of Vietnam
RIA 2	Research Institute for Aquaculture in Vietnam, No. 2
RSCs	Regional Steering Committees
ShAD	Shrimp Aquaculture Dialogue
SUDA	Sustainable Development of Aquaculture
SUMA	Support of Brackish Water and Marine Aquaculture
TAD	Tilapia Aquaculture Dialogue
TCVN	Vietnamese standards
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solid
TWG	Technical Working Group
UNDP	United Nation Development Program
UNEP	United Nation Environmental Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
VLU	Van Lang University
VNCPC	Cleaner Production Center of Vietnam
WB	World Bank
WWF	World Widelife Fund for Nature

Chapter 1 Introduction

1.1 The Vietnamese fishery sector

Fishery is one of the most dynamic food sectors in the world, with total production having grown to 110 million tonnes in 2006. Seafood is now the most globally traded product by value and volume (FAO 2009b). Coastal states around the world have striven to take advantage of this growing international demand by investing in modern fishing fleets and processing factories. In recent years, attention has been given to the stabilization or even possible decline (Watson and Pauly 2001) of capture fisheries production. The FAO now classifies 52% of fish stocks as fully exploited and 28% as over exploited fish stocks (FAO 2009b). The continued growth in fish production is now largely the result of the increased production of aquaculture - which has now emerged as the fastest growing production system in the world (FAO 2007c), (2009b).

In Vietnam the fishery sector is a significant and fast growing component of the Vietnamese economy. Starting with the market reforms of 1986 under *Doi Moi* (or 'renovation') the Vietnamese fishery sector has developed rapidly in terms of both production and exports. The largest dramatic growth occurred between 1997 to 2007 during which time total fish production increased 165%, from 1,570 million tons to 4,160 million tons (Dung 2008). It is now the fourth most important export sector to the national economy, after oil, garments and footwear, and the most important sector in terms of primary production (Figure 1.1). In 2007 fish and fish products make up approximately 4% of GDP, and contribute 8% to total export value and 10% to total employment (Dung 2008).

Similar to world production the growth of Vietnamese fishery production has been maintained predominantly through the expansion of aquaculture. As shown in Figure 1.2, capture fisheries have grown at around 7% per year in the last decade while aquaculture has grown at 16.3%. In real terms aquaculture production has grown from 481 million tons in 1997 to 2 billion tons in 2007 (Dung 2008). This production includes a wide range of species grown in freshwater, brackish and coastal waters. Between 2002 and 2004 Vietnam was the third country of the world in term of aquaculture growth (FAO 2007c), and from 2006 Vietnam ranks third in terms of quantity of aquaculture production (FAO 2009b). In 2007 Vietnam exported over 900 kton of fish products, which increased to 1,200 kton in 2008 (MARD 2009a). Vietnamese fish products are currently exported to over 128 countries, but 69% is traded to Europe, Japan, Russia and the US(MARD 2008b).

Among various aquaculture species which are being raised in Vietnam, two have the largest contribution to production and export value: the freshwater striped catfish, *Pangasius hypopthalmus (Ca Tra* in Vietnamese), and the brackish water black tiger shrimp, *Penaeus Monodon* (*Tom Su* in Vietnamese). These two species alone account for approximately 50 percent of the total production volume of aquaculture in Vietnam (Trong 2008) and 68% of export value (MARD 2009b). Both species can be considered what Hall (2003) has labeled ‘boom crops’ given the spectacular increases in production, the relative accessibility of production for some segments of the rural communities looking to ‘get rich quick’, as well as the parallel growth of both local and global political, environmental and economic uncertainties and vulnerabilities. In particular, both species have also come under increased scrutiny over their environmental performance as production and processing has expanded in a largely uncoordinated fashion.

The rise of pangasius has been particularly spectacular with total production having grown at around 30% per year since 2003. Due to low investment costs, high productivity and large export markets, pangasius cultivation has become a popular form of aquaculture and the largest single species farming system by volume in Vietnam (Phan et al. 2009). Over the last 10 years, pangasius has developed from a domestic to an export product. In 2007 the productivity of pangasius reached over 1 million tons/year, a government target previously set for 2010 (Bush et al. 2009), and is now exported to nearly 110 countries and territories mainly as frozen fillet products. The development of pangasius farming has created an important source of regional and national income, and contributing to the Mekong Delta having the highest regional economic growth rate in the country at 14% - compared to an average national economic growth of 9% (Loc et al. 2007).

Following the growth and subsequent stabilization of production in the 1990s the Vietnamese government has sought to reinvigorate production through a series of modernization program (Dung 2006; MARD 2009a). Shrimp farmers throughout the country have been encouraged to shift from extensive traditional systems to improved extensive, semi-intensive and intensive production models (classified according to the pond size, water use, capital, labor, feed and chemicals used, and stocking densities) (EJF 2003). In response, shrimp production has increased faster than the shrimp farming area since 2000. In 2008 the area of shrimp farms has decreased while production has continued to increase. In 2009, the area of shrimp farming was expected to decline 9% to 580,000 ha, while production was expected to grow 10% to 380,000 tones (Trong 2008)). However, shrimp production in Vietnam remains relatively ‘under-modernized’ with approximately 90% of the total farming area practicing extensive traditional production. Despite this Vietnam contributed with 12% to the global shrimp production in 2008 (Figure 1.4). Unlike most neighboring Asian countries, which are now producing primarily white leg shrimp (*Penaeus vannamei*), the production of black tiger shrimp (*Penaeus monodon*) still accounts for 80 – 90% of total cultured shrimp production in Vietnam (MARD 2009a). As a result, Vietnam is one of the few countries still producing large sized, high quality, black tiger shrimp and has few direct competitors, with the exception of India and Bangladesh.

To cope with the expansion of production the fish processing sector in Vietnam has also expanded rapidly since 2000, particularly in terms of investments made in large modern facilities which meet international food safety standards (MOFI and WorldBank 2005). There are about 400 registered fish processing plants in Vietnam with around 1.2 million tons input capacity for export oriented production of frozen fish and fish products (MARD 2009b). Of these, about 50% are processing shrimp or pangasius (Hien 2010; Van 2010). In addition, there are many local fish plants, that process mostly other traditional products such as fish sauce, fish paste, dried fish for domestic markets.

The exploitation of the aquatic resources of inshore waters and of shallow waters offshore had reached a maximum and is close to overexploitation. The growing human population, lack of enforced regulation, and low economic entry barriers to the business are major factors in this expansion. Hence in the coming decades, increased output of fish products will be based largely on planned aquaculture and less on wild captured fish.

In the coming decades, fish production in aquaculture may increase faster in Vietnam than wild captured fish (Dung 2008). An increase in aquaculture may be associated with a range of environmental problems, in particular water pollution caused by fish ponds and processing industries (Figure 1.5)

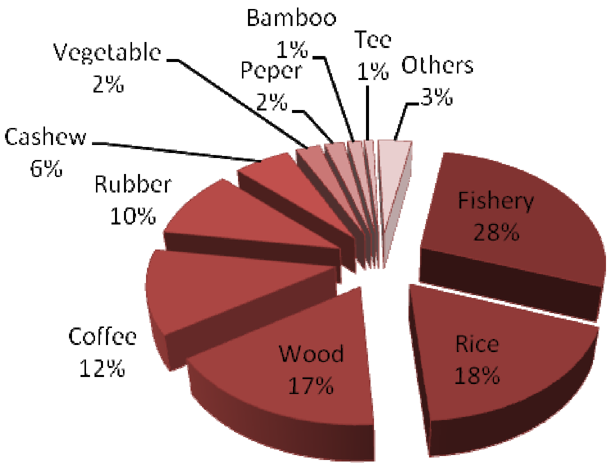
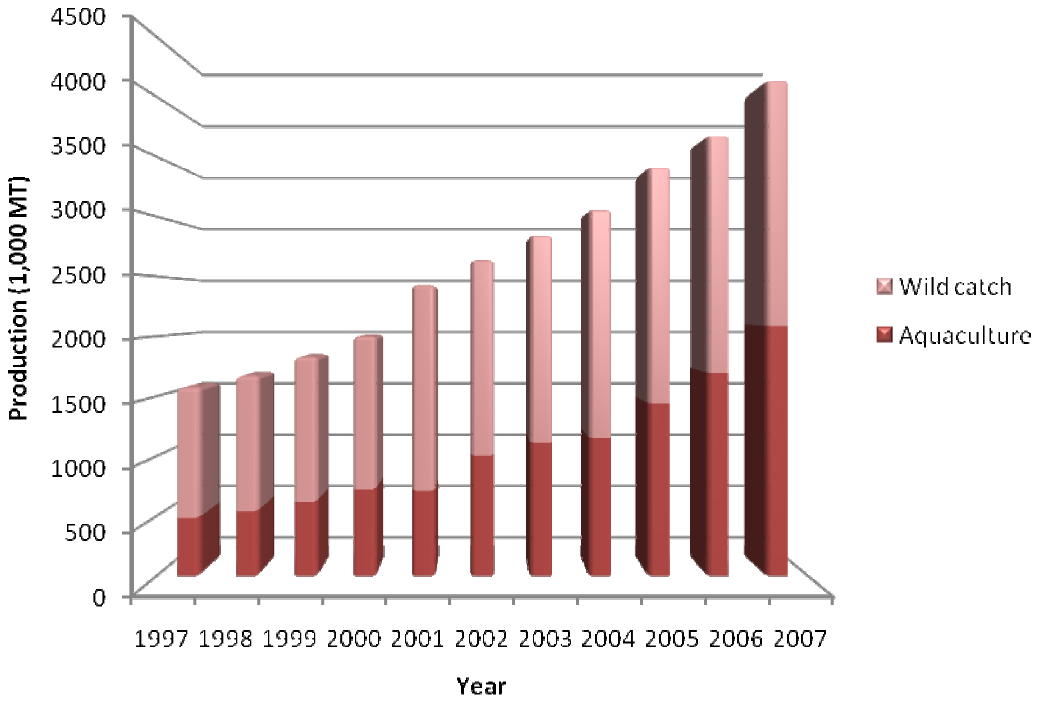


Figure 1.1 Relative share in export turnover value of different agricultural products in total export turnover from Vietnam (MARD 2008b)



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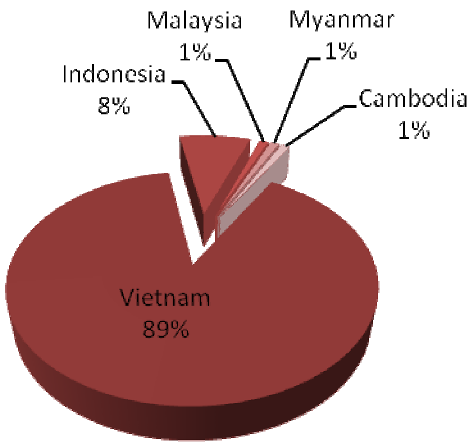

Figure 1.3 Relative share of different countries in pangasius production (in tons) (WWF 2008c)

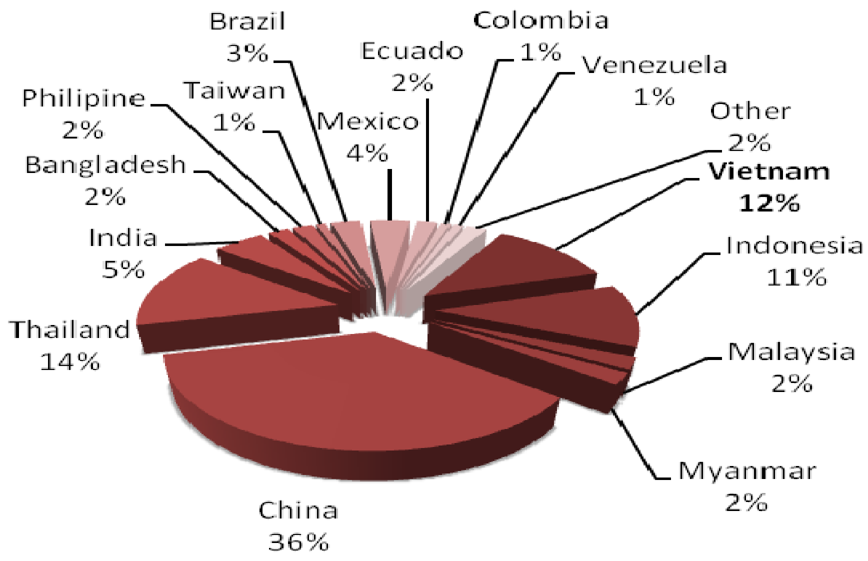

Figure 1.4 Relative share of different countries in shrimp production (in tons) (WWF 2008c)

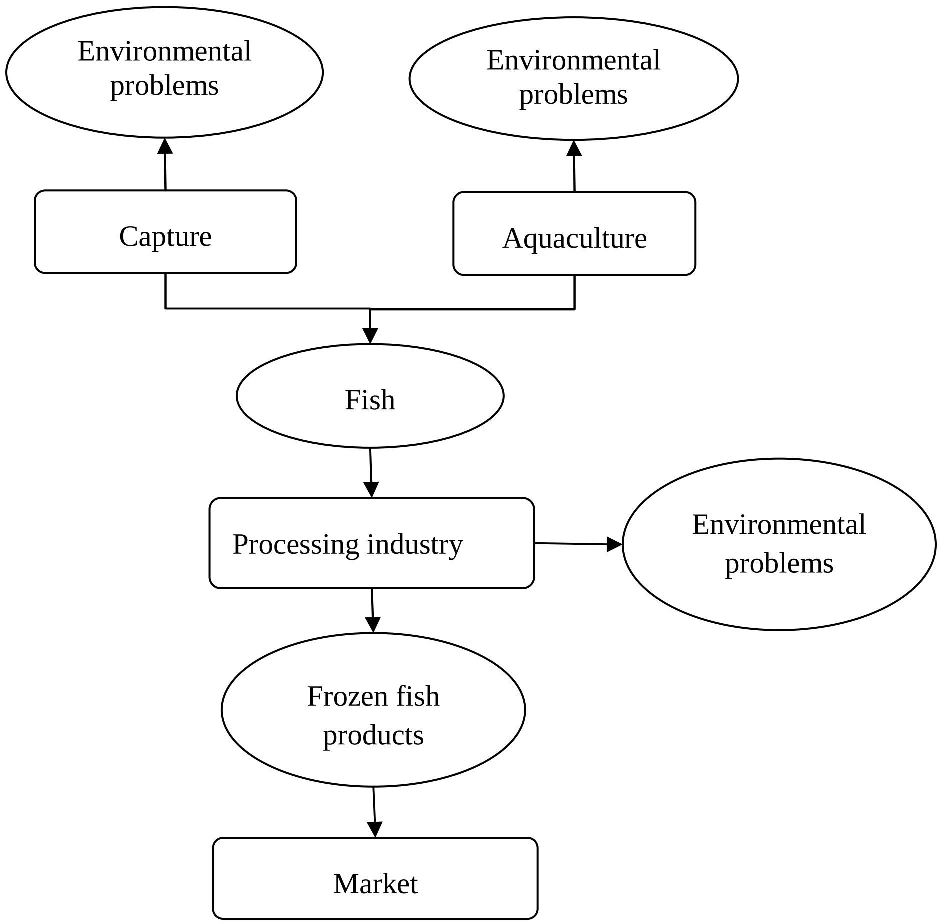

Figure 1.5 Overview of Vietnamese fisheries and related environmental consequences

1.2 The environmental impacts of aquaculture production in Vietnam

Following global trends aquaculture products have made an increasing important contribution to export value and trade in fishery products in Vietnam. However, the rapid growth of the industry has also brought with it a series of new challenges. As documented across Southeast Asia coastal aquaculture can have destructive effects on the natural environment (e.g. Muluk and Bailey 1996; Lebel et al. 2002a; Menasveta 2002; Tokrisna 2004; Tong et al. 2004; Vaiphasa et al. 2007; Bush et al. 2010). According to the Ministry of Fishery (MOFI and WorldBank 2005), the key environmental concerns relating to aquaculture development in Vietnam include: (1) local water pollution from freshwater and marine cage farms; (2) the introduction of new exotic species, with risks of diseases and impacts on aquatic biodiversity; (3) significant loss of mangroves and wetlands from conversion of coastal areas and estuaries to aquaculture (shrimp) farming; (4) the dramatic recent rise in the use of trash fish in marine and freshwater aquaculture.

Pangasius and shrimp aquaculture production are both representative of most if not all of these concerns. The unstructured development of pangasius aquaculture, accompanied by inadequate information and a poor understanding of the ecological conditions of the Mekong Delta, has raised concerns over the actual and *potential* impacts. This situation has drawn international attention to what until now has been regarded a ‘sustainable’ industry (Bush et al. 2009). Despite what until recently can be described as a dearth of scientific data related to pangasius farming, one of the most common voiced environmental concerns of pangasius farming, and one that is gaining increasing attention in policy and practice, is the discharge of wastewater and sludge to rivers and canals (Trai et al. 2006; Anh and Mai 2009b; Bosma et al. 2009; Phan et al. 2009). The main concerns of wastewater and sludge removal from pangasius ponds include water contamination with high organic content, nitrogen, phosphorus and disease spreading.

The environmental impacts of shrimp aquaculture have been documented in more detail than pangasius, due to the age of the industry and the global attention to the destruction of coastal habitats in other parts of the world. The impacts of shrimp production outlined specifically for Vietnam include increased soil salinity, the destruction of mangrove forests and loss of biodiversity in sensitive coastal areas. In provinces which were early adopters of shrimp aquaculture, at least 220,000 ha of mangrove forest was removed over the last 50 years (Tuan et al. 2003). In addition and in part resulting from mangrove deforestation, environmental impacts from shrimp aquaculture also include water pollution, the spread shrimp disease, as well as issues related to human health and social impact (Dierberg and Kiattisimkul 1996; Asche and Khatun 2006; Biao and Kaijin 2007; Nhan et al. 2008; Janeo et al. 2009). Water pollution has in particular been raised as a key area of concern; due to wastewaters containing high biological oxygen demand (BOD), and high nitrogen (N) and phosphorus (P) and pathogen.

In addition to farming systems, fish product processing factories produce waste streams of diverse composition and concentration which are also considered as holding considerable impacts for the environment. Frequently, operations are run on a seasonal basis, and with simultaneous production lines for several different raw materials. The main environmental concerns related to these industries are fourfold:

(1) *Water use and wastewater discharge:* In fish processing, the main environmental issue concerns the use of large amounts of clean water for processing, such as for washing raw material and products, cleaning of machines, containers or flushing the working floor, de-icing, thawing and salt soaking. All the water used is later discharged as wastewater. The quantity and quality of wastewater are highly dependent on the final products, fresh raw species processed and production processes used.

(2) *Solid waste:* Solid waste from all fish and shellfish operations normally consists of flesh, shell, bone, cartilage and viscera. Improper disposal of the solid wastes can result in odor problems. Smaller quantities of wasted packaging material are also released.

(3) *Consumption of energy:* Energy is principally used for machinery, freezing, cold storage, heating, drying, and water pumping. The consumption of energy contributes to increased air pollution and climate change.

(4) *Odor and aesthetic damage:* Odor problems are commonplace due to spoiling debris and offal. Discharge of wastewater containing high levels of solids, spoiled offal, oils and fat from the fish can spoil the natural beauty of surrounding beaches and cause the pollution for the fresh and marine water bodies. Islam and colleagues (2004) identified effluents from fish and shrimp processing industries as a potential source of coastal and marine pollution.

The available studies seem to agree that the largest environmental problems caused by aquaculture and processing industries are associated with water use and water pollution (Jesperson et al. 2000; Mungkung et al. 2006; Jegatheesan et al. 2007) (Figure 1.6). Discharged wastewater from fish ponds and processing industries is high in nitrogen, phosphorus, organic matter content, and therefore has a high chemical oxygen demand (COD) and biological oxygen demand (BOD). In addition, there may be chemical contaminants in the waste streams, pathogens, waste production, noise and odor (Dierberg and Kiattisimkul 1996; Asche and Khatun 2006; Biao and Kaijin 2007; Nhan et al. 2008; Janeo et al. 2009) The most important impacts of the pollution is water pollution, disease spreading (Trai et al. 2006; Phan et al. 2009), and other impacts such as air and soil pollution. And the most important responses to these problems are based on waste minimization and prevention via clean technology, treatment technology and management and governance options.

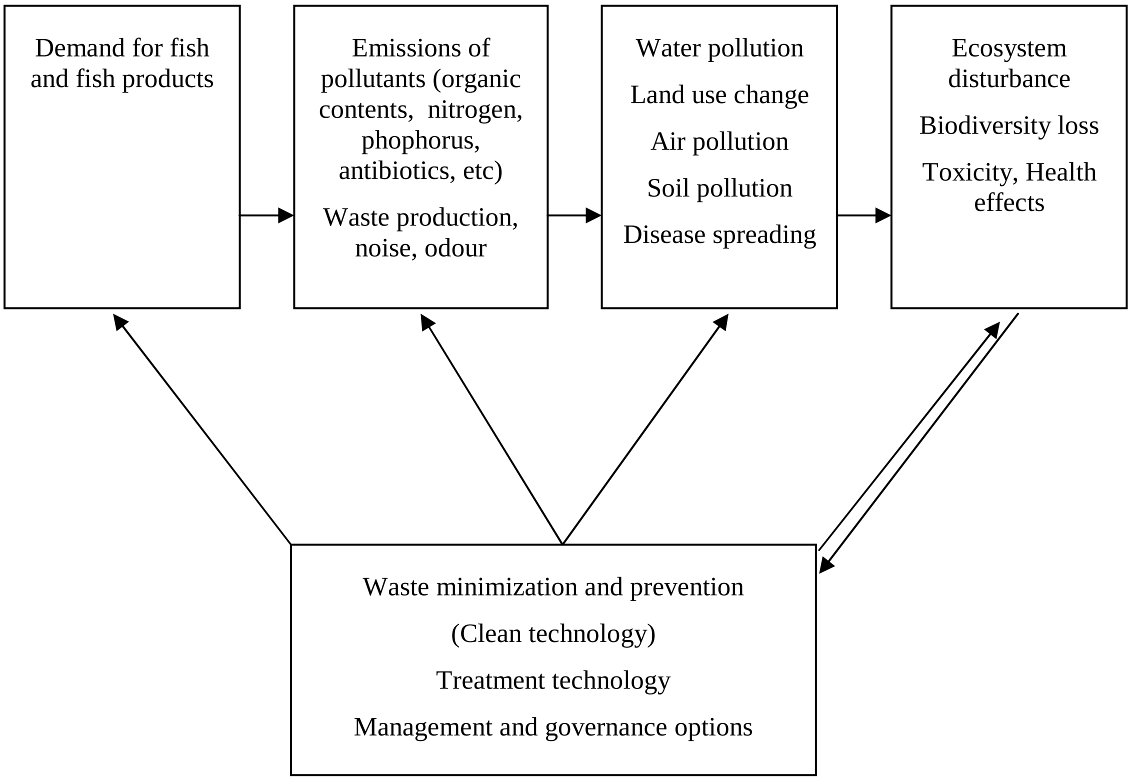

Figure 1.6 Causes, effects and possible solutions of environmental problems due to aquaculture and fish processing industry (D: Driving force; P: Pressure; S: State; I: Impact; R: Response)

1.3 Environmental management of aquaculture production in Vietnam

In response to the environmental impacts of aquaculture in Vietnam, the government and industry alike have invested in environmental management. In addition to the domestic impetus for improved environmental management pressure has also come through international trade relations. Recent events and trends show that significant challenges remain for Vietnam to be competitive in the international market for aquaculture products, which go beyond processing plant quality control and processing technology (Loc 2006; FAO 2007a; 2008). Although food safety is probably the most significant issue influencing aquaculture imports, there is evidence of increasing awareness of the environmental and social issues related to both pangasius and shrimp in importing countries and regions (Oosterveer 2006; Bush and Oosterveer 2007; Vandergeest 2007; Islam 2008; Bush et al. 2009). To meet the growing sustainability expectations of these export markets the fishery sector in Vietnam has made a number of steps towards certification and industry assurance systems that address social and environmental issues.

The Vietnamese fishery and aquaculture sector is large and complex. It is socially and economically important, supporting the livelihoods of several million people in coastal and inland areas. The sector has evolved rapidly and has made a major contribution to the country's economic and social development, as indicated above. However, it is also apparent that the sector is experiencing planning problems and limited enforcement capacity to deal with the challenges it is facing. Currently, very few aquaculture farms in Vietnam implemented technologies to reduce waste or pollution. For instance, only 10% of the farms in the Mekong delta have a sedimentation pond for pre-treatment of wastewater from fish farms (Hoa 2008). In the fish processing industry, it is compulsory to treat wastewater before discharging it into surface waters, but such measures are not always applied by all industries (Viet et al. 2008). Waste prevention and minimization at source is currently not applied at all in farms; and only in a few demonstration cases in the fish processing industry (Mitchell 2006).

Internationally, as well as in Vietnam, it has been recognized that the best approach to environmental management, especially in complex multi-actor industries such as aquaculture, is through consultation with producers and the development of shared management responsibilities through partnerships between producers and government (Glasbergen et al. 2007). This approach can greatly facilitate the introduction of measures required for sustainable aquaculture development and management, and is less dependent on stringent command-and-control policies and enforcement. In Vietnam the transition to inclusive 'governance' arrangements, which contribute to shared collaborative environmental management, is now addressing key issues such as water use and water pollution. Both issues have been publicly debated in the development of a range of national and international environmental and social standards for aquaculture being developed in Vietnam (seeMantingh and Dung 2007; Bush et al. 2009), including the World Wild Fund for Nature (WWF) aquaculture dialogues. The Pangasius Aquaculture Dialogue (PAD) and the Shrimp Aquaculture Dialogue (ShAD) Standards are representative of the shift to international standards that aim to define sustainable production of these species (WWF 2008c). Meanwhile, the Vietnamese governmental policy strongly supports aquaculture development, particularly as the visibility of the sector has increased with growing export earnings (MOFI and WB 2005).

Only a few studies exist on the environmental problems and management approaches of aquaculture and fish processing in Vietnam. Recently, Phan et al (2009) studied the current status of farming practices of pangasius in the Mekong Delta, and Trai and colleagues (2006) conducted a study on water pollution concerns in shrimp farming. Bush and his colleagues (2009) and Mantingh and Dung (2007) also recently reviewed the governing of environmental and social dimensions of pangasius production in Vietnam. However, so far no systematic analysis exists of the causes and effects of environmental pollution caused by shrimp and pangasius production and processing in Vietnam, aiming at identifying environmental management strategies for aquaculture farming and related fish processing. There is a need for such integrated and complex environmental studies of aquaculture production and processing in Vietnam, in order to identify appropriate management strategies to address the important environmental issues at stake.

1.4 Research objectives

This thesis focuses on environmental problems related to aquaculture fisheries in Vietnam. More specifically the research focuses on the environmental impacts of aquaculture and processing of pangasius and shrimp, and the potential options to mitigate these impacts. The main objective of this study is to analyze possibilities for environmental improvement in pangasius and shrimp production in Vietnam and to identify options for technological and management intervention.

The sub-objectives are:

Sub Objective 1: To identify causes and impacts of water pollution in the Mekong Delta, associated with pangasius farming and processing industry; and identify possible options to reduce these problems.

Sub objective 2: To analyze the causes of water pollution, contaminated sediment and spread of disease from intensive black tiger shrimp farming in Vietnam, and identify possible options to reduce these environmental impacts.

Sub- objective3: To apply the idea of eco-agro-industrial clustering for reducing pollution, protecting natural resources and improving the competitiveness of the shrimp production and processing sector in the Mekong delta, Vietnam.

Sub- objective 4: To analyze current attempts—at multiple levels—to govern water pollution in aquaculture in Vietnam, and illuminate how public-private multilevel governance complexes are starting to address conventional state failures in water pollution problems in Vietnam's aquaculture..

1.5 Research methodology

This study combines three analytical approaches: environmental systems analysis, industrial ecology and multi-level governance analysis (Figure 1.8). Environmental systems analysis is applied to analyze the causes of the environmental impacts of aquaculture production, and to identify technical options to reduce these impacts. Environmental systems analysis is an approach to assist decision making in finding solutions to complex environmental problems (Pluimers et al. 2000; Jawjit et al. 2007; Neto et al. 2009). Both grow-out farms and industrial processing plants are considered in this study (Figure 1.7). The results of this analysis can serve as a basis for an analysis of fish-based eco-industrial clusters. This requires a combination of material flow analysis with an analysis of actors and institutions that govern these material flows (Dieu 2003; Mol and Dieu 2006; Nhat 2007). Since aquaculture production is a global issue, the governing and managing of aquaculture cannot be limited to the national government/administration with its conventional management system. Hence, a multi-level governance perspective is needed (Bavinck et al. 2005; Kooiman and M. Bavinck 2008; Zeijl-Rozema et al. 2008), which includes international governance initiatives through certification and standards and local, community-based water management systems, next to conventional—and also new—national environmental governance approaches. The analysis of multi-level governance in this case identifies interactions between various key actors, and their respective interests and influence, at the local, national and international levels.

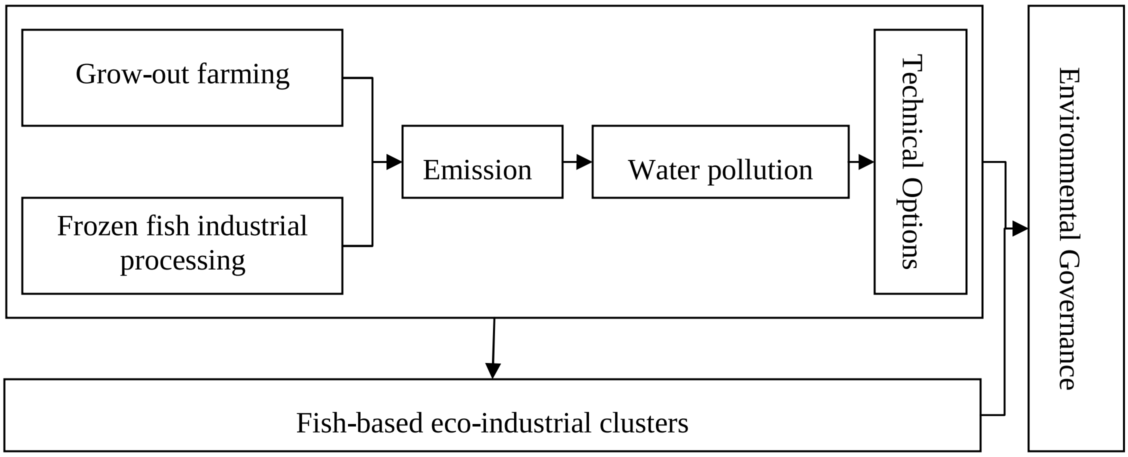

Figure 1.7 Research framework

1.5.1 Environmental system analysis approach

Environmental system analysis (ESA) is often applied to study complex environmental problems, and to evaluate possible solutions for these problems. Early ESA approaches were described by Checkland (1979), Wilson (1984), and Findeisen and Quade (1997). They describe an ESA stepwise approach. Many examples of application of this approach exist. For instance, Pluimers (2001), Jawjit (2006) and Neto (2007) applied these approaches to three completely different economic sectors in order to identify options to reduce the environmental impacts. These three examples consist of a step-wise ESA approach, with many iterations between the steps.

Depending on the specific goals of the study, each environmental system analysis follows its own approach. Pluimers (2001) performed the following steps: (1) defining the problem; (2) defining the objective; (3) model building; (4) systems analysis; (5) selecting the optimal system and (6) conclusions. She carried out a detail analysis of system boundaries and showed why it is essential in systems analyses that the boundaries are defined in a correct way. It provides insight into the causes of the environmental impact of human activities such as, in her case, tomato cultivation and greenhouse horticulture. Jawjit (2006) applied six similar steps. He analyzed the technical reduction potential as well as cost-effectiveness of options aimed to reduce the environmental pressure of the Kraft pulp industry in Thailand. Neto (2007) performed a stepwise ESA of aluminum pressure die casting. Her approach differed from that of Pluimers (2001) and Jawjit (2006) in three ways: (1) in her second step she evaluated and selected existing ESA tools, which was not done explicitly as a step by the other authors; (2) in step 5 – model application – the model was developed to analyze user-defined scenarios for pollution reduction by the industry; (3) in step 6 – evaluation of the methodological approach – she reflected more than others on the applicability of the approach to other industries or sectors. She argued that her user-defined analysis can serve as an example for assisting industrial managers in other industries in environmental management.

This thesis adapts the various approaches to ESA taken by these authors to fit the complexities of the aquaculture sector in Vietnam. The first steps in an environmental system analysis are designed to identify possible solutions to the problem at stake. This requires a solid description of the system, including appropriate definition of system boundaries, system elements and their relations. The last steps include an evaluation and comparison of the proposed options for environmental protection.

In considering the technical options, the thesis takes its lead from the integration of various environmental protection approaches promoted through the field of industrial ecology (Karamanos 1995). Industrial ecology (IE) provides a vision and basis for understanding how improvements can be made to current production processes (Roberts 2004). Options for preventing and reducing these environmental impacts can be identified in two domains: (1) Prevention and minimization of non-product sources onsite (cleaner production), (2) external re-use and recycling of non-product sources (waste exchange) (Mol and Dieu 2006).

1.5.2 Industrial ecology

The idea of industrial ecology has been described in different ways in the literature by Ehrenfeld (1997), Boons and Baas (1997), Krrisnamohan and Herat (2000), and Dieu (2003). All contributions to the concept emphasize the ideas of reduce, reuse, and recycle to advance sustainable industrial systems. Industrial ecology, as a broad framework for thinking and acting in the realm of sustainability, looks at industrial economies by using the metaphor of ecological systems. Through the use of that metaphor industrial ecology intends to improve the design of firms and larger, complex systems; a step towards sustainable development (Ferrão 2007).

Industrial ecology is partly similar to environmental system analyses. It also includes a design component by building a model, often in a specific geographical setting. The methodology of building industrial ecology models starts with analyzing the material and energy flows in industrial systems. These flows can cause emissions, waste and exhaustion of natural resources. Subsequently, various possibilities are identified from reducing these emissions, waste and natural resource use by these industrial systems. A systematic method is used to analyze the various physical-technological options for minimizing waste, following four steps. The first step focuses on the analysis of the material and energy flows that run through the industrial system and partly end up in waste. The second step focuses on the prevention of the waste generation: what is the maximum feasible prevention/reduction of all pollutants being generated at production sites. The identification and design of measures and options of prevention is often related to cleaner production studies. The third step concentrates on identifying, analyzing and designing potential external recovery, recycling and reuses options. To solve the problem of waste that cannot be recovered within the original production units, recycling and reuse in other plants/sectors play a vital role (Wei and Huang 2001). Finally, the remaining waste that needs proper treatment before discharging into the environment is identified. End-of-pipe treatment technologies are usually as an essential element for a (nearly) complete removal of the remaining contaminants. Together, these four steps lead us to a physical-technological model for (close to) zero waste industrial systems.

Based on Mol (1995), Dieu (2003), Khoa (2006), Nhat (2007) and others, we found that such natural science material flow analysis needs to be combined with social science approaches analyzing the actors and institutions that (can) govern these materials flows towards an industrial ecology model. Various authors within the industrial ecology school of thought are working to include such institutional perspectives, using different theories and methodologies (see various contributions in more recent volumes of the *Journal of Industrial Ecology*). Ideas of industrial ecology have also been applied for Vietnam. A methodology for analyzing the possibilities for waste prevention in food processing industry in Vietnam has been elaborated in Dieu (2006) and a practical application of the idea of industrial ecology, combining a physical-technological model for (close to) zero waste industrial ecosystem with an institutional analysis, has been reported for a specific case study on the Tapioca agro-industry by Mol and Dieu (2006).

1.5.3 Fishery governance analysis

The industrialization of shrimp and pangasius aquaculture has created complex commodity chains and networks that cross national boundaries (Lebel et al. 2002b; Bush and Oosterveer 2007; Khoi 2007). There is no single appropriate level of environmental governance. Mechanism to handle cross-scale and up-down linkages along the value chain are required to compliment institutional arrangements targeting individual parts of a system. Conventional hierarchical approaches to institutions may thus have become inadequate. The term governance is widely used nowadays to analyze a variety of institutions, instruments and policy processes, ranging from short term operational management to long term policy development and planning, and from conventional forms of administration to modern forms of participative decision-making processes.

Within fisheries governance and governability Kooiman and colleagues (Kooiman and Bavinck. 2005; Kooiman 2008) have developed a general conceptual framework for analyzing the interaction between governance systems and systems-to-be-governed, focusing on the characteristics of the two as well as the interaction between the two systems. Jentoft and colleagues (2007; 2007) further applied this systems perspective in looking at marine protected areas and coastal governance. Key concepts in these studies are the diversity, complexity, dynamics and vulnerability of the systems-to-be-governed, which demands specific qualities of the governing systems to facilitate interaction between the two systems. Although potentially supporting the basic premises of ESA, such a systems framework does not provide operationalized concepts for specific empirical investigation of the functioning of a nested governance system around aquaculture in Vietnam. Hence, drawing on the multi-level governance literature this thesis develops a combined set of analytical tools for analyzing governability at the three governance levels: international, national and local community.

In analyzing the ability to govern Vietnamese aquaculture towards sustainability we focus on actor networks at different levels, which aim to develop semi-permanent institutions and steering mechanisms for redirecting/redesigning shrimp and pangasius aquaculture and processing in Vietnam. At each level a specific actor network constructs specific institutional rules, principles and steering mechanisms for sustainable aquaculture, while at the same time these levels are highly interdependent and actors are engaged in multiple levels/networks. It is expected that the specific outcome of these networks could lead the aquaculture production in Vietnam to develop sustainably.

1.5.4 Combining approaches from environmental systems analysis, industrial ecology, and governance analysis

This thesis sets out a interdisciplinary analysis performed in five steps, based on Environmental System Analysis approaches from Checkland (1979), Wilson(1984), Findeisen and Quade (1997); Pluimers (2001) and Jawjit (2006), industrial ecology approach, following Mol and Dieu (Mol and Dieu 2006) and governance analysis with a focus on actor networks at different levels (see Figure 1.8).

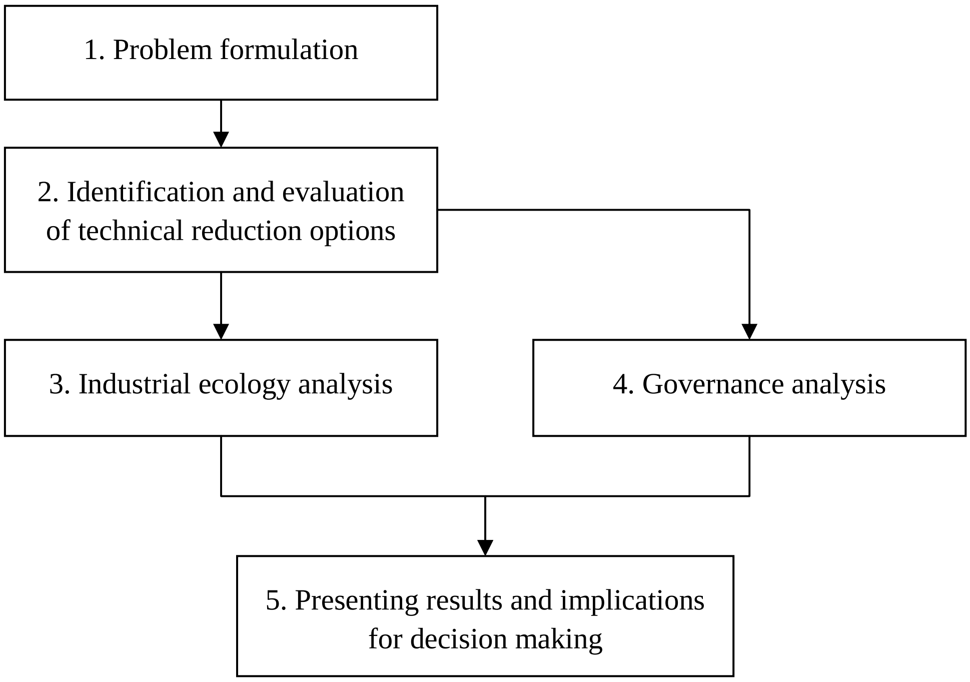

Figure 1.8 Five step approach to analyze technical and management options to increase the sustainability of aquaculture production in Vietnam.

The first two steps focus on defining problem formulation and selecting technical options. Step 1– problem formulation – is a starting point in which problems are clearly defined. It is necessary to ascertain that the right problem is correctly formulated, because failures in the analysis are often caused by solving the wrong problem rather than generating the wrong solution to the right problem (Ackoff 1974). In this thesis, the problem at stake is water use and pollution of the aquaculture production and industrial fish processing in Vietnam. In step 2 the reduction options to water pollution and use problems are proposed in accordance with the defined system boundaries and the objectives. After gaining insight in the system boundaries with the proposed feasible technical reduction options, step 3 is elaborated with developing an eco-agro-industrial cluster and step 4 is the multi-level governance analysis with the interaction between governance systems. Step 5 presents the results and implication for decision making.

In order to test this approach and its suitability for greening aquaculture production in Vietnam using the technological and management model with the integration of the environmental system analysis, industrial ecology and governing analysis, a case study approach is most suited for various reasons. First, our environmental system analysis is based on substance flow analysis and mass balance methods for data collection. Experimental research on specific cases can give complete information on material flow of the existing industrial system. Second, in order to obtain data to develop the technical options, it is helpful to carry out in depth studies on a limited number of cases, rather than superficial ones on a large number of entities. Requirements on understanding the existing production processes, waste handling methods, interactions of different system result in measurements at site and more intensive face-to-face interviews with open, semi-structures questions. Third, a multi-level analysis of interactive governance, which includes the interdependencies between the levels is impossible for large data sets, and requires in-depth participatory analyses of a few interactive stakeholder meetings. Fourth, the influence of geography/location, scale, and technological differences require on site study/observation and do not allow for mathematical modeling, statistical analysis, large sampling or survey questionnaires.

The detailed methodologies and research methods are summarized below and explained in detail in the subsequent studies.

1.6 Structure of thesis

The thesis is divided into six chapters. This chapter has presented an overview of the development of the Vietnamese fishery sector, its environmental impacts, and the current state of environmental management in aquaculture and fish processing in Vietnam. Subsequently, research objectives and overall research methodology have been formulated.

The second chapter focuses on pangasius farming and processing industry in An Giang province. An Giang is a riverhead province of the Tien and Hau rivers. Tien River has a length of about 100 km and Hau River of about 80 km. In addition, there are many canals in this river system. With this advantageous geography, An Giang has developed the current quantity and quality of aquaculture. Pangasius is one of the key export products of An Giang province, accounting for 90% of export turn-over of the province. Over the past years pangasius aquaculture production has increased around 25% annually, and the province currently holds about 70% of the total pangasius production in the Mekong delta (An Giang Fisheries Association, 30/09/2008).[1] According to the provincial plan, in 2009 the area for pangasius aquaculture in An Giang province was 3,000 ha, with an estimated production of 312,000 tons fresh pangasius. This paper focuses on two embedded case studies: pangasius grow-out farms and pangasius frozen fillet processing industries. Information for these two case studies was obtained on the basis of literature, site visits, interviews as well as a limited number of experiments. Four pangasius farms were investigated, including 23 ponds and 8 ‘pens’ (fenced off areas along the banks of large rivers and canals) in My Hoa Hung commune, An Giang province. During these visits, detailed information was collected on farming processes of each sub-system, and on the activities, problems and current solutions. Wastewater and sludge were sampled from five ponds and analyzed in the laboratory on temperature, pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand

[1] Based on personal communication with the An Giang Fisheries Association on the situation of production aquaculture farming of whole country in 9 months of 2008.

(COD), Total Suspended Solids (TSS), Total Nitrogen (TN), Total Phosphorus (TP), Ammonia ($N-NH_3$), Dissolved Oxygen (DO) and coliforms. In addition, three pangasius processing companies were visited. One company had the largest capacity in An Giang Province, while the other two companies had an average processing capacity. Wastewater from these processing industries was sampled and analyzed at the laboratory, focusing on similar parameters as for farming. Options were identified in both pangasius farming and processing to improve the environmental performance.

The third chapter focuses on shrimp farming in Can Gio. Can Gio is an area located in the coastal district southeast of Ho Chi Minh City, Vietnam. It covers 75,740 hectares and is dominated by mangroves, including both salt water and brackish water species. Can Gio has been the site of extensive mangrove rehabilitation after extensive deforestation, first during the military conflicts in the 1960s and 70s, and subsequently through the expansion of shrimp farming. The mangrove forests are regarded as the "green lungs" of Ho Chi Minh City. Because of their ecological importance, the Can Gio mangrove forests have been recognized as an International Biosphere reserve zone by UNESCO. Within the Can Gio area 40% of the shrimp farmers are located in the area of Tam Thon Hiep commune. These farmers conduct intensive and semi-intensive shrimp culture, occupying only 3% of the total shrimp farming area but contributing 8% to shrimp production in Can Gio. Given the push for intensive production in the country it is believed Can Gio, and Tam Thon Hiep commune in particular, provides a representative case to investigate the impacts of intensive black tiger shrimp farming on the environment, from which wider lessons can be learnt for the improved environmental production of shrimp farming in Vietnam. Data was generated through a combination of field visits, experiments, interviews and secondary information. Twenty-two farms were visited to collect information about farming practices and environmental problems, and samples of wastewater and sludge from shrimp ponds were collected and analyzed. A total of 33 water samples were collected from farms in Can Gio, and analyzed on temperature, pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Nitrogen (TN), Total Phosphorus (TP), Ammonia Nitrogen ($N-NH_3$), Dissolved Oxygen (DO) and coliforms. Three samples of sludge were also collected and analyzed as dry matter, measuring TN and TP. Subsequently options were identified for improving the environmental performance of black tiger shrimp intensive and semi-intensive production.

The fourth chapter deals with shrimp processing in Soc Trang province, using an industrial ecology perspective. Soc Trang is one of the Vietnamese provinces with large production of shrimp in terms of farming and processing industries (MARD 2009a). Soc Trang province is used as a case to study the question how to move shrimp production industries into more sustainable direction, using the perspective of industrial ecology and eco-industrial clustering. One industry of frozen shrimp processing has been selected for a material flow analysis, subsequent technological option identification and an analysis of the economic and policy actors and institutions governing shrimp processing. Data were collected through observation, site visits, secondary literature and interviews with workers, industry staff, chain organizations and state authorities at various levels. Based on this the paper designs a model of an eco-industrial cluster, where environmental impacts have been minimized. In addition the most relevant actors and institutions have been analyzed for moving such a model into the reality of Soc Trang province.

The fifth and last empirical chapter analyses and assesses the role and impact of stakeholder meetings at various levels in governing shrimp and pangasius production towards more ecologically sound production systems. Three types of stakeholder meetings have been analyzed in detail, also through participatory observation and data collection. First, at the international level, different stakeholder dialogues have been organized by WWF since 2007 in setting PAD and ShAD standards. Discussions and meetings carried out as part of setting the PAD standards and on those of the ShAD dialogue were attended and observed. In these meetings, different stakeholders from local to transnational participated. Second, at the national level, a key stakeholder meeting organized by the An Giang People's Committee in December 2008 was attended. In this meeting different provincial governments participated (An Giang, Dong Thap, Can Tho, Kien Giang, Soc Trang provinces) as well as fish farmers, processors, suppliers, scientists and environmental experts. They discussed the technical and management approaches for environmental improvements in aquaculture in the Mekong delta. This meeting is analyzed against wider attempts of national governments to improve the environmental performance of pangasius and shrimp aquaculture. Finally, at the local level, community-based approaches to governing pangasius aquaculture is based on several visits and meetings with the communities at Hoa Lac village – Phu Tan district – An Giang province in 2009. The focus of this analysis is on community groups and cooperatives for pangasius aquaculture. Other community shrimp farming cooperatives were also visited in Soc Trang and Ben Tre provinces of the Mekong Delta. Together and interdependently, these three cases provide us a better understanding of structure, successes and failures of multi-level governance practices in Vietnamese aquaculture.

Chapter 6, the final chapter, comprises the conclusions and discussions. The overall water pollution, reduction options and governance systems from shrimp and pangasius production are compared. In addition, methodological issues, and the strengths and limitations of the current study are discussed. Finally, recommendations for environmental management and future studies are presented.

This study provides not only a better understanding of pangasius and shrimp aquaculture and processing in Vietnam, their technical reduction options for reducing water pollution problems, and their complex management system. It also provides insight in how to combine system analysis, technology assessment, industrial ecology perspectives, and governance analysis in analyzing complex problems from different angles. As such it forms an attempt at interdisciplinary analysis of a complex environmental problem.

Chapter 2 Water pollution by pangasius production in the Mekong delta – Vietnam: Causes and options for control[2]

Abstract

We analyze water pollution caused by the production of frozen fillets of *Pangasianodon hypopthalmus,* including both pangasius farming and the processing industries in the Mekong Delta, Vietnam. The results show that one tonne of frozen fillets releases 740 kg BOD, 1020 kg COD, 2050 kg TSS, 106 kg Nitrogen and 27 kg Phosphorus. Wastewater from fish ponds contributes 60-90% of these emissions. Sludge from fish ponds and wastewater from processing facilities have relatively high contents of pollutants, but because of their relatively small volumes, these waste streams contribute only 3 to 27% of total emissions. Overall, the combined waste emissions from pangasius production accounts for less than 1% of total TSS, N and P loads in the Mekong Delta. Despite the relatively low contribution of pangasius production and processing to water pollution, further reductions are possible through more efficient use of inputs and low cost treatment and reuse of effluent streams. The use of cleaner production technologies; and the development of wastewater treatment plants could be applied to a small number of large farms and processing facilities to reduce water pollution in pangasius processing. Low cost options for small-scale farms include the optimization of the discharge design for the reuse of wastewater.

Key works: Pangasius, farming, processing, wastewater

2.1 Introduction

Pangasianodon hypopthalmus (pangasius) production has grown at an average of 35% per year since 2003 (Figure 2.1), reaching 1.13 million tons in 2008 (MARD 2009a), to meet consumer demand across a number of markets in Europe, North America, China Oceania and the Middle East (Hau 2008). The European Union, with its strict food safety and quality standards, is an important export market of pangasius from Vietnam. About 40% of exported pangasius of Vietnam is for the European market (MARD 2009b). The export orientation of the industry has meant the export fish processing industries in Vietnam are equipped with modern technology and are increasingly

[2] This chapter contains article which has been published online as Pham Thi Anh, Carolien Kroeze, Simon R. Bush, Arthur P. J. Mol (2010), Water Pollution by pangasius production in The Mekong Delta – Vietnam: Causes and Options for Control, Journal of Aquaculture Research, DOI: 10.1111/j.1365-2109.2010.02578.x

regulated by international food safety and quality standards such as ISO, HACCP, and HALAL. In recent years the environmental sustainability of the Vietnamese pangasius industry has been questioned by domestic and international regulators and market actors. A number of state and private standards have been developed to regulate the environmental performance of pangasius production (Bush et al. 2009). However, despite claims that the industry is unsustainable, there remains relatively little evidence of the nature or extent of the impact the industry has on the environment of the Mekong Delta.

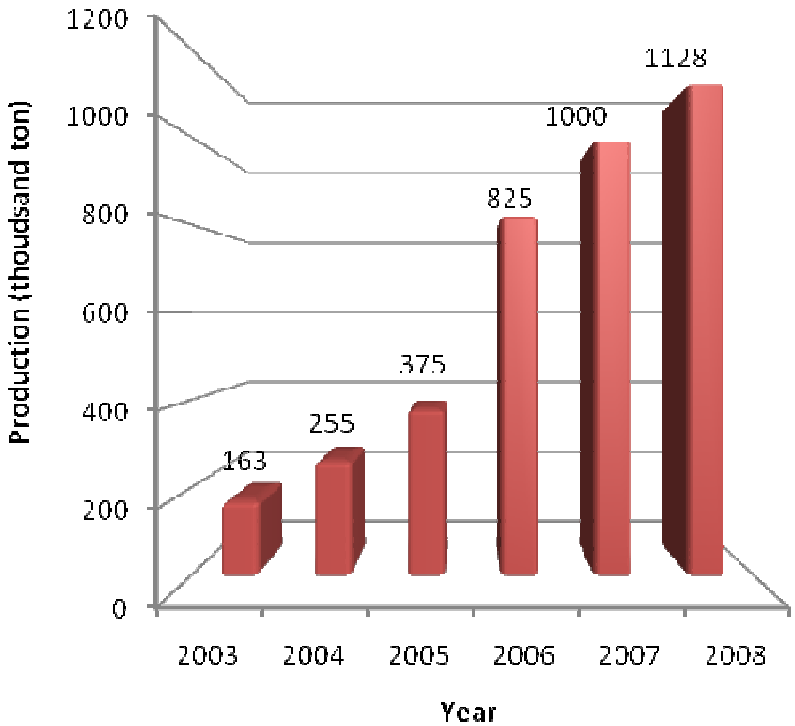

Figure 2.1 Pangasius production in the Mekong delta by farming type (Sources: (Dung 2008) and (MARD 2009a)).

Despite the lack of evidence, there is a growing awareness of the *potential* environmental problems of pangasius production, especially in terms of water pollution (e.g. (Mantingh and Dung 2007); (WWF 2009a), drug and chemical use (Sarter et al. 2007), adverse affects of high feed conversion ratios on wild stocks (APFIC 2005), farm health management and disease control (Chinh 2005; Sinh 2007), and the carrying capacities of terrestrial and inland water areas (Braak 2007). Socioeconomic impacts have also been speculated over, including the impacts of rapid growth on rural communities, increasing land prices, the availability of credit and technology availability, and the effects of political and economic dynamics in global trade on local livelihoods (Sinh 2007);(Bush et al. 2009); (Loc et al. 2007)). Mantingh and Dung (2007) identified priority issues, based on risks identified by key-informants and literature. Their priorities are (in order of importance): (1) to support an environmental impact assessment of the pangasius industry, (2) research support for the development of more sustainable techniques and systems which focus on wastewater treatment and disease prevention and treatment; (3) the stimulation of the vertical integration through either public private partnerships or stimulation of business to business (B2B) initiatives; (4) to support the pangasius sector in the development of strategic planning. However, these suggestions are not based on empirical data since a comprehensive quantitative analysis of the environmental impacts of pangasius production is not available.

In Vietnam, pangasius farms are typically 0.5 – 1 hectare in size, and located close to rivers and scattered over large regions. Pangasius is farmed either in floating wooden cages in rivers, in ponds with water supply or in pens. Ponds are characterized by semi-closed water flows, containing feed inputs and thereby making them considerably more efficient and economical than cages. As a result, there has been an 80% decrease in the number of cages since 2003 and a consequent increase in the area of pond culture up to 98%.

One of the most commonly voiced environmental concerns of pangasius farming is the discharge of wastewater and sludge from ponds, ranging in size from 0.2 to 1 ha, into to rivers and canals. These ponds have become the most common method of farming, currently making up 98% of all farming (the rest is made of open pen and cage systems), as the industry has increasingly searched for higher economic efficiencies in an increasingly diversified set of global markets (RIA 2 2008). In addition, the pangasius processing industry, concentrated in the Mekong Delta close to pangasius farming areas, is also widely regarded as a major source of wastewater with high organic matter content. The specific impact of these pollutants into the Mekong Delta, agricultural activities and the health of local people are not well understood. Nevertheless, water use and water pollution are two of seven key issues that have publically debated in the development of environmental and social standards facilitated by the World Wide Fund for Nature (WWF) pangasius Aquaculture Dialogue, to be finalized during 2010. These standards aim to define sustainable production through the use of low cost technological interventions with which it is anticipated 20% of all farmers will be able to comply (WWF 2009a).

The available studies seem to agree that the largest environmental problems caused by fish farms and fish processing industries are associated with water use and water pollution. However, the extent to which pangasius production is a major source of water pollution in Vietnam is as yet not clear. Moreover, an environmental assessment of pangasius production in Vietnam that includes both the pangasius farming as well as industrial processing does not exist. Furthermore, an inventory of options to reduce water pollution problems for the pangasius production sector is also not yet available.

To identify the environmental impacts of fish production and processing we can draw upon industries that have been studied more extensively. For instance, Islam et al. (2004) identified effluents from fish and shrimp processing as a potential source of coastal and marine pollution. Using existing data, they analyzed the global production and discharge of waste from processing plants and discussed the available options for waste treatment and management. Several other studies focus on technological approaches for wastewater treatment, and cleaner production. Thrane et al. (2009) reported significant environmental improvements in selected companies producing pickled herring and canned mackerel – especially concerning reduced water consumption, wastewater production, and improved use of fish 'waste' for valuable by-products. In these studies, a reduction of energy use is not considered, nor is a change in packaging type, or the environmental impacts in other stages of the products' life cycles. Casani (2006) evaluated the microbiological safety issues associated with water recycling during the production of shrimps (*Pandalus borealis*) in brine, and indicates how hazards may be effectively controlled using a Hazard Analysis and Critical Control Points (HACCP) approach. Following these procedures, water recovered from peeling during shrimp processing and treated by means of reverse osmosis could be recycled within the same unit of operation. Barros et al. (2009) indentified potential techniques from the literature and from their experience in the seafood sector. Best Available Technologies (BATs) were then assessed for possible implementation in a mussel canning facility. In this paper we follow a similar line of argumentation, by analyzing the source and relative contribution of water pollution from pangasius production and processing and then focus on the potential of existing technological solutions to mitigate any potential impact.

This study, therefore, analyses water pollution problems arising from the pangasisus farming and processing industry, and identifies technical reduction options for these problems. We do not intend to perform a complete environmental assessment. Rather, we limit our analysis to water pollution in the Mekong Delta. In doing so, our study is the first to systematically analyze the impact of pangasius production on water quality in the Mekong delta. The specific objectives of the research are:

- To identify causes and impacts of water pollution in the Mekong Delta, associated with pangasius farming and processing industry;
- To identify possible options to reduce the water pollution caused by pangasius farming and processing industry.

Addressing these questions, the paper is divided into 5 sections. Section 2 deals with methods applied during the research. Section 3 and 4 deal with the analysis of water pollution caused by pangasius farming pangasius processing industry in turn. In directly addressing the research questions above, both of these sections first present the empirical results of the water quality systems analysis and second presents an inventory of possible solutions, discussion their feasibility in the context of Vietnam. The final section presents outlines the conclusions of the research.

2.2 Materials and methods

This paper uses an Environmental System Analysis (ESA) approach, defined as a practical strategy for carrying out decision-oriented multidisciplinary research, using a broad range of analytical tools (Quade and Miser 1997). A key benefit of the ESA approach is that it aids decision makers faced with complex problems to make choices under uncertainty. More specifically the study adopted a partial environmental systems analysis, following Quade and Miser (1997), Pluimers (2001), Jawjit (2006) and Neto (2008), by defining a system's boundaries, identifying environmental indicators and exploring solutions for mitigating impacts. The boundary is defined by identifying and describing the relationship between inputs and outputs to the system in question (Findeisen W and Quade E.S 1997). For pangasius this step requires identifying the most important sources of water pollution associated with farming and processing. Second, environmental indicators are selected and used to assess the extent and nature of the environmental problem. Finally, we will identify reduction options to the water pollution problems proposed in accordance with the defined system boundaries and the objectives.

For this study we distinguish two systems with the pangasius production industry: pangasius grow-out farming and pangasius frozen fillet processing because of their significance in development and scale. Hatchery and nursery farming are not included in this study (Figure 2.2).

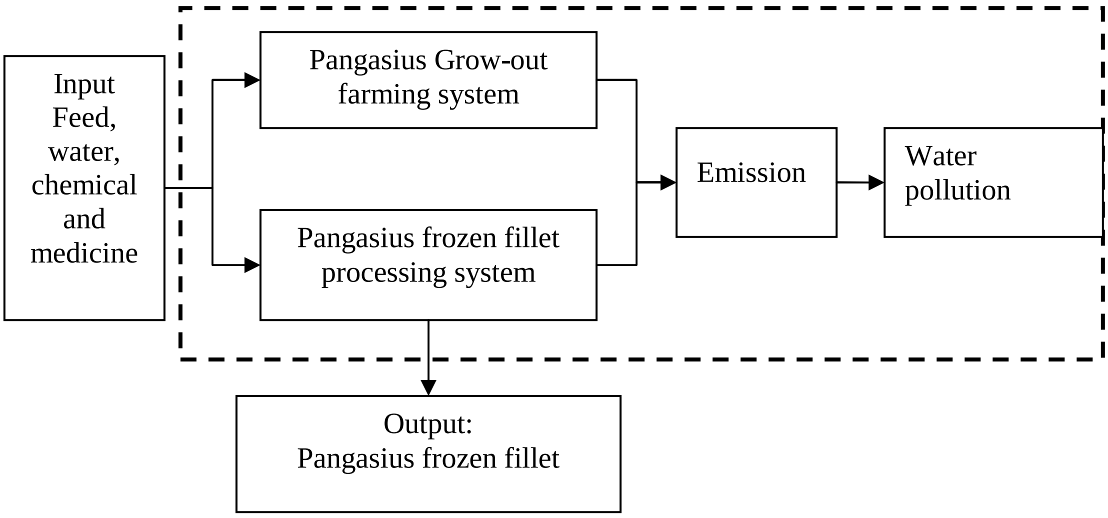

Figure 2.2 Schematic overview of the pangasius production, including 2 systems: The pangasius grow-out farming and pangasius frozen fillet processing system. Dashed line indicates boundaries of the system studies here. See figure 4 for details.

Information for these two sub-systems was obtained on the basis of literature, site visits as well as a limited number of water and sediment quality experiments. Four pangasius farms were visited with a total of 23 ponds in My Hoa Hung commune, An Giang province – an area considered typical of larger, commercial scale farming operations (Schut 2008). During these visits, detail information was collected through observation and interviews with farmers and technicians on the production processes and activities of each sub-system, their associated wastewater problems and the efficiency of current solutions for mitigating pollutants. Additionally, wastewater and sludge was sampled from five ponds during multiple visits to farms, at various moments throughout the production cycle. Because farmers exchange water every day the diurnal variation in the water quality is larger than the variation in the production cycle. Care was therefore taken to sample between 3-6 hours after the water in the pond was exchanged. Sludge samples were analyzed in three settling columns, each with 10 sampling valves. The quality of the water content and settling capacity of the pond sludge were analyzed. The water quality parameters used in the analysis were BOD, COD, TSS, Total Nitrogen, Total phosphorus, and N-NH3. More parameters as temperature, pH and Coli-forms were additionally measured in *situ* wastewater. All samples were analyzed according to the Standard Methods of Water Sampling and Analyzing (APHA 2005).

Three pangasius processing companies were also surveyed. One of these companies has the largest processing capacity in An Giang Province at 100 ton per day, while the other two companies are representatives of more average processing plants, with a capacity of 47 ton per day and 50 ton per day respectively. Wastewater from these processing industries was sampled and analyzed following the same procedure as for water from production ponds. The measurement results have been reported to the Ministry of Agriculture and Rural Development in an internal report (Anh and Mai 2009b). This report also includes the results of a pilot study in which wastewater from the pangasius farm with a sedimentation pond was used to irrigate and fertilize rice field in order to minimize water pollution. The following presents a synthesis and interpretation of the results.

2.3 Results: Pangasius farming

2.3.1 System definition

Our analysis focuses on pangasius production in ponds with particular attention to the preparation, cultivation, and harvesting phases in the production cycle (Figure 2.3). In the preparation phase (I), the pond is treated by draining the water, cleaning algae and grass from the bottom and surrounding embankment, dredging sludge and lining the bottom with $Ca(OH)_2$ (10-15kg/100 m^2) to adjust the pH and to disinfect the pathogens. After this the pond is left empty for 2 to 3 days in order to further sterilize through sunlight before being filled again with water directly from the nearest rivers or canals. The ponds sampled in My Hao Hung are a mix of 'inland ponds', located adjacent to river banks, with a surface of less than 5,000 m^2 and a depth of about 2 to 3 meters, and 'island ponds', located on riverside wetland areas or in river banks, are generally larger than 5,000 m^2 and up to 5 meters deep (Mantingh and Dung 2007).

In the cultivation phase (II), the pond is commonly stocked at a density of about 20-40 fingerlings/m^2 (Hao 2007). Feeding and Nursing follows, and is the most high risk and most expensive step in pangasius farming (Hung and Huy 2006). Feeding costs therefore largely determine the price of the fish (Phuong et al. 2007). Two main types of fish feed exist: industrial pellet feed and home-made feed. Using home-made feed can cause more sludge and water pollution because it is less efficient, requiring larger quantities than pellet feed to reach the same growth rate of the fish. This is in part the result of difference in moisture content between the two feeds. The Feed Conversion Ratio (FCR) ranges between 2.0 and 3.5 if the farmer uses home-made feed or 1.5 and 1.7 for industrial pellet feed (Hung and Huy 2006).

If the fish exhibit symptoms of disease, the farmers that we visited will apply antibiotics following the instructions of a veterinarian. There are nearly 400 products, including a wide variety of antibiotic, vitamins, and pro-biotics available on the market for pangasius farming alone (Chinh 2005). Most widely used are vitamins and pro-biotic, although it is not always clear what exactly these pro-biotic contain (Mantingh and Dung 2007). There is also a high degree of uncertainty around what impacts these drugs and chemicals have on the surrounding environment. For export products there are often checks on antibiotic resistances in the fish products by authorities or clients.

The farmers reported that the high daily water exchange increases the growth rate of the fish and the quality of the meat. More specifically high water throughput is believed to increase the proportion of white meat, which is considered the highest quality given it s sold to higher value European and US markets (Khoi 2007). Feed also impacts water pollution because the surplus feed contributes a large concomitant emission to the water phase. The amount of surplus nutrient that is discharged from the pond differs depending on the phase of the grow-out cycle. The percentage of daily water exchange is about 20% during the first three to four months and 40% during the last two to three months (Anh and Mai 2009b). In addition, the sediment sludge from the bottom of the pond is also contributed to by redundant feed through faeces matter, algae, and soil. In the farms visited, the sludge is discharged from the ponds approximately once in every two months when the sediment level in the bottom of the pond is about 20 cm thick with a part of water.

The harvesting phase (III) begins after six months of the grow-out cycle, when individual fish weight reaches 1 to 1.2 kg. After harvesting, the pond is once again emptied and a large amount of wastewater and sludge are discharged to the surrounding environment. The emptied pond then repeats the preparation phase.

Based on this description we distinguish between several sub-systems in pangasius farming (see Figure 2.3). Pond treatment, first water input, feeding/nursing, water exchange, sludge discharge and pond emptying are considered as important in influencing environmental impacts. Within these sub-systems, four main activities that are particularly critical for water quality: (1) Chemicals and drugs use, (2) Feed use, (3) Water use and discharge, and (4) Sediment discharge. We realize that pangasius farming is also contributing to a number of other environmental problems. Pond construction is a one-off event and after harvesting the pond will be treated and used again for the next crop, therefore it is not included in this study. Breeding stock and harvesting activities, as well as the production of chemicals and medicine, fertilizer, pangasius larvae, the production of pellet feed and electricity, are also not included in the system. The system includes the use of these inputs to calculate the pollutants and production of waste in the pangasius farming process.

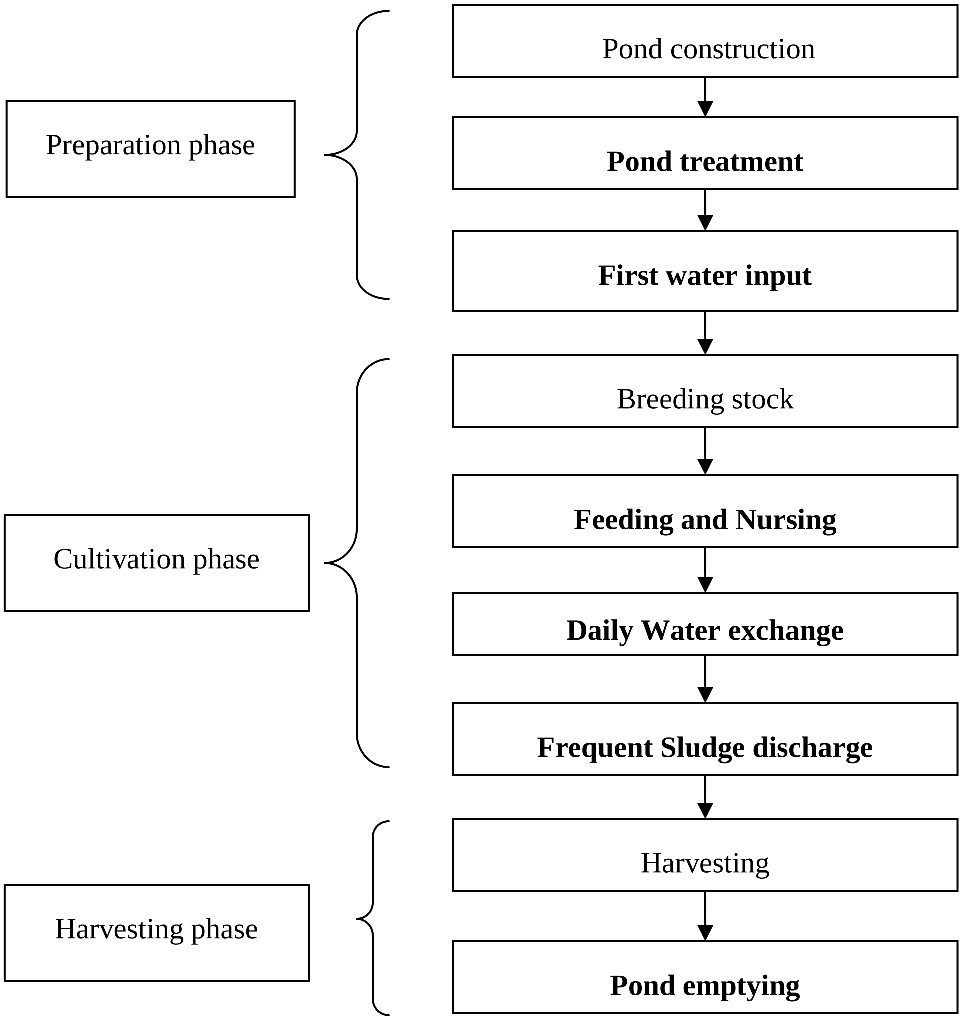

Figure 2.3 Schematic overview of pangasius production in ponds; Bold: included in this study

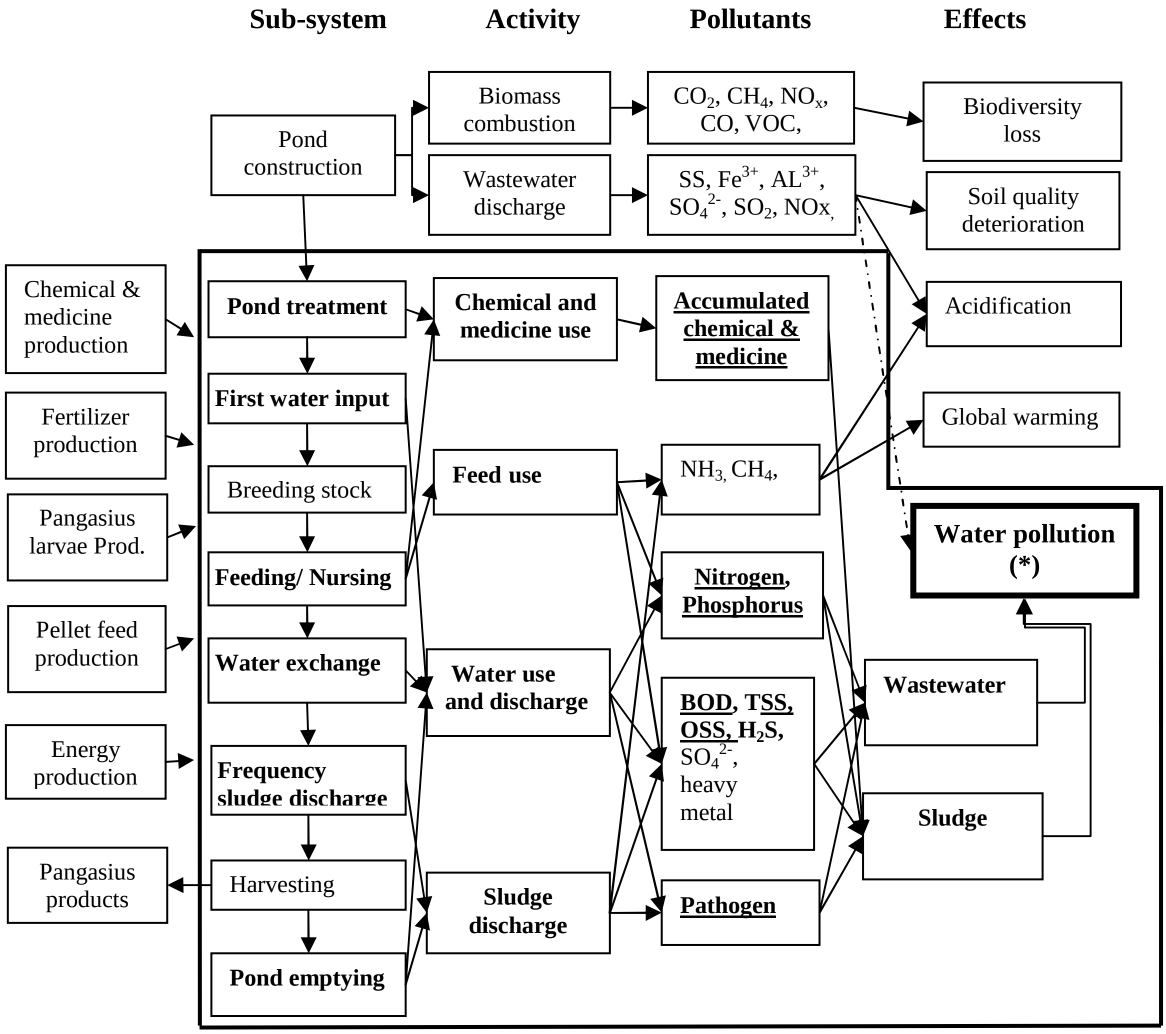

Figure 2.4 Schematic overview of pangasius farming and its environmental impacts. The bold line indicates the system boundary; bold system elements and the underlined substances are included in the analysis. (*) Including eutrophication and toxicity problems

2.3.2 Assessment of water pollution

Water pollutants from pangasius farming originate from four main activities as mentioned above. The pollutants enter the river from either wastewater or sludge. In this study, we refer to wastewater as the water discharged through water exchange and emptying the pond at the end of the grow-cycle. We recognize that sludge also has high moisture content; however we exclude this from the analysis. The environmental indicators used to assess these pollution sources are summarized in Table 2.1.

Table 2.1 Indicators for water pollution by pangasius farming, as used in this study.

Environmental issues	Indicator number	Indicators	Unit
1. Wastewater	1.1	Total volume of water use	m^3/ha/y
	1.2	Total volume of wastewater	m^3/ha/y
	1.3	BOD	mg/l
	1.4	COD	mg/l
	1.5	TSS	mg/l
	1.6	Total Nitrogen	mg/l
	1.7	Total Phosphorus	mg/l
	1.8	$N-NH_3$	mg/l
	1.9	$N-NO_2$	mg/l
	1.10	H_2S	mg/l
	1.11	DO	mg/l
	1.12	Total Coli-forms (Pathogen)	MNP/100ml
2. Sludge	2.1	Volume of sludge	m^3/ha/y
	2.2	BOD	mg/l
	2.3	COD	mg/l
	2.4	TSS	mg/l
	2.5	Total Nitrogen	mg/l
	2.6	Total phosphorus	mg/l
	2.7	$N-NH_3$	mg/l

To assess the indicators for pollution from wastewater, a water balance of pangasius ponds is used. Input water includes water supplied at the start of a growing cycle and supplemented water pumped during the cycle. Wastewater includes the water that is exchanged during the cycle and water discharged after harvesting. Rainfall and evaporation were not taken into account, because both can be considered negligible when 30% of the pond water is exchanged on a daily basis regardless of weather conditions. It should also be noted that water use is relatively high in pangasius farming compared to other aquaculture production systems. For instance, in shrimp production in Vietnam farmers exchange 15% of the pond water every 10 days (Anh et al. 2010a).

2.3.2.1 Water pollution by wastewater

According to the description in the farming process, the following box outlines the parameters of the typical intensive fish pond for the calculation of the volume of water use (Indicator 1.1; see Box 2.1 for parameters used for calculation). Ignoring the slope between the surface and the bottom of the pond, as well as the differences of width and length of the pond, the volume of initially supplied water is 40,000 m^3 and water exchange occurs at a rate of approximately 2,160,000 m^3/ha/crop (assuming 180 days per crop). This gives a total water supply for the whole crop of about 2,200,000 m^3/ha.

Box 2.1 Typical characteristics of a pangasius farming pond of 1 hectare

- Area of the pond:10,000 m^2
- The water level in the pond: 4 m
- The daily water exchanged during the cultivation: 30% of pond water
- Density at stocking: 30 pangasius fish/m^2
- Average farming period: 6 months (180 days/crop)
- Average mortality: 20%

The volume of wastewater (Indicator 1.2.) is almost equal to the amount of water use, about 2.200.000 m^3/ha/crop. Of this amount, an estimated 8,000 m^3/ha/crop is sludge (see indicator 2.1 – volume of sludge), and an estimated 2,192,000 m^3/ha/crop is wastewater from exchange and after harvesting.

The values of indicators 1.3 to 1.12 (BOD, COD, TSS, Total Nitrogen, Total Phosphorus, N-NH_3, N-NO_2^-, H_2S, DO, Coli-forms) are partly based on literature, and partly on experimental research for this study (Anh and Mai 2009b). We combined our results with the results from Giang (2008) who sampled between farms that are infected and those that are uninfected by common pangasius diseases. He studied water quality in 64 intensive pangasius farming ponds in the six main farming areas in An Giang province from March 2005 to December 2006 with a total of 139 samples, comparing uninfected and infected farms, and analyzing water samples according to Standard Methods of Water Sampling and Analyzing (APHA 2005). These results were complemented with data from Tuan (2007) and Dan (2008). The resulting compilation of wastewater characteristics is presented in Table 2.2, which compares the average (and range in) pollutant levels of wastewater that is discharged to rivers, to the standards for river water quality (TCVN). If the pollution content of the wastewater of a farm does not exceed those standards, we consider that farm as non-polluting.

Table 2.2 Selected characteristics of the wastewater in pangasius farming (wastewater), compared with Vietnamese standards for surface water quality (TCVN 5942 - 1995)

Parameters	**Unit**	**Average (Min – Max)**	**TCVN 5942 -1995 (*)**
Temperature	^{0}C	30.7 (27.5 – 34)	
pH		7.8 (6.7 – 9.2)	5.5 – 9.0
BOD	mg/l	22 (10 – 78)	< 25
COD	mg/l	27 (23 – 196)	<35
TSS	mg/l	61.0 (3.5 – 274.2)	< 80
Total Nitrogen	mg/l	4.0 (3.2 – 6.0)	
Total Phosphorus	mg/l	1 (0.4 – 2.21)	
$N\text{-}NH_3$	mg/l	1.4 (0.05 – 4.4)	< 1
$N\text{- }NO_2^-$	mg/l	0.158 (0.01 – 1.36)	< 0.05
H_2S	mg/l	0.035 (0.001 – 0.64)	
DO	mg/l	5.73 (0.44 – 15.90)	≥ 2
Coli-forms	MNP/100ml	$317.32 x 10^4$ ($63.2 x 10^4$ – $640 x 10^4$)	10^4

Source: compilation of results by Giang et al. (2008), Tuan (2007), Dan et al. (2008) and this study.
(*): TCVN 5942 – 1995: Vietnamese standards for surface water quality

The average values of water quality parameters generally do not exceed the Vietnamese surface water quality standards. However, when we consider the variation among ponds (as indicated by the minimum-maximum range in Table 2) we conclude that there are probably many individual ponds where the standards are exceeded. For instance, the average $N\text{-}NH_3$ concentration (1.4 mg/l) is close to the standard. However, Giang (2008) found that in 30% of the studied ponds $N\text{-}NH_3$ concentrations exceeded 2 mg/l. When $N\text{-}NH_3$ concentrations exceed 2 mg/l (Boyd and Craig S. Tucker 1998) the water is rich in nitrogen. The TSS loads also show a large variation among ponds, and in addition vary with season. In the rainy season the suspended solids in the rivers are higher and enter ponds via daily water exchange. For a number of indicators, the maximum values measured exceed the standards by a factor of 3 to 5 (e.g. BOD, COD, TSS, $N\text{-}NH_3$). For some indicators the values do not exceed the standards to a large extent, but given the large volume of wastewater they indicate a large pollutant loading in surrounding rivers (Dan et al. 2008). Similarly, total coli-forms in the wastewater samples are very high if compared to the standard.

On the other hand, Table 2.2 indicates that there are also individual ponds that meet the water quality standards, since the lower end of the range of concentrations for most pollutants is well below these standards. This indicates that not all pangasius production is currently causing water pollution. We did not investigate the reasons why some farms perform better than others. However, it may be related to differences in farming practice or the amount of water used, causing a diluting effect.

2.3.2.2 Water pollution by sludge

Sludge settles at the bottom of pond and is pumped out regularly every two months during the grow-out phase and after harvesting. The calculated volume of sludge (Indicator 2.1) is discharged to the environment is about 8,000 m^3/ha per crop (Anh et al. 2009). There is not much available data on sludge quality – defined by COD, BOD, TSS, Total Nitrogen, Total Phosphorus, $N\text{-}NH_3$ (Indicators 2.2 - 2.5). In our limited analysis of sludge (in 3 farms), we found that the COD was 1769 mg/l, BOD was 1061 mg/l, TSS was 6497 mg/l, VSS was 1034 mg/l, $N\text{-}NH_3$ was 12.8 mg/l, Total Nitrogen was 45.6 and Total phosphorus was 22.7 mg/l. These values all exceed the standards listed in Table 2 considerably. However, sludge is only causing problems when it is discharged to surface waters and, as discussed below, this is not always the case.

2.3.2.3 Pollution by unit of production

Based on the results presented in Table 2.2, we can estimate the pollution per ton of fresh fish and for the total Mekong Delta (Table 2.3; Figure 2.5). This estimate assumes that our average per pond is representative for the total pangasius production in the Mekong delta, which we feel is realistic given 90% of pangasius is produced in ponds. Wastewater is the largest source of water pollution in the Mekong delta (responsible for 60-90% of the loading) because of the large volumes compared to the sludge. The concentrations of pollutants in sludge are much higher, but lower in volume. Nevertheless, the discharge of sludge can cause local pollution problems when it is discharged to surface waters.

Table 2.3 Pollution caused by pangasius farming in the Mekong delta

		Measured(1)		Per ton of fresh fish(2)		Total for Mekong delta(3)	
No	Indicator	Value	Unit	value	Unit	Value	Unit
I	Wastewater(4)						
1.1	Water use	2,200,000	m3/ha/y	9166.7	m3/ton	10,340,000,000	m3/y
1.2	Wastewater production	2,192,000	m3/ha/y	9133.3	m3/ton	10,302,400,000	m3/y
1.3	BOD	22	mg/l	200.9	kg/ton	226,652,800	kg/y
1.4	COD	27	mg/l	246.6	kg/ton	278,164,800	kg/y
1.5	TSS	61	mg/l	557.1	kg/ton	628,446,400	kg/y
1.6	Total N	4	mg/l	36.5	kg/ton	41,209,600	kg/y
1.7	Total P	1	mg/l	9.1	kg/ton	10,302,400	kg/y
1.8	N-NH_3	1.4	mg/l	12.8	kg/ton	14,423,360	kg/y
II	Sludge						
2.1	Sludge	8,000	m3/ha/y	33.3	m3/ton	37,600,000	m3
2.2	BOD	1,061	mg/l	35.4	kg/ton	39,893,600	kg
2.3	COD	1,769	mg/l	59.0	kg/ton	66,514,400	kg
2.4	TSS	6,497	mg/l	216.6	kg/ton	244,287,200	kg
2.5	Total N	45.6	mg/l	1.5	kg/ton	1,714,560	kg
2.6	Total P	22.7	mg/l	0.8	kg/ton	853,520	kg
2.7	N-NH_3	12.8	mg/l	0.4	kg/ton	481,280	kg

Notes: (1) Compilation results - see table 2; (2) calculated from (1) based on the characteristic of box 1; (3) assuming 1128 ktons total pangasius production in ponds (data for 2008 according to MARD (2009)); (4) Excluding N-NO_2, H_2-S, DO.

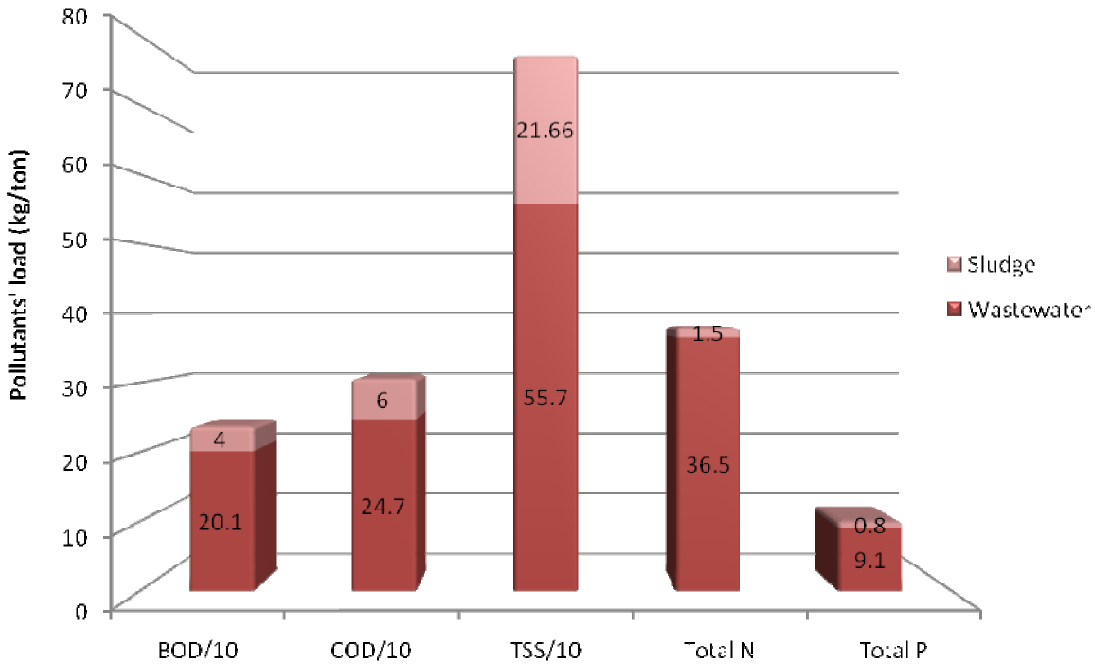

Figure 2.5 Water pollution by pangasius farming. Units: kg per ton of fresh pangasius fish. Source: Table 2.3

2.3.3 Reduction options

The second objective of this study is to identify options to reduce water pollution by pangasius farming. This identification will in part be based on the above analysis, which provides insight in the causes of water pollution. Based on the results above, it may also help explain the large variation in pollutant concentrations in wastewater among farms. The most important sources of water pollution are wastewater and sludge. It is therefore most interesting to focus on these sources first in our search for pollution reduction options. This may lead to the identification of effective reduction options. The effectiveness is not the only criterion for the selection of promising options. We also prefer options to be feasible, both technically and economically. Although farmers, in general, profit from pangasius farming (Phuong et al. 2007), there are financial risks from fluctuations in the pangasius price, export market, and in costs of production, and from conflicts between farmers and processors (Hau 2008; Loc et al. Forth comming). This affects the willingness of farmers to invest in technical options to reduce water pollution. Several sources of information are used to identify reduction options, including literature as well as newly collected information from field research, and the systems analysis presented above. Based on this, methods for reducing wastewater pollution are identified, and evaluated.

There are different ways to reduce pollution from water exchange and sludge. First, waste prevention and minimization at the source is an effective pollution abatement strategy. Producers can reduce the generation of wastes from their production processes via various approaches: good housekeeping (European Commission 1997); (Ramjeawon 2000); (Henningsson et al. 2001); (Hyde et al. 2001), changing to other raw material inputs (Jorgenson and Wilcoxen 1990); (Chaan-Ming 1995); (Vigneswaran et al. 1999), or adopting new technologies (European Commission 1997)

A second approach to mitigating pollution is through recycling and reuse of waste materials. Often, waste material can be reused in other production processes as secondary raw materials for production of new products. Generally, these offsite reuse and recycling options create economic benefits as less energy is consumed for producing new products from recycled materials, and it spares the environment from further abuse and degradation as less virgin material is used (EPA 1996). If there are no possibilities of waste minimization nor recycling and reuse, the treatment of waste streams is the approach of last resort. The treatment technologies for aquaculture effluents are mainly based on the mechanical separation of solids when draining water from the ponds. Sedimentation in tanks or ponds is one of the mechanical treatment methods (Schulz 2003).

Based on the results above, the following outlines two approaches for the prevention and minimization of the water pollution in pangasius farming, each with different advantages and drawbacks: (1) waste prevention and minimization at the source and (2) treatment and reuse of effluent streams. Treatment and reuse are combined as the two processes, schematically illustrated in Figure 2.6, are technically similar.

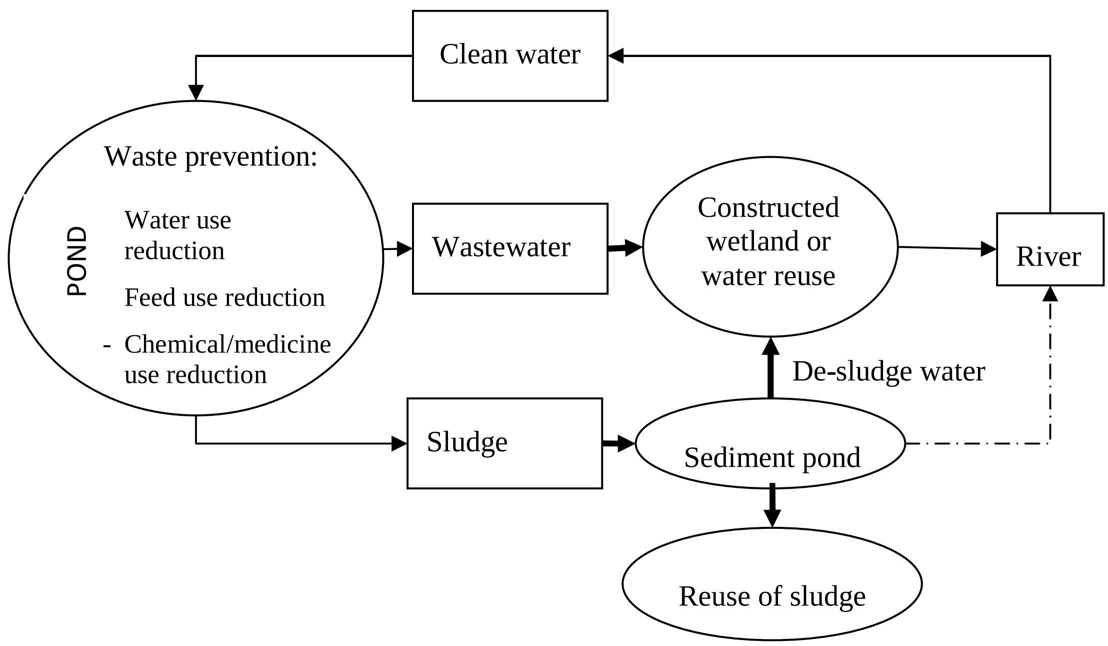

Figure 2.6 Options to reduction water pollution by pangasius farming

2.3.3.1 Waste prevention and minimization in the fish ponds

The different measures, summarized in Table 2.4 and outlined below, include techniques for the reduction of water, feed, chemicals and drugs use, as well as treatment of input water and improved farm cleaning.

Water use reduction includes several techniques to reduce the use of refreshment water. Currently, two techniques are currently under investigation for pangasius farming in Vietnam: ozone aeration and the use of pro-biotics. Both tend to improve the water quality in the pond, as a result of which the refreshment frequency can be reduced. It should be noted that these two techniques have not been thoroughly tested in tropical conditions, and their economic feasibility needs further study. Nevertheless, we include these in our study because they seem promising options for pollution control. We consider the costs of ozone aeration and pro-biotics considerable for Vietnamese farmers and classify these options as relatively expensive.

Ozone aeration technology is generally used in USA, Korea and India. It has several advantages for farmers and the environment. With this technology, ozone is aerated into ponds via ozone generation equipment. Exchanging water in ponds is then not necessary and, as a result, the associated environmental pollution is minimized. This method has also proved to be economically efficient. For instance, the shrimp production in *Macrobrachium rosenbergii* ponds using ozone aeration was 10,000 kg/ha, while the highest productivity of *Macrobrachium rosenbergii* in Thailand is 6,000 kg/ha and in Vietnam 4,000 kg/ha, in ponds using a water fan instead of ozone aeration (Liêm 2008). Luan (2008) experimented with ozone aeration in pangasius ponds. Several positive effects on water quality in the pangasius ponds were observed: (1) the fish eat normally and crowd near the ozone devices; (2) the number of dead fish is reduced by 35-50% compared with control ponds without ozone aeration; (3) the pH increase (from 6.5 to 7.1) leading to the precipitation of aluminium; and (4) other parameters as TSS, COD, BOD and $N\text{-}NH_3$ are also reduced significantly. Ozone aeration is currently not yet applied in pangasius farming because pangasius can survive at relatively low oxygen levels. As a result, ozone aeration requires the installation of a full aeration system. This makes it a relatively expensive option.

Pro-biotics are microorganism that can feed on organic substances and other minerals. As a result, the mass of living organisms in ponds increases after the introduction of pro-biotic. These organisms are used for the conversion of organic and inorganic substances from aquacultural waste. Attempts have been made to use pro-biotic bacteria in aquaculture to improve water quality by balancing bacterial population in water and reducing pathogenic bacterial loads. Li Hui-Rong *et al.* (1999) studied the use of pro-biotics in raising *Penaeus japonicus*. The application of Alken Clear-Flo 1200 bacteria in an aquaculture pond reduced the level of ammonia after one week relative to ammonia levels in a pond left untreated with no effect on the shrimp. This method also was studied largely by Austin et al. (1992); Karunasaga (2001); Abidi (2003); and Gomez et al. (2007). Currently pro-biotics are hardly studied yet are liberally applied in pangasius farming. To ensure their proper use it is necessary to either have clearer guidelines and control over private sector extension workers, in conjunction with the development of publically accessible guidelines to farmers on suitable pro-biotics thereby increasing their efficiency and reducing pollution.

Feed use reduction is another option to reduce pollution given that redundant feed is the most important factor in the generation of waste sludge. Hung et al. (2006) concluded that industrial pellet feed is more efficient for pangasius than homemade feed. It is, however, also more expensive, costing from 3.6% to 14.2% more than homemade feed. It can reduce the amount of redundant feed in the sludge. Better feed management using formulated feeds is also needed to ensure the quality of feed. Other disadvantages of homemade feed are the overexploitation of natural aquatic resources, as so-called 'trash fish' is heavily used (APFIC 2005). Nevertheless, more research is needed on feed efficiency improvement, especially as at least 50% of the farms continue using homemade feed in An Giang province, where most of the pangasius is grown (Hoa 2008).

Chemicals and drugs use reduction is necessary and possible to reduce the pollutants in wastewater, sludge and the accumulation of these components in fish itself. Better guidelines and monitoring for correct use of chemicals and drugs on appropriate doses and frequency are needed. If applied appropriately, reduced chemicals and drugs use will not lead to reduced pangasius yield. It is then a cost-saving option.

Treatment of input water and pond cleaning is necessary to reduce the impact of external pathogens and pollutants. Currentl**y,** river water is used in ponds untreated. Filtering will reduce the risk of pathogens, and reduce the frequency of diseases. Keeping farms clean also reduces water pollution caused by diseases and fouling from dead fish. This step could be carried out during the first water input, water refreshment and pond emptying. The investments costs (for installing filters) are considerable, making this a relatively expensive option.

2.3.3.2 Treatment and reuse of effluent streams

The treatment and reuse of effluent streams include both the treatment and reuse of the sludge and the treatment and reuse of wastewater. The costs of these options are relatively low, provided that land is available.

The treatment and reuse of sludge can be achieved by the use of a sedimentation pond followed by desiccation and reuse of sludge. A sedimentation pond is a place to collect runoff and retain moisture to allow soil and debris in the water to settle out to become sediment. Currently, about less than 10% of fish farms in An Giang have sedimentation ponds (Hoa 2008). These have been installed to avoid that discharge water contains suspended solids in excess of water quality discharge standards (Caldwell 2008). Our laboratory experiments show that sludge from wastewater settles quickly (Anh and Mai 2009b) . In one hour the sludge volume can be reduced to less than 20% of its original volume. For this reason, sedimentation ponds can be considered an effective and simple way to reduce pollution of sludge.

After one hour of sedimentation, the supernatant still contains most of the N and P present in the wastewater. This de-sludge wastewater can be treated together with wastewater. In general, the sludge at the bottom of the sedimentation pond needs further dewatering in order to make reuse possible. Currently, some farmers in An Giang and Can Tho provinces have used the dewatered sludge for leveling low land areas. Some farmers have put it into the fruit gardens with Mango, Longan and other fruits (Anh and Mai 2009a). Re-use of de-watered sludge resulted in improved yields, and reduced number of insects. It appeared to be easy to implement for farmers, at low costs. Nevertheless, more research is needed on the practical and long term aspects of treatment and reuse of sludge.

There are many methods for the treatment and reuse of wastewater. In general, the selection of wastewater treatment technologies depends on the characteristics of the wastewater, effluent requirements, available land and the demands with respect to energy and chemical use. In the case of the water exchange from pangasius ponds the treatment technology has to fit with the high volume of wastewater and the low concentration of pollutants and be manageable in the rural area. For these reasons, the methods of wastewater treatment should be simple with low use of mechanized equipment and low cost for energy and chemicals. For the Mekong delta, wetland methods are considered the most feasible, both technically and economically, although large areas of land are needed (Dan et al. 2008).

Constructed wetlands - represent a natural treatment system based on biological symbiosis between macrophytes and microorganisms (bacteria, fungi, algae), and their interactions with the soil (Schulz 2003). Schulz et al. (2003) show that subsurface horizontal-flow constructed wetlands, consisting of a coarse sand bed with emergent macrophytes, can be used for the treatment of effluent of aquaculture flow-through systems applying hydraulic retention times of 1.5, 2.5 and 7.5 hrs. Treatment efficiencies of TSS and COD were in the range of 96-97% and 64-74%, respectively and appeared independent of hydraulic load. Removal rates of TN and TP were 21 – 42% and 49 - 69%, respectively, showing lower efficiencies at decreasing residence times. Clogging phenomena of the sand bed at the given high TSS loading rates (9 - 73 g TSS/m^2/d) were expected, but were not observed during the six months the experiments lasted.

Constructed wetlands purify the water that flows through them. Compared to conventional treatment methods, they tend to be simple, inexpensive (where a sufficient supply of filter bed material is available), and environmentally friendly. Constructed wetlands also provide food and habitat for wildlife and create pleasant landscapes. The disadvantage of this technology is the need of a large area of land at low loading rates.

If hydraulic retention times in the order of 6 – 8 hrs as applied by Schulz et al. (2003) could also be applied to effluent of pangasius ponds, the land requirement would be relatively modest. Currently constructed wetlands are not yet used for pangasius effluents in Vietnam.

Discharge design - Another option is to reuse wastewater with optimization of the discharge design. Wastewater from fish ponds usually contains nutrients and organic substances. Therefore, reuse of this wastewater in agriculture for irrigation and fertilization can reduce environmental pollution. It also can save production costs when wastewater replaces the use of synthetic fertilizers. This is turn reduces, energy use and emissions of greenhouse gases during the production of synthetic fertilizers, such as N_2O and CO_2 (IPCC 2006). If this option requires the development of irrigation systems, the investment costs can be considerable. In agricultural areas, however, irrigation systems are often available. The additional operational costs are relatively low.

An example of a low cost technology discharge design is demonstrated by the An Giang Fisheries Association (AFA) who has successfully combined pangasius farming with rice cultivation yielding two crops per year. In this system, wastewater from pangasius ponds was used to irrigate the rice fields, reducing the need for fertilizer use. This system has been applied more than 3 years by several farmers in My Thoi, Khanh Hoa in Long Xuyen city – An Giang (Quyen 2008). Beside, this wastewater can be used for breeding other species (Van 2007) or watering Indian taro fields (Diep 2007).

Optimization of the discharge design is needed for better reuse of wastewater. It is necessary to study irrigation and drainage systems that can combine aquaculture farming with agricultural production, and not pollute the environment. These methods can be applied in regions where sufficient crop land surrounds the aquaculture activities. Most important is to gather insight in the impact of the treatment and reuse methods on pathogens from pangasius ponds to avoid the transmittance of the disease to other ponds. A good plan for wastewater and sediment discharge ensures the wastewater to not return directly to the river or overflow to other system.

In a pilot study in farms in Hoa Lac Village, Chau Phu district, An Giang province, the wastewater from different fish ponds was discharged to the common irrigation system (Anh et al. 2009). This wastewater is passed through rice fields and is discharged into the environment with a continuous flow. We analyzed this water flow. The results show that BOD_5, TSS, total Nitrogen and total Phosphorus have decreased significantly. All rice farmers who had used this system agreed that the rice grows very well, with a high production and that large amounts of fertilizers are saved (Anh et al. 2009).

Table 2.4 Options for the reduction of water pollution by pangasius farming in the Mekong Delta

Name of option	Description of the option	Pollutants or problems reduced	Subsystem and activity to be applied	Remarks	Currently applied/ costs
Waste prevention and minimization at source					
Water use reduction	Techniques for cleaning water so that less refreshment is needed: ozone aeration and probiotic	Volume of wastewater;	Water refreshment	Reduce volume of water use and wastewater	Hardly applied; relatively expensive options
Feed use reduction	More efficient feed use: replace homemade feed by good quality pellet feed	BOD, COD, SS,	Feeding	This will also reduce wasted feed in sediment	At least half of the farms use homemade feed; pellet feed more expensive
Chemical, medicine use reduction	Techniques for efficient use of chemicals and drugs	Accumulated chemicals and drugs	Pond treatment/ nursing	Reduce amount of accumulated chemicals and drugs in the sludge	Not applied; if applied appropriately, no cost included but gains
Treatment of inlet water and good farm cleaning	Techniques for cleaning farms and filtering inlet water	Risk of pangasius disease and dead fish	First water input, water refreshment and pond emptying	Reduce risk of disease and dead fish, (one of the cause of water pollution)	Filtering is not applied; relatively costly

Table 2.4 Options for the reduction of water pollution by pangasius farming in the Mekong delta (cont.)

Name of option	Description of the option	Pollutants or problems reduced	Subsystem and activity to be applied	Remarks	Currently applied
Treatment and reuse of waste stream					
Sludge treatment in sediment ponds	Using a pond for settling the sludge, the effluent can be treated as wastewater	All substances	Frequency sludge discharge and pond emptying	Dewatering sludge can be used for levelling of low land or putting in fruit garden	<10% of farms applied[3]; costs are relatively low if land is available
Treatment of wastewater in constructed wetlands	Sub-surface horizontal flow constructed wetland is possible	All substances	Water exchange Pond emptying and effluent from sediment pond		Not applied; costs are moderate if land is available
Reuse wastewater with optimization of the discharge design	Land treatment of wastewater in agriculture	All substances	Water exchange and pond emptying	The investment costs can be considerable; the additional operational costs are relatively low.	Pilot for use of wastewater in rice field, no optimization of discharge design

[3] Hoa P.T. (2008) and Phan L.T et al (2009)

2.4 Results: Pangasius frozen fillet processing

2.4.1 System definition

In Vietnam almost all pangasius processing industries are located in An Giang, Can Tho, Dong Thap and Vinh Long provinces in the Mekong delta, close to pangasius farming areas. The most common export product is frozen fillets, for which the pangasius is processed into Block Quick Frozen (BQF) or Individual Quick Frozen (IQF) forms. We may distinguish four phases in the filleting processing of both BQF and IQF: (1) pre-treatment (2) filleting of fish, (3) trimming of fillet and (4) freezing, packing and storage (Figure 2.6). We refer to these as processing subsystems (Figure 2.7). Two other sub-systems not included in our analysis are: (5) ice production for chilling the pangasius during the process, and (6) cleaning in all of steps during and after the processing.

Figure 2.7 shows the typical method of frozen fillet processing phase into a block or individual form. The fish is transported from ponds to the factories by boat. The pre-treatment of fish involves two steps. First, after receiving, the fish are weighed, classified and soaked in basins with chloride (2-10 ppm) for cleaning and temporary paralysis (1). Second, the fish are slaughtered and soaked in basins with chloride (0.5-1 ppm) (2). According to interviewed processors, these chlorine ranges are in line with Sector standards on fishery processing establishments- HACCP-based quality management program and basic hygiene and food safety conditions (MOFI 1998a; MOFI 1998b), and reflect the optimal range of concentrations to apply. Water is exchanged once per ton of raw fish in steps 1 and 2. Filleting of fish is also done in two steps. The fish are filleted under the water tap, and washed in three basins with chloride (2-10 ppm) (3). The water exchange frequency is once per 10 baskets (100-150 kg of fish/ basket). Next, the skin will be taken off from the fillet (4). The skin is collected as by-product for other processes. Trimming of fillets starts with (5) weighting fillets to obtain 5 kg per basket, reforming (i.e. removal of remaining fat, bones, skin and red parts), and washing in basins with chloride (2-10 ppm). The water exchange frequency is once per 500 baskets. Next, the fillets undergo a first check, and are weighed and classified with respect to size and color (6). The surplus parts of the fish are removed and the fillets are tested for parasites (7). The fillets are then weighed into baskets of 10 kg and washed to remove remaining fat and fragmented parts in water with chloride (2-10 ppm). During this step water is also changed once per 500 baskets (8). The fillets are then treated with a solution in order to limit water loss from the fish and optimize the form of fillets (9). After that, the fillets are graded and checked with respect to color and size (10), and washed in a basin with chloride (3 to 5 ppm). Finally, freezing, packaging and storage starts with the actual freezing to BQF or IQF and re-icing (11), after which the product can be packed and stored in a cold storage room (12). For each kg of pangasius fillet product, on average 2.6 kg fresh pangasius fish is needed.

Figure 2.7 Processing of fresh pangasius into frozen fillets (as block or individual)

We distinguished six sub-systems in frozen pangasius fillet processing as mentioned. Within these six sub-systems, there are eight activities. Water pollution is mainly caused by four activities: (1) water use and discharge, (2) blood removal, (3) fat removal (4) and small fragments removal (Figure 2.8). However, it should be noted that there are other environmental problems associated with pangasius production. For instance, a relatively large amount of electricity is used for freezing and ice production. We therefore also include electricity use here as an indicator for the environmental pressures caused by the processing industry. With our focus on water pollution and electricity use we do not intend to be complete. Nevertheless, these two illustrative indicators may be considered to cover an important part of the environmental impact of the sector.

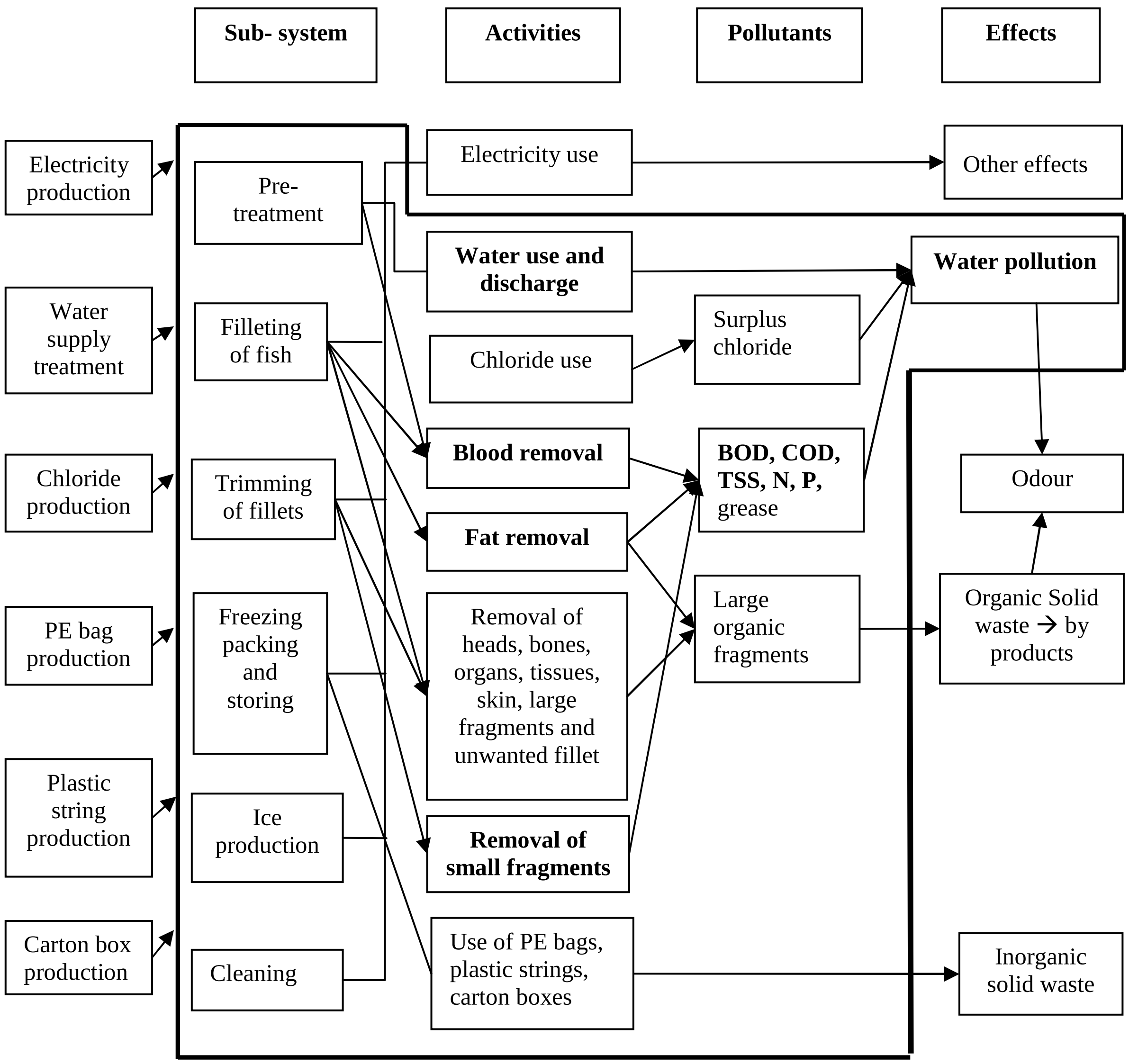

Figure 2.8 Schematic overview of pangasius frozen fillet production and its environmental impact; bold lines indicate the system boundary; bold system elements are included in the analysis

2.4.2 Assessment of environmental pressure

Wastewater generated from fish processing contains organic material in the form of oils, blood, proteins and suspended solids, as well as potentially high levels of phosphates and nitrates. To assess the potential environmental impact, we identified the following indicators: the volume of water use, the volume of generated wastewater and the BOD, COD, TSS, Total nitrogen, Total phosphorus and coli-forms content of the wastewater (Table 2.5). In the following, these indicators are investigated and if possible quantified. This is in part based on data from three different pangasius processing factories in An Giang province collected in 2006 and 2007. These factories do not yet apply cleaner production technologies in their production process.

Table 2.5 Indicators for the environmental pressures caused by pangasius processing

Environmental issues	Indicator number	Indicators	Unit
Water pollution	3.1	Volume of water use	m^3
	3.2	Volume of wastewater	m^3
	3.3	BOD content of wastewater	mg/l
	3.4	COD content of wastewater	mg/l
	3.5	TSS content of wastewater	mg/l
	3.6	Total Nitrogen concentration	mg/l
	3.7	Total Phosphorus concentration	mg/l
	3.8	Number of coli-forms	MNP/100ml

2.4.2.1 Water pollution

The volumes of water use and wastewater (Indicators 3.1 and 3.2) are calculated from the survey data for different steps in the process. The inventory included various activities, such as the amount of water used in each soaking and washing basin, inputs of raw material and fillet production and water for cleaning. The average water use per ton of raw fish found in three factories with different capacities ranged from 6.2 to 12.7 m^3. This data is reasonable if compared to the data from Jesperson et al. (2000) for filleting white fish (5-11 m^3 of water use per ton of raw fish) and for oily fish (5-8m^3). pangasius is considered a type of oily and white fish by the processors interviewed. Wastewater production ranges from 6.16 to 12.66 m^3 for processing one ton of pangasius fish. The water balance for the production of one ton of pangasius is shown in Figure 2.9. For an annual production of 1,128,000 tons of pangasius in 2008, both water use and wastewater production are approximately 7 to 14 million m^3 per year.

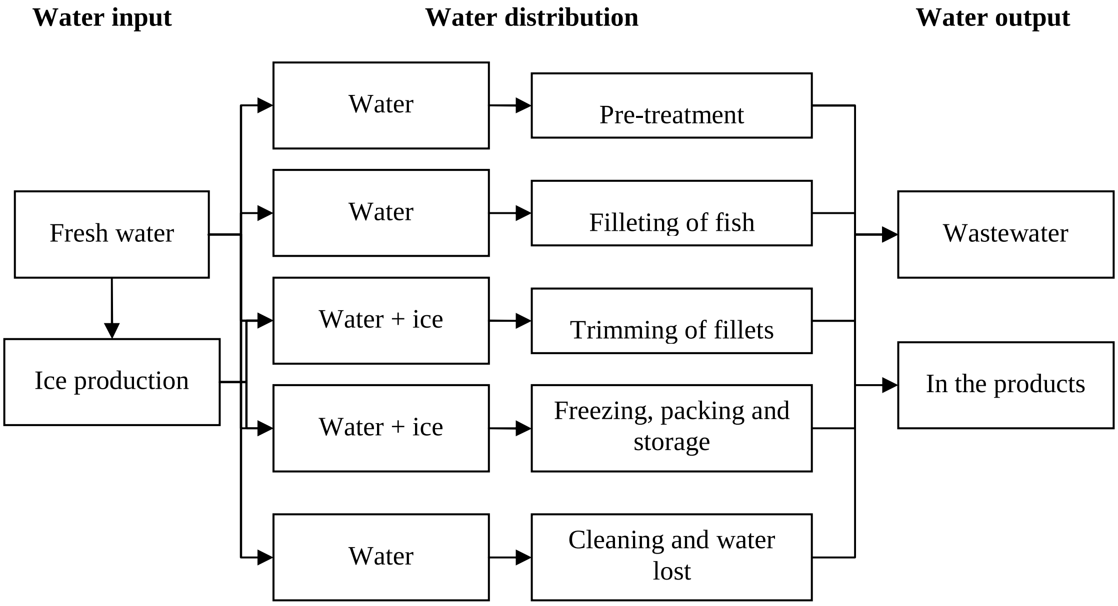

Figure 2.9 Water balance for the processing of one ton of pangasius fresh fish

Fish processing industries in Vietnam have to establish their own wastewater treatment systems for a range of pollutants including BOD, COD, TSS, Total Nitrogen, Total Phosphorus, coli-forms (Indicator 3.3 – 3.8). According to the Vietnamese Environmental law they are not allowed to discharge untreated wastewater into rivers or canals. However, not all companies apply effective wastewater treatment. In one of the companies that we surveyed, the daily wastewater was $800m^3$, while the wastewater treatment capacity was $500m^3$/day. This means that about 300 m^3 of untreated wastewater is discharged directly into rivers per day.

The wastewater composition varies among fish processing factories. For instance, Islam et al. (2004) concluded from processing industry outside Vietnam that the BOD may range from 100 to 200,000 mg/l, while suspended solids may be up to 120,000 mg/l. Nutrients such as nitrogen and phosphorus may be absent or so high that biological treatment becomes difficult. We also observed differences between the three studied industries in water use, processing techniques and in the way the domestic wastewater from the workers of the industry was handled. Because of the large variability in data, we supplemented data from measurements in the three Vietnamese factories with information from the literature. Pollutants loading in wastewater of filleting white fish processes from UNEP (2000) are relatively high compared to what we measured in the three processing industries in Vietnam. The results presented in Table 2.6 are therefore synthesized from Jesperson et al. (2000), Caravan (1991) and our measurements. In the calculations, we take into account the highest loads. Following Jesperson et al. (2000), the highest loads for filleting oily fish are for BOD: 50 kg/ton of fish, COD: 85 kg/ton, total N: 2.5 kg/ton, and total P: 0.3 kg/ton. The TSS level was taken from our measurement and Caravan (1991). Parameters such as pH and total coli-forms are not available from the literature. We therefore used our own measurements and found a maximum wastewater generation of 12.7 m^3 per ton of fish.

Table 2.6 Composition of wastewater from pangasius processing factories

Indicators	Unit	Value	Sources	TCVN 5945-1995, B(**)
pH	-	6-8 – 8	1	5.5 – 9
TSS	mg/l	1190	1, 2	50
COD	mg/l	6692	3	100
BOD_5	mg/l	3937	3	50
Total Nitrogen	mg/l	197	3	60
Total phosphorus	mg/l	24	4	6
Total coli-forms	MNP/100ml	43×10^4	1	10^4

Source: (1) This study ; (2) Caravan (1991); (3) calculated following Jesperson et al. (2000)

(**) TCVN 5945 – 1995, Vietnamese standard for industrial wastewater discharging into the receiving water which use for transport, aquaculture, irrigation - type B (for water supply source – Type A).

If compared to the Vietnamese standard for Industrial wastewater discharging into the receiving water which use for transport, aquaculture, irrigation, all parameters in the wastewater from pangasius processing are very high. They range from three times (for total nitrogen content) to more than 20 times (for COD, BOD and total coliforms) higher than the national Vietnamese standards.

2.4.2.2 Pollution by unit of production

Table 2.7 presents the overall pollution per ton of fresh fish, and for the total Mekong Delta. The latter is based on a maximum wastewater production per ton of fillet fish processing of 12.7 m^3, and 1,128,000 tons of pangasius processing in the Mekong Delta in 2008. The results indicate that the total estimated pollutant load in Mekong delta due to the pangasius production in 2008 are approximately 56 ktons BOD/y; 96 ktons COD/y; 17 ktons TSS/y; 3 ktons total N/y and 338 tons total P/y. If we compare these loads to total river loads of TSS, total N and total P in the Mekong of 380806 Gg/y

(Seitzinger et al. 2005), we find that pangasius production accounts for less than 1% of total TSS, Nitrogen and Phosphorus.

Table 2.7 Pollution caused by processing of pangasius to frozen fillets in the Mekong delta

No	**Indicators**	**Measured[(1)]**		**Per ton of fresh fish[(2)]**		**Total for Mekong delta[(3)]**	
		Value	Unit	Value	Unit	Value	Unit
3.1	Water use	12.7	m3/ton	12.7	m3/ton	14325600	m3/y
3.2	Wastewater production	12.7	m3/ton	12.7	m3/ton	14325600	m3/y
3.3	BOD	3937	mg/l	50	kg/ton	56400000	kg/y
3.4	COD	6692	mg/l	85	kg/ton	95880000	kg/y
3.5	TSS	1190	mg/l	15	kg/ton	16920000	kg/y
3.6	Total N	197	mg/l	2.5	kg/ton	2820000	kg/y
3.7	Total P	24	mg/l	0.3	kg/ton	338400	kg/y

Notes: (1) From Table 6; (2) calculated assuming 12.7m^3 wastewater per ton of fresh fish (3) assuming a total production of 1128 ktons of pangasius fresh fish in ponds.

To calculate the total water pollution per ton of frozen fillet product we summarize the results from Tables 4 and 7 into Figure 2.10. We base this calculation on the assumption that 2.6 ton of fresh fish is needed to produce 1 ton of frozen fillet product (see Section 4.1). From this we estimate the average estimated pollutants' load for producing one ton of pangasius frozen fillet is about: 740 kg BOD, 1020 kg COD, 2050 kg TSS, 106 kg N and 27 kg P.

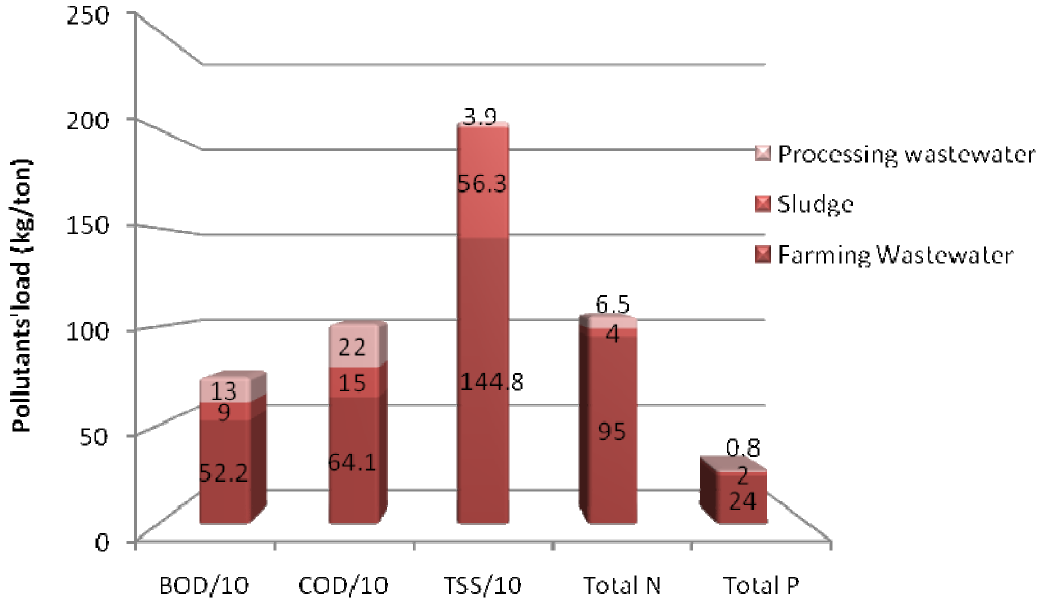

Figure 2.10 Water pollution by the production of frozen pangasius fillet. The graph shows pollution from ponds and processing. Units: kg pollutant per ton of fillet

Our results also show that wastewater from fish ponds is a relatively larger source of water pollution than processing, contributing 60-90% to the total loadings of pollutants to the Mekong delta from pangasius production. Sludge from fish ponds and wastewater from processing facilities have relatively high contents of pollutants, but because of their relatively small volumes, these waste streams only contribute 3 to 27% of the total pollution.

2.4.3 Reduction options

Pangasius processing consumes large quantities of water and discharges significant quantities of organic material, both as effluent and as solid waste. However, there is relatively little use of hazardous substances and most of solid waste is organic material from the fish, which can be recycled in animal feed industries. The following reviews water pollution reduction technologies falling under the categories of cleaner production technology and second wastewater treatment plants.

2.4.3.1 Cleaner production technologies

Water pollution can be diminished by reducing water consumption, reducing pollutant loadings of fish processing effluent, and by end of pipe treatment of wastewater. For reducing water consumption and pollutant load of fish processing effluent, many industries are encouraged to apply cleaner production technology by government, agencies or consultant firms. There are several cleaner production opportunities through improved management techniques and technology. The types of cleaner production options are good housekeeping, process optimization, raw material substitution, new technology and new product design (UNDP 1994). Thrane et al. (2009) has shown that in development of water consumption, most of the improvement obtained in the beginning of the period is the result of better housekeeping practices and mainly related to more efficient cleaning procedures. For instance, to install high pressure washer required an investment of about 1000 USD, while the savings were about 1,900 USD per year (Dan et al. 2003), Large reduction can be obtained by making cleaning staff aware of water consumption, for example by encouraging them to register their water consumption after each day. This only requires an investment in a few water meters, a piece of paper and pencil. Nevertheless, cleaner production has not been widely accepted and implemented yet Vietnamese industries, despite substantial promotion by the government and academic institutions (Mitchell 2006).

Other opportunities for reducing the pollutant load of fish processing wastewater principally focus on avoiding the loss of raw materials and products to the effluent stream. This can be obtained in several ways such as by using good practices in filleting and trimming, including the use of sharpen knives, preventing small fragments of fish being added to wastewater flows and collecting waste in a dry state by using dry cleaning methods. Additional benefits from improved housekeeping include optimization of existing processes and use of more energy-efficient equipment and heat recovery systems can also reduce the energy use in fish processing.

2.4.3.2 Wastewater treatment

Wastewater treatment methods are based on physical, chemical and/or biological processes. Biological processes are usually used in conjunction with physical and chemical processes, with the main objective of reducing the organic content and nutrient content of wastewater (United Nations 2003). Anaerobic technique as a biological process has been applied popularly in seafood processing wastewater, obtaining high COD removal efficiencies (75-80%) at volumetric loading rates of 3-4 kg COD/m^3.day (Balslev-Olesen and Lyngaard 1990; Mendez 1992). Hung (2004) concluded that 60-70% of the biogas produced by a balanced and well functioning anaerobic system consists of methane, with the rest being mostly carbon dioxide and minor amounts of nitrogen and hydrogen. This biogas is an ideal fuel for producing low cost electricity and providing steam for use in the stirring and heating of disinfection tanks. A greenhouse gas as Methane can be effectively reduced, rendering great potential for Clean Development Mechanism (CDM) initiatives under the Kyoto protocol. In a CDM program, “carbon credit” represents reduction of the amount of greenhouse gas emissions from an emission source. Carbon credits can be claimed by issuing Certified Emission Reductions (CERs) through advanced anaerobic wastewater treatment

(K.Y.Show and D.J.Lee 2008). Other techniques in biological processes used for wastewater treatment of seafood processing industries had studied, analyzed and mentioned in European Commission (2006), Hung (2004), Rollon (1999) and Sridang et al. (2006).

2.5 Discussion and conclusions

The results presented in this paper are the first to systematically estimate the extent and nature of water pollution from pangasius farming and processing on the environment of the Mekong Delta. Our results from pangasius grow out farms show that pollutant loading from wastewater and sludge in order to produce 1 ton of pangasius fish are 201 and 35 kg BOD, 247 and 59 kg COD, 557 and 217 kg TSS, 37 and 1.5 kg TN, 9 and 0.8 kg TP. Our results from processing pangasius into frozen fillets show that emissions to water pollution for producing one ton of pangasius fillet product are 130 kg BOD, 221 kg COD, 39 kg TSS, 6.5 kg N and 0.8 kg P. Scaling these results up we estimate the overall pollution by pangasius production as the sum of emissions from wastewater, sludge and processing wastewater for one ton of fillet product and analyzed the relative shares of these sources in the overall pollutants' loading. We conclude that overall emissions associated with the production of one ton of pangasius frozen fillet product amount to 740 kg BOD, 1020 kg COD, 2050 kg TSS, 106 kg N and 27 kg P. Wastewater from fish ponds is the most important source of water pollution from pangasius production, contributing between 60-90% of pollutant loading in wastewater . However, sludge from fish ponds and wastewater from fish processing have relatively high pollutants' content, which may lead to severe local environmental problems. Nevertheless, we estimate that overall pangasius production is a minor source of nutrients in the Mekong River, accounting for less than 1% of total TSS, Nitrogen and Phosphorus loads.

Based on our review of available technologies to mitigate the impacts from farming and processing of pangasius we propose two approaches for reducing water pollution problems. First, we propose waste prevention and minimization in fish ponds, including a range of techniques for reduction of water use, feed use, chemicals and drugs use and treatment of input water and good farm cleaning. Second, we suggest treatment and reuse of effluent streams, with sludge the use of sediment pond, followed by dewatering and reuse of sludge. For wastewater, constructed wetlands are simple, inexpensive and environmental friendly methods. The costs of these options vary. Among the relatively cheap options are reduced use of chemicals and medicines, sludge treatment in sedimentation ponds and constructed wetlands and the re-use of wastewater through existing irrigation systems. In addition, the optimization of discharge design can be implemented for better reuse of wastewater in pangasius processing by applying cleaner production technologies and investing in wastewater treatment plants. Several low-cost cleaner production opportunities are currently applicable to small, medium and large processing factories including improved management techniques and low-tech technologies such as the application of anaerobic wastewater treatment which have the added benefit of potentially generating alternative income streams from carbon credit schemes. Given the attention that is being given to the sustainability of pangasius further research should is urgently needed in Vietnam to establish more exact costs associated with each of the technologies proposed.

Chapter 3 Water pollution by intensive brackish shrimp farming in South-East Vietnam: causes and options for control[4]

Abstract

This paper focuses on both the environmental impact of intensive shrimp farming in the coastal region of Vietnam and the identification of options for cleaner production. We investigated water pollution, sediment contamination and the spread of diseases related to shrimp farming in the Can Gio district of Ho Chi Minh City (Vietnam), an area representative for the impacts of intensive shrimp production in the country. Data on the production process was compiled from site observations, interviews with local farmers and experts, as well as from secondary sources. The results indicate that, while a large number of individual farms may exceed environmental standards; intensive shrimp farming is not always associated with waste streams exceeding water quality standards. This is interesting because it shows currently available technologies can reduce pollution from intensive shrimp farms. The paper concludes by identifying technologically and economically feasible options for reducing water pollution, problems associated with contaminated sediment, and the spread of diseases.

Key words: Environmental system analysis, Shrimp farming, water pollution, sediment

3.1 Introduction

Shrimp farming plays an important but controversial role in the economic development of many countries in Asia because of the high economic returns and often catastrophic environmental impact of production in coastal areas (Senarath and Visvanathan 2001; Huitric et al. 2002; Lebel et al. 2002a; Hall 2003; van Mulekom and A. Axelsson 2006; Vandergeest 2007; Islam 2008). Nowhere is this trade off between growth and environmental impact seen more clearly than in Asia where approximately 75% of the global production of farmed shrimp takes place. The three largest producing nations being China (1,242,000 tons), Thailand (501,000 tons), and Vietnam (349,000 tons), followed by Indonesia (326,000 tons), and India (132,000 tons) (FAO 2007b). Thailand is by far the largest shrimp exporting country with a market share of more than 30%, followed by China, Indonesia, India, Vietnam, Bangladesh, and then Ecuador (ibid.).

[4] This chapter has been published as Pham Thi Anh, Carolien Kroeze, Simon R. Bush, Arthur P. J. Mol (2010), Water pollution by intensive brackish shrimp farming in Southeast – Vietnam: causes and options for control, Journal of Agriculture Water Management, **97**(6): 872-882

Shrimp farming in Vietnam began in earnest at the end of the 1990s in response to international market demand and supported by government coastal land conversion policies (Lebel et al. 2002). Today, almost 90% of the brackish shrimp farming in Vietnam takes place in the Mekong Delta (about 600 ha). Black tiger shrimp (*Penaeus monodon)* is the dominant species with 289,000 tons produced in 2008 (MARD 2009a). In recent years, the Vietnamese government has promoted the production of white leg shrimp (*Littopenaeus vannamei*) as a more environmentally friendly alternative to black tiger shrimp. It is hoped this alternative species will help the industry maintain high yields, while providing more efficient use of water, low-feed conversion rates, high survival rates, and faster growth cycles (Wyban 2007; Mishra et al. 2008). However, black tiger shrimp is preferred in most international markets and remains the most important species in tropical shrimp farming.

Farming systems have gradually shifted from extensive traditional systems to improved extensive, semi-intensive and intensive production that are classified according to the pond size, water use, capital, labor, feed and chemicals used, and stocking densities (Table 3.1). Although traditional and improved farming systems continue to exist in parallel, production does appear to have intensified. During the past ten years shrimp production increased faster than the area of shrimp ponds (Fig. 3.1). Since 2008, the area of shrimp farming has decreased while production has increased. Although statistics are not yet available, the area of shrimp farming in 2009 was expected to decline 9% to 580,000 ha, while production was expected to grow 10% to 380,000 tons (MARD 2009).

Table 3.1 Comparison of the general characteristics of brackish shrimp farming systems in Vietnam

Farming System	**Size**	**Culture method**	**Stocking**	**Density (shrimp/ m^2)**	**Feed**	**Water exchange**
Extensive/ traditional shrimp farming	4-5 ha	Dyke enclosed with Polyculture	Natural recruitment	1-3	Natural	Tidal
Improved extensive shrimp farming	4-5 ha	Dyke enclosed with Polyculture	Artificial	1-5	Supplemental	Tidal
Semi-intensive shrimp farming	Small (1-5 ha)	Pond with Monoculture	Artificial	5-8 (up to 10-20)	Artificial	
Intensive shrimp farming	Small (<1ha)	Pond with Monoculture	Artificial	>20	Artificial	15% every 10 days

(Source: (EJF 2003)

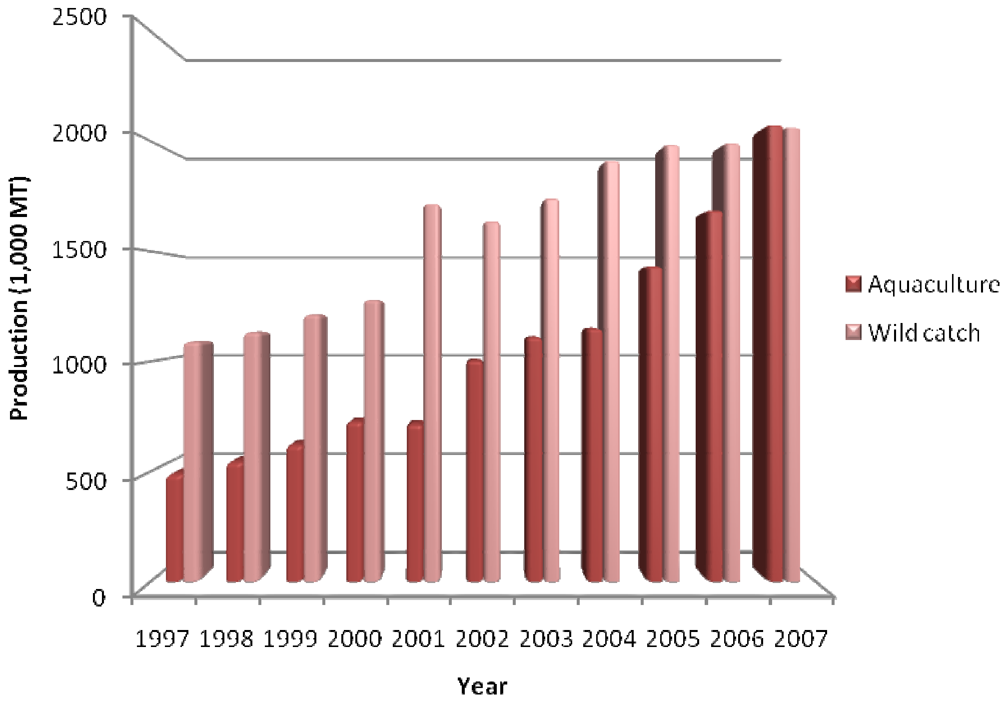

Figure 3.1 Area and production of shrimp farming in Vietnam in 1999 – 2008

Compared to other countries intensive shrimp production systems in Vietnam have a relatively low stocking density. In Can Gio, the area focused on in this study, the stocking density in aerated ponds ranges from 20 to 40 post larvae (PL)/m^2. In comparison, stocking density of comparative systems in Thailand, Taiwan, China or Mexico range between 50 to 100 PL/m^2 (Dierberg and Kiattisimkul 1996; Páez-Osuna and Ruiz-Fernández 2005; Flaherty et al. 2009). Nevertheless, Can Gio represents the highest concentration of intensive shrimp production in Vietnam. In addition, Can Gio is an area of significant ecological value with a large area of rehabilitated mangrove recognized as an International Biosphere reserve zone by UNESCO (2002). Combined, the concentration of intensive shrimp aquaculture and the ecological value of coastal mangrove make an important reference site to determine the potential impacts of intensive production as this farming system develops further in other parts of the country.

Like in many other Southeast Asian countries (e.g. Valiela et al. 2001; Alongi 2002; Huitric et al. 2002) mangrove deforestation in Vietnam has become a serious issue, with at least 220,000 ha of mangrove forest removed over the last 50 years (Tuan et al. 2003). Disease outbreaks and acidification of soils, has led to crop failure rates as high as 70 to 80% in some areas of Vietnam, and subsequently the abandonment of ponds and further expansion of shrimp cultivation to new coastal areas (Lebel et al. 2002b;

EJF 2003). Whereas agriculture, salt pan development and the war-time use of chemicals were previously the most important threats to mangroves, for the last decade the greatest threat has been shrimp aquaculture (EJF 2003).

To reduce the risk of crop failure, Vietnamese farmers use a relatively large amount of feed, pesticides and antibiotics in shrimp farming. Several concerns have been raised about the use of toxic compounds, including their persistence in aquatic environments, the possibility of residues in non-cultured seafood, the toxicity to non-target (off farm) species, the possible effects on sediment biogeochemistry and, finally, the possible effects on the health of farm workers (EJF 2003). As other studies have noted (e.g. Trai et al. 2007; Mang et al. 2008; Long and Toan 2008), shrimp farming in Vietnam may also lead to serious water pollution with wastewaters containing high biological oxygen demand (BOD), and high nitrogen (N) and phosphorus (P) concentrations from feed residue, is often released directly into canals and rivers causing oxygen depletion and eutrophication. Several studies have also indicated that intensive shrimp farming in particular has the largest share in the overall environmental impact of all shrimp production systems (Dierberg and Kiattisimkul 1996; Senarath and Visvanathan 2001; Jackson et al. 2004; Tzachi M Samocha et al. 2004)

This paper adds to several recent studies on the environmental impact of intensive shrimp production in coastal areas of Southeast Asia by providing the first system analysis of black tiger shrimp production in Vietnam. The specific aims of the paper are to analyze the causes of water pollution, contaminated sediment and spread of disease from intensive black tiger shrimp farming in Vietnam and to identify possible options to reduce these environmental impacts. For this purpose we focus our attention on the Can Gio region, a man and the biosphere reserve with high coastal environmental value and also a site representative of the impacts from the intensification of shrimp production.

Our study consists of two parts. First, we perform a systems analysis of intensive shrimp farming in Can Gio. This is an area close to Ho Chi Minh City in Vietnam with large scale of intensive black tiger shrimp production. Second, we extend the systems analysis by identifying options to reduce the environmental impact by shrimp farming. We focus on options that are both already applied in other sectors in Vietnam, or which have the potential to be applied given experience from other countries with shrimp farming and compatibility with state legislation.

3.2 Methods

3.2.1 Can Gio area

Can Gio is an area located in a coastal district southeast of Ho Chi Minh City in Vietnam with latitude: 10^{0}22'14'' – 10^{0}40',09'' and longitude: 106^{0}46'12'' – 107^{0}00'59''. It covers 75,740 ha and is dominated by mangroves, including both salt water and brackish water species. Can Gio has been subject to extensive mangrove rehabilitation after extensive deforestation during the conflict in the 1960s and 1970s, and subsequently through the expansion of Shrimp farming. The forests were replanted in stages starting in 1991 and most recently in 2000-2002 (Tuan et al. 2003). As such, Can Gio provides the opportunity to work on environmental protection on a continuum of habitats, ranging from the sea to the boundary of Ho Chi Minh City, the largest industrial city in Vietnam.

Because of their ecological importance, the Can Gio mangrove forests have been recognized as an International Biosphere reserve zone by UNESCO (The core area of this Biosphere reserve zone is 4,721 ha). The buffer zone around it covers an area of 70,000 ha and a further transition area between residential and agricultural land covers another 30,000 ha. Shrimp farming is only allowed in the transition area. Nevertheless, there are serious concerns over the sustainability of shrimp production even in these areas. Trai et al. (2007) studied water pollution by shrimp farming in Can Gio and concluded that intensive and semi-intensive shrimp farms are larger sources of pollution than less intensive shrimp farming. They also concluded that intensified shrimp farming in Can Gio is not environmentally sustainable.

There are in total 66 thousand people living in Can Gio (HCMC statistical office 2006), engaged in a range of livelihood activities including agriculture, fisheries, aquaculture and salt production. Families in the communes of An Thoi Dong, Ly Nhon, Long Hoa Binh Khanh and Thanh An are predominantly involved in shrimp production. These families have been given access to above mentioned transition areas through land allocation programmes in the 1990s. Today approximately 2,830 households conduct shrimp farming. The shrimp farming area is almost 5,000 ha, of which about 343 ha is used for intensive shrimp farms and 524 ha are used for semi-intensive shrimp farms. The remaining 4,264 ha are used for extensive and improved extensive shrimp farms. The average production of intensive shrimp farming in Can Gio is about 5.3 tons/ha (Can Gio Economic Division 2007).

Within the Can Gio area 40% of the shrimp farmers are located in the area of Tam Thon Hiep commune (Can Gio Economic Division 2007). These farmers conduct intensive and semi-intensive shrimp culture. They occupy only 3% of the total shrimp farming area but contribute 8% of the total shrimp production of Can Gio. As such, this is one of the areas with the highest intensive and semi-intensive shrimp farming densities in Vietnam. Given the interest in intensive production in the country we believe Can Gio, and Tam Thon Hiep commune in particular, provide a representative case to investigate the impacts of intensive black tiger shrimp farming on the environment; and one which wider lessons can be learnt for the improved environmental production of shrimp farming in Vietnam.

3.2.2 Systems analysis

To determine the environmental impact of shrimp production we employed a partial environmental systems analysis following Quade and Miser (1997), Pluimers (2001), Jawjit (2006) and Neto (2008). The analysis begins by defining the problem by identifying system boundaries, inputs, outputs, system elements, and their (inter)relationships (Findeisen W and Quade E.S 1997). In this step we identify the most important causes of environmental pressures associated with shrimp farming. We then assess the environmental impact within the system under investigation by measuring key environmental indicators. This is done in part through substance flow analysis and simple material mass balances (van der Voet et al. 1997). Based on this analysis we then identify options to reduce the impact of these environmental problems in accordance with the defined system boundaries and the objectives of the production system being assessed.

Data were generated through a combination of field visits, experiments and secondary information. Twenty-two farms were visited to collect information about farming practices and environmental problems, and samples of wastewater and sludge from shrimp ponds. A total of 33 water samples were collected from farms in Can Gio at the point of water discharge during the shrimp production season. Samples were taken based on the production cycle, with 11 samples from ponds of less than one month old, 12 samples from ponds two to three months old, and 10 samples from ponds three to four months old. We also collected sediments from three of the oldest ponds.

Water quality parameters were analyzed in the water samples according to the APHA (1995). The parameters included: temperature, pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen demand (COD), Total Suspended Solids (TSS), Total Nitrogen (TN), Total Phosphorus (TP), Ammonia ($N\text{-}NH_3$), Dissolved Oxygen (DO) and coliforms. Three samples of sludge were also collected and analyzed as dry matter, measuring TN and TP. The results of these analyses have been reported to the Ministry of Fisheries (CENTEMA 2004a). Here we focus on an interpretation and synthesis of the results and their relevance to the environmental performance of intensive shrimp farming.

3.3 The shrimp farming system

3.3.1 Phases and processes in shrimp cultivation

Our analysis focuses on shrimp production in ponds with particular attention to the preparation, cultivation and harvesting phases in the production cycle. The preparation phase includes deforestation, pond construction, pond treatment and inlet water treatment. The cultivation phase includes breeding stock, feeding and pond water exchange. The harvest phase includes harvesting and pond emptying. A number of farming processes in these phases have potentially significant impact on the environment. We focus in particular on pond treatment, inlet water treatment, feeding, water exchange, and final water discharge and sediment dredging. The system studied here is described in Figure 3.2. As indicated above, Can Gio was accepted in 2000 as a World Biosphere Reserve. This implies that the area of shrimp production cannot increase. As a result, shrimp ponds are not abandoned.

Typical shrimp farms have one production cycle per year, which lasts for four months. Before each production cycle, farmers empty their ponds and dredge the sludge (both after harvest and before the new cycle). Depending on the natural conditions of each area the ponds may require further treatment before the new cycle. In the case of acid sulfate soil, common to many parts of the Mekong Delta, this may include flushing the ponds three to four times followed by treatment with lime (CaO) to increase the pH.

The ponds are then aerated continuously for three to four days, to kill vectors of infectious diseases such as snails and crabs. The ponds are sterilized with chlorine, Saponine (of herbal origin), or $KMnO_4$, and then fertilized to promote algal production with urea phosphate (or super phosphate), and/or a mix of chicken dung and lime in a ratio of 1:3. The quality of the water before stocking shrimp larvae is supposed to meet the criteria listed in Table 3.2 according to the guideline for black tiger shrimp farming from the government (MoFI 2001), and should be maintained throughout the cultivation season.

Table 3.2 Recommended water quality for black tiger shrimp farming

Parameters	Unit	Optimal range	Remark
pH (water)	-	7.5 – 8.5	Daily fluctuation ≤0.3
Temperature	^oC	28 – 33	No sudden change
Salinity	‰	15 – 25	Possible range: 10-30 ‰
Transparency	m	0.4 – 0.5	-
Hardness $CaCO_3$	mg/l	> 80	-
H_2S	mg/l	< 0.02	-
NH_3	mg/l	< 0.10	-

Source: (MOFI 2006)

After preparation the ponds are stocked and fed with pellet industrial feed. The Feed Conversion Ratio (FCR) measures the efficiency of converting the total quantity of feed in one grow-out period with the total biomass of shrimp harvested. Different feeds have different conversions, but current feeds on the market have an FCR between 1.4 to 2 (Funge-Smith and Briggs 1998; SEAFDEC 2008). At these FCRs it is estimated that approximately 80% of the feed nitrogen enters the pond nutrient cycling, through both inefficient conversion and excrement (Australian Prawn Farmers Association 2004).

Depending on the age of the shrimp and the scale of the pond, there are several ways to ensure efficient feed use. First, the calculation of feed quantity needs to be made in accordance with shrimp size. The quantity of feed for 100.000 PL_{15} (Post Larvae 15 days of age) can be calculated as: PL_{15}- PL_{20}: 1-2 kg of food/100.000 PL/day (MOFI 2006). After five days from PL_{21} and onwards, the feed can be increased by 0.1-0.4 kg/day, depending on the capacity of the Post Larvae. After one month, when the shrimp are approximately 1.5 to 2.0 g, the amount of feed in intensive farms can double from 2% to 4% of the estimated total shrimp weight in accordance with Standard 28 TCN 171: 2001 from the Vietnamese Ministry of Fishery (MOFI 2006).

Controlling water quality involves careful control of water exchange. The water level in the pond increases over time. In the beginning of the cycle, the water in the pond is set at a depth of 0.8 - 1 meter. After one month, the water level in the pond is increased to 1.2 – 1.5 meters, and after the third month the water level is increased and maintained at a depth of 1.5 m to 2.0 meters.

Depending on the season and the quality of the water in the shrimp pond, the water needs to be exchanged about every 10 days. During the dry season, the temperature and salinity of the water increases, requiring between 10-15% water exchanges. When the shrimp pond is polluted or diseases show up, also 10-15 % of the water is exchanged.

The duration of a typical crop of intensive shrimp farming is usually 100 to 120 days, after which the harvested shrimp reach a size of 40-50 shrimp/kg. After harvesting, a large amount of wastewater is discharged to the surrounding environment and clean water is pumped into the pond to flush the pond sediment. This water is then often pumped back into canals or used for putting in the mangrove forest area. The cycle is then started again with pond treatment.

3.3.2 System definition and indicators

From the above description of shrimp cultivation we distinguish five important subsystems in intensive black tiger shrimp farming: (1) Pond treatment, (2) Inlet water treatment, (3) Feeding (4) Water exchange and (5) Pond emptying (Figure 2). The analysis and evaluation of other sub-systems such as deforestation, pond construction, breeding stock and harvesting are not included in this study. The reason for not including deforestation is that since 2000 Can Gio was accepted as a World Biosphere reserve and the Vietnamese government issued regulation and policy outlawing any deforestation activities for shrimp cultivation. Breeding stock and harvesting are also not explicitly included but, along with the production of shrimp larvae, food and other input materials are implicitly included through other sub-systems to calculate the pollutants and production of waste in the shrimp cultivation process.

The five sub-systems considered include six activities, giving rise to emissions of a number of different pollutants and waste streams. These include the use or application of chemical and drugs, fertilizer, feed and discharge of water and sediment. In this study, we focus in particular on what are generally considered key environmental problems of intensive shrimp farming, including the release of polluted water resulting in eutrophication and elevated toxicity levels, contaminated sediments, and the spread of disease (Figure 3.2). Other regional and global problems, such as global warming, acidification and biodiversity loss are not taken into account. Heavy metals are also not considered in this study.

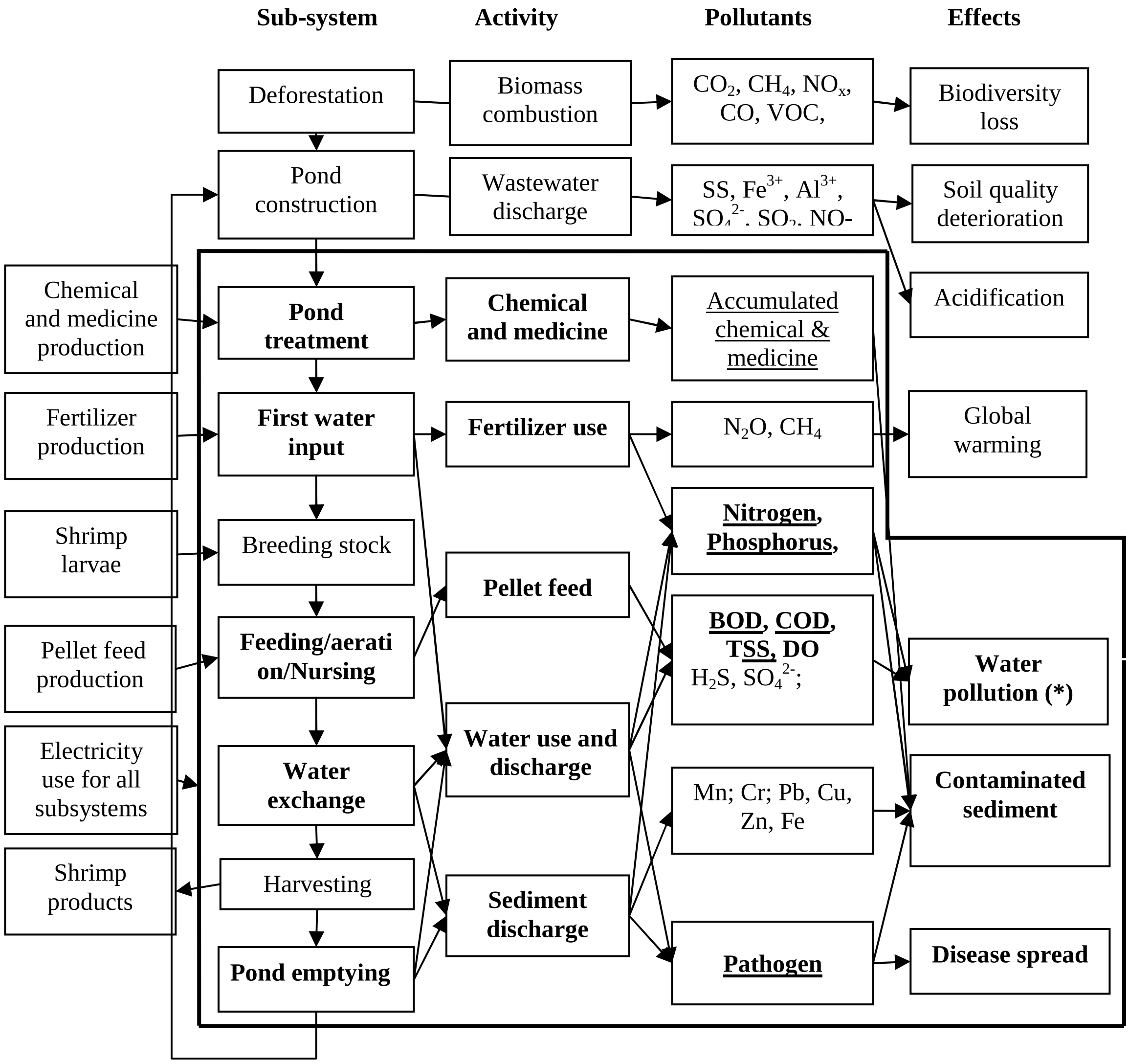

Figure 3.2 Schematic overview of shrimp production in Can Gio area and its environmental impact.

The bold line indicates the system boundary; bold system elements and the underlined substances are included in the analysis. Characteristics of a typical intensive black tiger shrimp pond in Can Gio: Area = 5000 m^2 (50 x 100 m); Water depth = 1.5 m; after one month of cultivation, 15 (10-25) % of the water is exchanged every 10 days; Density: 20 - 40 shrimps/m^2; Average production: 5.3 tons/ha/y.

(*) Including eutrophication and toxicity problems

The associated environmental impacts are assessed by use of environmental pressure or effect indicators (Table 3.3). For water pollution the following indicators are used: the volume of water use, the volume of wastewater generated, and the BOD, COD, TSS, Total Nitrogen, Total phosphorus, N-NH_3, DO, Total Coli-form content of wastewater. Indicators for problems associated with contaminated sediment include the volume of sediment, total Nitrogen, total Phosphorus and accumulated chemicals and medicines in the sediment. Finally, the indicator for the spread of diseases is the number of infected shrimp ponds. The following identifies, and where possible quantifies these indicators (summarized in Table 3.3) at the pond level.

Table 3.3 Indicators for environmental pressures caused by shrimp production in Can Gio

Environmental issues	Indicator number	Indicator	Unit
Wastewater	1.1	Total volume of water use	m^3
	1.2	Total volume of wastewater	m^3
	1.3	BOD	mg/l
	1.4	COD	mg/l
	1.5	TSS	mg/l
	1.6	Total Nitrogen	mg/l
	1.7	Total Phosphorus	mg/l
	1.8	$N\text{-}NH_3$	mg/l
	1.9	DO	mg/l
	1.10	Total Coli-forms	MNP/100ml
Sediment	2.1	Volume of sediment	m^3/y
	2.2	Total Nitrogen	mg/l
	2.3	Total Phosphorus	mg/l
Disease spread	3.1	Infected shrimp ponds	(%)

3.4 Environmental impact of intensive black tiger shrimp farming

3.4.1 Water pollution

Water pollution is largely associated with the use and discharge of water in shrimp ponds. Each time water is exchanged; wastewater is discharged to the surrounding surface waters, as indicated in Figure 3.3. The wastewater carries a number of pollutants, reflected in the selected indicators. These pollutants ultimately stem from chemicals, fertilizers and feed added to the ponds.

Lime ($CaCO_3$, $CaOH)_2$ or CaO is used to neutralize the acidity of the soil in the pond in the preparation phase, and the amount used depends on the pH of the soil. Typically 200-250 kg/ha of lime is applied to the surface water during the grow-out phase to stabilize the acidity of the water. In Can Gio, the soil often has a pH below 6 or 5. According to the experiences of the farmers, 1.0 to 1.5 tons/ha of Lime is required. Fertilizers are used for increasing the food (algae) for shrimps in the preparation phase (also referred to as coloring). In intensive farming, pellet industrial feed is increasingly being used instead of fertilizers. Fertilizers are typically organic such as chicken, pig or cow manure, or inorganic such as ammonium phosphate called NPK (N:P:K =16:20:0), di-ammonium phosphates – called DAP (N:P:K =16:46:0), applied in a NPK: DAP ratio of 1:3. The average dose is 0.7 kg per 1000 m^3 of water per crop. For this study the total amount of fertilizer is estimated at 3.5 kg/pond/crop, including NPK and DAP.

Chemical flocculants like aluminum-sulfate and kali-sulfate are used at concentration of 10 – 20 mg/l to reduce the turbidity of water. Zeolite is used at 100-500 kg/ha to remove NH_3 in the pond, however, the efficiency of this chemical has been subject to recent discussion (Anh et al. 2004). Axit Dinatri Ethylendiamin Tetra acetic (EDTA) is used to reduce the effects of heavy metals in the water by creating compound matters. Decontaminants used include chlorine at 25 – 30 ppm, $KMnO_4$ at 5-10 ppm, and formalin at 15 - 250 ml/l. Other antibiotic agents, despite being illegal, such as Nitrofuran, Phenicol, 4-Quinolon, Tetracycline and other pesticide agents such as Rotenone, organic phosphate, and Saponin are used to kill other fish in the pond preparing phase.

Feed rates depend on the shrimp density and body weight. We assume a stocking density of 25 shrimp/m^2 in a shrimp pond with an area of 5,000 m^2 and, after four months, a survival rate of 65% with shrimp size of about 40-50 shrimp/kg. The crop would then be about 1.6 to 2.0 tons of shrimp per crop. We also assume an FCR of 1.3 with an average shrimp harvest of 1.8 tons. Therefore, the amount of feed used is 1.8 x 1.3 = 2.34 tons.

We assessed the indicators for water pollution on the basis of a water balance for shrimp ponds. Water supply includes initial and supplemental water, as well as rainfall. Water removals are through continual exchange during the grow-out phase (at a rate of 15% of total volume every 10 days), emptying ponds after harvesting, and through evaporation (see Figure 3.3).

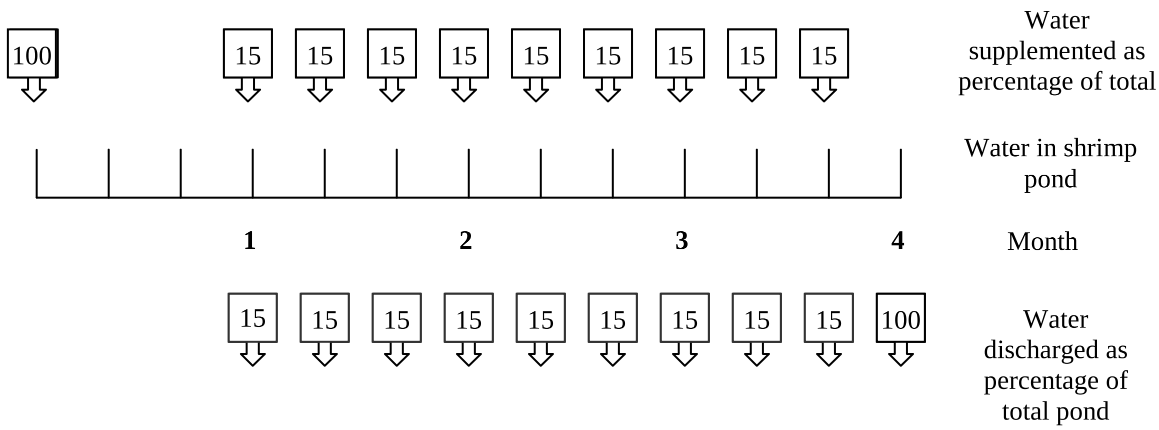

Figure 3.3 Overview of water supply and discharge in ponds over time

The volume of water used (Indicator 1.1) was calculated based on the average dimensions of surveyed shrimp ponds and the total initial and supplemental supply. The volume of initial water supply is 7,500 m^3/pond/crop and supplemental water is estimated at 10,125 m^3/pond/crop. The total water supply for one pond over one crop is therefore estimated at 17,625 m^3.

The volume of wastewater (Indicator 1.2) is calculated using an evaporation coefficient of K_e^d for the dry season of 173 mm/month and 83 mm/month for the wet season (based on Vietnamese meteorological data). This gives a total volume of wastewater in the dry season of approximately 14,165 m^3/pond/crop and, with an estimated amount of rainfall of 150 mm/month, an estimated 18,965 m^3/pond/crop in the wet season.

The rest of the key indicators (1.3 to 1.10 in Table 3.3) are based on direct measurements taken from ponds in Can Gio with different cultivation periods. The results are compared with Vietnamese water quality and BAP[5] standards (Table 3.4).

The results indicate that there are no significant changes in pH during the cultivation period because pH is maintained by adding dolomite and lime. The levels of BOD_5, COD and TSS increase with the cultivation period. This result concurs with Senarah et al (2001), and can be explained by the fact that older shrimp need more feed and produce more waste than younger shrimp.

[5] BAP: Global Aquaculture Alliances Best Aquaculture Practices Standards

Table 3.4 Characteristics of wastewater from intensive black tiger shrimp ponds in Can Gio.

Parameter	Unit	Wastewater from shrimp ponds by month during grow-out period			Standard
		<1month	2-3 month	3-4 month	
Temperature	^0C	30.5 (30 – 32.4)	30.8 (29.4 – 32.9)	30.5 (30 – 32.4)	n.a.
pH		7.6 (7.2 – 8.4)	7.6 (7.3 – 8.2	8 (7.2 – 9.1)	6.0 – 9[(1)]
BOD_5	mg/l	21 (8 – 48)	39 (15 – 84)	41 (22 – 59)	≤ 50[(1)]
COD	mg/l	68 (6 – 106)	100 (72 – 120)	132 (79 – 246)	≤ 100[(2)]
TSS	mg/l	69 (26 – 95)	81 (53 – 158)	254 (22 – 1031)	≤ 100[(1)]
N_{total}	mg/l	2.2 (0.08 – 3.2)	3.2 (0.1 – 7.6)	5.7 (1 – 14.8)	n.a.
P_{total}	mg/l	0.25 (0.1 – 0.5)	0.4 (0.1 – 1.0)	0.7 (0.1 – 1.7)	n.a.
$N\text{-}NH_3$	mg/l	0.5 (0.1 – 0.6)	0.8 (0.1 – 1.6)	0.7 (0.56 – 0.84)	≤ 5[(2)]
DO	mg/l	6.6 (3.5 – 8.2)	6 (3.9 – 8.6)	6.6 (5.5 – 7.5)	≥ 4[(2)]
Coliforms	MPN/100ml	4475 (2100-11000)	$2.4.10^3$ - 24.10^3)	11.10^5 - 15.10^5	≤ 5000[(2)]

n.a. = Not Available

(1) BAP standard (Global Aquaculture Alliances Best Aquaculture Practices Standards) and Vietnamese water quality standard for industrial effluents discharged into coastal water using for protection of aquatic life (TCVN 6986-2001)

(2) TCVN 6986 – 2001

After two months, the average water quality parameters in the ponds exceed the BAP and Vietnamese standards for BOD, COD, TSS and coliforms. For other indicators this is not the case. However, because of the variation among ponds (Table 3.4) we may conclude that there are many individual ponds that exceeded the standards. For instance, COD and TSS concentrations show large variation among ponds and periods. This also implies that some indicators do not exceed the standards. However, given the large volume of wastewater collected in canals high pollutant loading in the surrounding environment greatly exceed water quality standards. Similarly, total coliforms in the wastewater samples were high compared to standards.

3.4.2 Contaminated sediment

Sediment in shrimp ponds is generated from many sources: (1) suspended solids from inflow, lime, fertilizers, chemicals, and antibiotics, (2) uneaten feed, dead phytoplankton, and prawn moult, (3) solid waste from shrimp production process, and (4) inorganic matter eroded from the pond walls. The contribution of different sources of sediment in shrimp ponds is outlined in Table 3.2.

Solid waste from shrimp production includes bottles, cans, paper, plastic bags of chemicals, food and additives, and plastic bottom layers. According to the farmers, total solid waste generated after one crop is about 30 to 50 kg per pond. Because there is no solid waste collection system in Can Gio we added total solid waste to the total volume of sediment.

There is a relationship between accumulated sediment, pond water, feeding rate, and stocking density throughout all stages of shrimp farming cycles. An upward trend in shrimp stocking or shrimp biomass level results in an increased input of organic matter into the pond in terms of feed, as well as a downward trend in feed efficiency (increasing the FCR). Consequently, more waste is produced when organic matter accumulates in sediment and degrades, beginning a nutrient cycle in which ammonia, nitrite, nitrate, are formed.

The volume of sediment (Indicator 2.1) that accumulates within the shrimp farming pond during each rearing cycle and that is removed from the pond after harvesting have been estimated at 185-199 t dry wt/ha or 139-150 m^3/ha (Funge-Smith and Briggs 1994) or 200 – 836 t dry wt/ha or 151 – 629 m^3/ha (Tunvilai et al. 1993). In our study, we estimate the calculated sediment to be approximately 150 - 200 m^3/ha. This sediment is not suitable for agriculture and horticulture fertilizer because of its low organic content, large volume and high salt content (Dierberg and Kiattisimkul 1996).

Our measurements indicate that total nitrogen (TN) content in sediments is about 0.7 – 1.7 mg/g, and total phosphorus (TP) content about 0.003 - 0.2 mg/g. This is considerably less than concentrations found in sediments of shrimp pond systems outside of Vietnam. For example, in New Caledonia the TN content was 1.1 - 2.66 mg/g of dry sediment in semi-intensive shrimp ponds (Lemonnier and Faninoz 2006). In Sri Lanka, TN contents were 0.7 – 2.8 mg/g and TP contents 0.36 mg/g – 0.74 mg/g (Senarath and Visvanathan 2001).

Finally, the use of chemical, fertilizers, drugs as antibiotic into the shrimp ponds can accumulate into the sediment (Indicator 2.4). This raises an important issue in shrimp hatcheries. Antibiotic concentration in shrimp ponds may do harm to the environment, and contribute to the increase in drug-resistant diseases (Tuan et al. 2003). Chemical characteristic of shrimp pond effluents have been evaluated in different shrimp culture systems (Briggs and Smith 1994; Rivera-Monroy et al. 1999; Lyle-Fritch et al. 2006). However, the use of chemical substances in shrimp aquaculture remains low in comparison with agriculture and other economic activities (Paez-Osuna 2001). The most common substances used in shrimp ponds are fertilizers and liming materials; other substances are used less frequently. However, sediment only causes problems when it is discharged to surface waters, and this is not always the case if there is good management and awareness by farmers.

3.4.3 Spread of diseases

Shrimp diseases are often caused by polluted water in the pond itself. High BOD and COD concentrations are a favorable condition for pathogenic microorganisms. Most of the wastewater and contaminated sediment from shrimp ponds is discharged into receiving waters. This, however, is the source of water for other shrimp ponds. Without proper treatment, the pathogens from infected ponds are likely to spread to other ponds. Currently, hardly any shrimp farm carries out water or sediment treatment in Can Gio since the costs of between VND 4 – 5 million (about USD 300) for a 5000 m^2 pond, are relatively high compared to the costs of losing a crop. The disease spread is partly a result of shrimp cultivation in the second season (from July to November) when the farmer wants to get higher prices in the market. Breeding stock in inappropriate conditions also enhances the risk for disease epidemics. When the diseases can be detected, they are difficult to control because of poor regulation, and the 'open' nature of land and water resources.

The majority of current shrimp disease problems can be categorized into two major groups: bacterial and viral. The causes of bacterial diseases are mostly Vibrio spp. Vibriosis outbreaks constitute a serious problem in intensive shrimp ponds (Menasveta 2002). Viral shrimp diseases include the Monodon Baculo virus (MBV), Yellow-Head virus (YHV), and White Spot Syndrome virus (WSSV). Viral diseases provoke the largest losses in shrimp farming (Rosenberry 1998), with many countries having faced significant reduction in production because of different diseases, although they include varying degrees of intensification, different climates, and distinct cultured species (Páez-Osuna et al. 2003).

Since 2005, Vietnamese shrimp cultivation has been hindered by disease in many regions. Less than 70% of shrimp farmers stop farming in order to avoid further infection. As a result, many shrimp farmers suffered a loss of income and some abandoned production altogether. To illustrate the impact of disease, in the 2006 shrimp season, approximately 22,500 households practiced shrimp cultivation, stocking approximately 2 billion larvae in 23,000 ha of ponds. Of this approximately 1 billion larvae, aged between 30 and 50 days, belonging to around 14,000 households were infected and died (Hoang 2006).

3.4.4 Overall pollution

Table 5 summaries the overall pollution of intensive black tiger shrimp farming in Can Gio (Table 3.5). These calculations ignore evaporation and rainfall, and assume that the average amount of wastewater produced equals the amount of water used in shrimp farming. We calculate the pollutants' load based on the frequency and amount of water exchange. We estimate that during the first month of farming about 1,125 m^3 of wastewater is produced per farm (0.5ha); during the second and third month about 6,750

m^3, and during the fourth month about 9750 m^3. Based on this, we calculated the average pollutant load of farming per ton of shrimp produced and per hectare.

Table 3.5 Pollution caused by black tiger intensive shrimp farming in Can Gio district

No	Indicator	Pollutant load (1)		Per ton of shrimp (2)		Per ha of farming	
		Valued	Unit	Value	Unit	Value	Unit
1.1	Water use	35,250	m^3/ha/crop	6,651	m^3/ton		m^3/ha
1.2	Wastewater	28,330 – 37,930	m^3/ha/crop	5,345 – 7,157	m^3/ton		m^3/ha
1.3	BOD	0.04	kg/m^3	259	kg/ton	1,373	kg/ha
1.4	COD	0.12	kg/m^3	769	kg/ton	4,077	kg/ha
1.5	TSS	0.18	kg/m^3	1,170	kg/ton	6,202	kg/ha
1.6	Total N	4.5	g/m^3	30	kg/ton	159	kg/ha
1.7	Total P	0.6	g/m^3	3.7	kg/ton	20	kg/ha
1.8	N-NH3	0.7	g/m^3	4.8	kg/ton	26	kg/ha

Notes: (1) calculated from Table 3 and the volumes of wastewater in different periods of shrimp farming; (2) average 5.3 ton of shrimp/ha

The water pollution per ton of shrimp product and per hectare of shrimp farming from farming process are 259 and 1373 kg BOD, 769 and 4077 kg COD, 1170 and 6201 kg TSS, 30 and 159 kg of total nitrogen and 3.7 and 20 kg of total phosphorus, 4.8 and 26 kg of Ammonia-Nitrogen ($N\text{-}NH_3$), respectively. The loads per hectare are considerable. For instance, N and P loads exceeding 150 and 20 kg per hectare in shrimp ponds are comparable with N and P loads in agriculture fertilizers, and pose a real threat to oligotrophic aquatic systems. Our estimates for total pollution are calculated from wastewater discharge only. Where sediment is discharged direct to the river or canal, the estimated pollution load to water surface would be higher.

Table 3.6 Comparison of intensive shrimp farming in Vietnam (Can Gio) and Thailand

Stocking density	Unit	Thailand[1]		Can Gio[2] (Vietnam)
	Shrimp/m^2	50-60	80 - 100	20 - 40
TSS	kg/ha/crop	6650	9658	6201
Total Nitrogen	kg/ha/crop	178	223	159
Total Phosphorus	kg/ha/crop	15.7	24.9	19.6
$N\text{-}NH_3$	kg/ha/crop	18.4	71	26

Source: [1] (Dierberg and Kiattisimkul 1996); [2] This study

Comparable studies do exist on shrimp farming in Vietnam (Mang et al. 2008), but most have not been published. Table 3.6 therefore compares our TSS, TN, TP and Ammonia Nitrogen loads with those from intensive black tiger shrimp in Thailand (Dierberg and Kiattisimkul 1996). The result first of all indicates that the Vietnamese ponds, although intensive, have lower stocking densities than the ponds in Thailand and, in line with this, lower concentrations of TSS, TN, TP and N-NH3. Compared with other studies on black tiger shrimp with almost the same production of 2 to 5 tons/ha/crop, our results show a lower net nitrogen discharge of 159 kg/ha/crop than in Thailand, where estimates range between 190 kg/ha/crop and 509 kg/ha/crop (Robertson and Phillips 1995; Jackson et al. 2003).

3.5 Options to reduce the environmental impact

The second objective of this paper is to identify options to reduce the environmental impacts of water pollution, contaminated sediment and the disease spread. However, effectiveness is not the only criterion for selecting the following options. We have also taken into consideration both technological and economic feasibility of the technologies. This is especially important because of the variability of income from shrimp farming in Vietnam and the reluctance of farmers to invest in high cost technologies (Lebel et al. 2002a; Hue and Scott 2008). The identification and evaluation of these technologies is based on secondary sources, as well as newly collected information from field research and the system analysis presented above. The following reports on two approaches for ameliorating the impacts of water pollution, contaminated sediment and disease spread: (1) waste prevention and minimization at source and (2) treatment and reuse of effluent streams.

3.5.1 Waste prevention and minimization at source

Waste prevention and minimization at the point source of pollution holds some promise as an abatement strategy for shrimp production in Vietnam. These approaches adopted in other sectors include more efficient use and management of waste streams, often labeled ‘good housekeeping’ (Ramjeawon 2000; Henningsson et al. 2001; Hyde 2001), as well as more strategic changes to input control, including changing raw material inputs (Chaan-Ming 1995; Vigneswaran et al. 1999), or adopting new technologies (European Commission 1997). The information presented in sections 4.1, 4.2 and 4.3 reveal there are considerable gains in pollution mitigation through appropriate options for prevention and minimization of environmental problems from shrimp farming. The different measures, outlined below and summarized in Table 3.7, include techniques for the reduction of water, feed, chemical and medicine use, as well as improved farm management.

Table 3.7 Waste prevention and minimization at source

Options	Description	Pollutants/problems reduced	Subsystem to be applied	Problems reduced			Remarks
				WP	CS	DS	
Water use reduction	Ozone aeration	BOD, COD, Pathogen, water use, wastewater	Aeration/ water	+++	+++	+++	Need a technical transfer to farmer
Feed use reduction	More efficient feed use: Careful in checking optimum use of feed	BOD, COD, Pathogen,	Feeding	++	++	++	Lack of information on experiences with different type of feeds. Need information exchange
Chemical, medicine use reduction	Better guidelines and monitoring for correct use of chemical and medicine on appropriate doses and frequency are needed	Accumulated chemical and medicine	Pond treatment/ nursing	+	+	+	

[1] WP: Water Pollution; S: Contaminated Sediment; DS: Disease Spread;

+ indicates a moderate improvement, ++ a considerable improvement, +++ a large improvement

3.5.1.1 Ozone aeration technology

Water use reduction by ozone aeration technology is a widely proposed technology for use in shrimp farming to improve the water quality in the pond, which means the frequency of water exchange can be reduced. Currently, ozone aeration technology is generally studied and used in USA, Thailand, Korea and India for shrimp farming and other forms of aquaculture (Schuur 2003; Jongsuphaphong and Sirianuntapiboon 2008). With this technology, ozone is aerated into ponds via ozone generation equipment. In Thailand, Jongsuphaphong (2008) have demonstrated success with the oxygen supply apparatus in shrimp farms with a water flow rate of 10 l/min. The results show that when the apparatus was used with ozonation there was more of an effect than aeration with oxygen supply alone. Moreover, ozone generation showed the additional advantage of reducing organic matter in the water, such as BOD and COD, while increasing DO at the same time. By doing this, the disease outbreak is also reduced because of less water discharge and degradation of water quality in the receiving streams.

Ozone aeration technology is not currently applied in Vietnam. Some experiments have been carried out in Nam Dinh province with freshwater shrimp (*Macrobrachium rosenbergii).* The results show higher yields of 10 ton/ha compared to 4 ton/ha in normal aeration system, as well as less water use and a low mortality rate (Liêm 2008). Ozone aeration has been promoted by provincial governments for Tiger shrimp. However, due to the added cost and required technical knowledge farmers have not adopted this technology. If it can be demonstrated to farmers that ozone aeration increases production at minimal extra cost, as seen in Nam Dinh, it may prove a very suitable. Costs can also be reduced given many farmers have already invested in oxygen-based aeration equipment and by selectively applying aeration in the last months of the grow-out cycle when the concentration of wastewater pollutants are at their highest. If ozone aeration is limited to this last grow out phase, thereby reducing the overall cost of water treatment, it may prove suitable for Vietnamese intensive production.

3.5.1.2 Feed strategies

Reduction of feed is another option to reduce pollution given that feed residue is the most important factor in the generation of sludge. Currently in Vietnam pellet feeds are predominantly used is semi-intensive and intensive shrimp farms. Domestic companies produce over 100 types of feed and many more are imported from Germany, Thailand, Korea, China. Although attempts are made by the National Fisheries Quality Assurance and Veterinary Directorate (NAVIQAVED) the large number of feeds available on the market means the government is unable to test and control feed quality across the industry. Because of the uncertainty over the composition and quality of feed farmers often fail to determine the most efficient feeding regime for their ponds.

The FCR used in this paper demonstrates a high efficiency, however according to interviewed farmers FCR in intensive farmers in Vietnam can be as high as 2.2. In Thailand FCR is even as high as 4 (NACA 2004). The individual FCR of farms varies greatly between brands and the experience with feeding techniques used by farmers. If farmers can gain access to more accurate information over the composition of feed it is likely they could better determine the most efficient feeding regime. However, many farmers interviewed in Can Gio and other provinces in this study were unable to accurately calculate their FCR. Further research is therefore needed to determine the benefits of quality testing and control would support farmers to improve their feeding efficiency.

3.5.1.3 Drug and chemical use

A reduction in the use of drug and chemical use is also an option to reduce pollutant load in wastewater and sediment, as well as the accumulation of these components in the shrimp itself. Shrimp remains one of the most risky aquaculture products in terms of food quality (Dey et al. 2006). In Vietnam technical guidelines are available to farmers listing over 17 banned and 34 limited use substances (Decision 07/2005/QD-BTS). Yet it is only since the private sector drug and processing companies have began offering greater control over the input of drugs for intensive farms in Vietnam that the incidence of contaminated shrimp products has reduced in consumer markets.

More stringent food safety testing has led to a reduction in product contamination, yet farmers remain highly sensitive to the risk of crop failure and continue to use both pro and anti-biotics. Farmers know techniques to reduce the level of chemicals and drugs in shrimp, for example by stopping inputs in the weeks before harvest. Although reducing the food safety risk, these chemicals and drugs are flushed with water exchange and accumulate in water and sediment, and subsequently, the development of antibiotic resistance in bacteria in the environment (Tuan et al. 2005). As such, the environmental risk of drug and chemical use remains high.

3.5.2 Treatment and reuse of effluent

In addition to more efficient use and management of inputs farmers also have a range of water treatment and reuse options available. Generally, these offsite reuse and recycling options create economic benefits as less energy is consumed for producing new products from recycled materials, thereby sparing the environment from further degradation as less virgin material is used (EPA 1996). If there are no possibilities of waste minimization nor recycling and reuse, waste treatment of waste streams is the approach of last resort (Table 3.8).

Table 3.8 Treatment and reuse of effluent streams

Options	Description	Subsystem to be applied	Problems reduced[1]			Remarks
			WP	**CS**	**DS**	
Treatment and reuse of sediment	Make compost, or soil conditioner from sediment	Sludge discharge	+	+++	+	More research is needed on the practical and species of plant
Treatment and reuse of wastewater	Use Mangrove forest wetland or Constructed wetland	Wastewater discharge	+++		+	Research on feasible plant in the constructed wetland in the soil and saline condition of Vietnam
Wastewater and sediment discharge	Optimal design and plan for the shrimp farming area to ensure that wastewater do not return directly to the surface water or overflow to other system		+	+	+++	

[1] WP: Water Pollution; S: Contaminated Sediment; DS: Disease Spread;

+ indicates a moderate improvement, ++ a considerable improvement, +++ a large improvement

3.5.2.1 Sediment treatment and reuse

The treatment and reuse of the sediment through composting remains limited in shrimp farming in Vietnam. Such approaches have been proposed by Xia (2004) in China and Páez-Osuna (2003) in the Gulf of California. Currently, bioremediation or bacterial augmentation has received increasing attention because it appears an environmental friendly approach to minimize environmental degradation. Bioremediation products are known as probiotics. Some studies indicated that the application of probiotics to pond sediments could accelerate decomposition of undesirable organics and other waste products (Wang and Han 2007; Nimrat et al. 2008). In Vietnam, the use of probiotics is not officially recommended. However, to ensure their proper use it is necessary to develop publically accessible guidelines to farmers on suitable probiotics, thereby increasing their efficiency and reducing pollution. In Vietnam, the Centre of Applied Science and Technology in Binh Dinh province has researched the possibility of using shrimp pond sediment for composting (Mai 2006). Their study found that the sediment contained less nutrients than other compost and has a high salinity content as also noted by Boyd et al (1994). In the trial they mixed in coconut husk and other additives to increase the nutrient content and reduce the salinity. The compost residues from the Binh Dinh trial have been tested in onion cultivation and have shown promising results, doubling the production compared to normal cultivation. The study is continuing with different composition for different products.

The N and P content of sediment found in Can Gio (see section 4.2) is relatively similar to other parts of the country (Long and Toan 2008) - including Binh Dinh. Sediment reuse therefore appears to be a viable option for intensive shrimp farming. However, further research is needed to determine if there is enough economic incentive for farmers to engage in sediment composting. In addition, more information is needed on the practical and long term aspects of treatment and reuse of sludge including the possibilities for on farm production and trade.

3.5.2.2 Constructed wetlands

Because the low concentration of pollutants found in Can Gio intensive farming systems one of the most suitable, low-cost wastewater treatment technologies may be the use of wetland sedimentation. Constructed wetlands represent a natural treatment system based on biological symbiosis between macrophytes and microorganisms (bacteria, fungi, algae), and their interactions with the soil (Schulz 2003). Schulz et al. (2003) show that subsurface horizontal-flow constructed wetlands, consisting of a coarse sand bed with emergent macrophytes, can be used for the treatment of aquaculture effluent flow-through systems by applying hydraulic retention times of 1.5, 2.5 and 7.5 hrs. Treatment efficiencies of TSS and COD were in the range of 96-97% and 64-74%, respectively and appeared independent of hydraulic load. Removal rates of total nitrogen (TN) and total phosphorus (TP) were 21 – 42% and 49 - 69% respectively, showing lower efficiencies at decreasing residence times. The filtering characteristics of the sand bed at high TSS loading rates (9 - 73 g TSS/m^2/d) were expected, but were not observed during the six months of testing.

Such methods have been identified in various forms in the Best Management Practices and Good Aquaculture Practices (GAP) of the Vietnamese Government (NACA 2008), and also in international standards, including GlobalG.A.P., the Aquaculture Certification Council Best Aquaculture Practice standards and the ongoing WWF Shrimp Aquaculture Dialogue standards (ACC 2007; WWF 2008b; GlobalGAP 2009). Compared to conventional treatment methods, wetlands tend to be simple and inexpensive (where a sufficient supply of filter bed material is available). The disadvantage of this technology is the need of a large area of land at low loading rates. Indeed, farmers have had difficulty building these wetlands, or even more simple sedimentation ponds, because of a lack of available land (Gowing et al. 2006). If hydraulic retention times are in the order of 6 – 8 hrs, as applied by Schulz et al. (2003), the land requirement would be relatively modest.

In some cases natural or rehabilitated Mangrove forest can be considered as bio-filters for the pond effluents in place of constructing wetland areas (Fitzgerald 2002; Primavera 2006; Vaiphasa et al. 2007). However, within these systems farm density is important so as to not exceed the capacity of the environment to assimilate waste as ponds are flushed during low tide, and therefore are less suitable for intensive farming systems. The main indirect impacts from shrimp farming on mangroves could be changes in the hydrological pattern, as well as hyper-salinity and eutrophication (Páez-Osuna et al. 2003). In order for optimal functioning of mangroves to remove nutrients it has been estimated that 2-3 ha of forest is needed for one hectare of semi-intensive shrimp ponds (Robertson and Phillips 1995).

Can Gio provides a very suitable site for bio-filtration given the large area of rehabilitated mangrove forest. However, it is not possible to discharge to Mangrove areas for bio-filtration, because of the Man and the Biosphere designation the Vietnamese government is unlikely to approve the application of such techniques. Shrimp production areas in other provinces, such as Kien Giang and Ca Mau, may be more suitable given their large area mangrove and tendency towards more intensive shrimp production. The potential for provinces with a high degree of deforestation to develop bio-filtration technology will depend on the extent to which mangrove reforestation, as seen in Can Gio, can be implemented.

3.6 Conclusions

This paper has assessed the environmental impact of intensive black tiger shrimp farming and discussed relevant cleaner production techniques for Vietnam. We show that in an assessment of the environmental impact of shrimp farming, the following five activities need to be considered: pond treatment, inlet water treatment, feeding, water exchange and pond emptying. Within these activities, six practices can be identified as important sources of pollutants: chemical and medicine use, fertilizer use, water resource use, pellet feed use, wastewater discharge and sediment discharge. The most important environmental problems caused by shrimp farming are associated with water pollution, contaminated sediments and the spread of diseases. Based on this we identified fourteen different indicators that can be used to assess the environmental pressure (Table 3).

The pollutant loading from wastewater to produce one ton of shrimp are 259 kg BOD, 769 kg COD, 1170 kg TSS, 30 kg N, 3.7 kg P and 4.8 kg $N\text{-}NH_3$. The results indicate that the levels of BOD_5, COD and TSS increased within the culture period as well as the age of ponds. The concentration of pollutants in wastewater varies greatly among shrimp ponds. Given the variation in our results there are probably many individual ponds where the water quality standards are exceeded by a large degree. On the other hand, not all intensive shrimp farming is causing environmental problems. Intensive and semi-intensive shrimp farming in Can Gio account for about 17% of the total shrimp farming area. The remainder include improved extensive farming (55%) and extensive farming under rice shrimp farming (28%) (Can Gio Economic Division 2007), that are not considered a major source of pollution.

Two groups of technical options are identified for reducing the environmental pressure of water pollution, contaminated sediment and disease spread from individual shrimp farming pond in Vietnam. Based on the scale and potential of intensive shrimp farming in Vietnam the most viable options for waste reduction include more efficient feed use and ozone aeration. For the reduction of feed it is important that adequate and sufficient information is available to farmers and that the government can efficiently regulate the quality and composition of feeds. Aeration is noted as a particularly suitable technology given the low level of expense needed to implement it in existing intensive systems.

Options for waste treatment through sediment reuse and the construction of artificial wetlands are both viable options in Vietnam. Sediment reuse in agriculture may prove successful if the economics of its production can be justified to farmers. Wetland construction, although practiced on some farms, remains difficult to implement due to the lack of land available to farmers. Coordinated communal lands, or the rehabilitation of mangrove areas for this purpose, as partly seen in Can Gio, may prove a more viable low(er) cost option. Future research should assess the feasibility of these options, as well as the network of material flows creating waste/by product exchanges and the role of actors involved in their implementation to analyze the political/institutional feasibility of existing and potential options to reduce the environmental problems in aquaculture.

Chapter 4 Towards eco-agro industrial clusters in aquatic production: the case of shrimp processing industry in Vietnam[6]

ABSTRACT

The concept of industrial ecology has been applied in this research to study possibilities to develop an eco industrial cluster model for fishery production industry in Vietnam. By learning from experiments of other developed countries, we apply the principles of Industrial Ecology and of Ecological Modernization in the context of Vietnam. We design a physical-technological conceptual model for minimizing waste in agro-industries, with a case study of frozen shrimp production. The results indicate that it is possible and feasible to develop an eco industrial cluster including aquaculture, fishery processing companies, by-product plants, and wastewater treatment units. By doing so, aquaculture and industry can cooperate for environmentally sound development. Actors and institutions that may govern the proposed eco industrial cluster of shrimp processing industry are also analyzed in this paper.

Key words: eco-industrial cluster, eco-industrial park, industrial ecology, shrimp, aquaculture, shrimp processing

4.1 Introduction

Vietnam is an important producer or seafood worldwide. Today the country is among the world's top 10 seafood exporters (FAO 2009b). Half of the seafood produced in Vietnam comes from aquaculture (Nichols 2008). In 2007, aquaculture produced 2.1 million ton of aquatic products, evenly divided between freshwater and brackish/marine aquaculture (Dung 2008). The Mekong delta covers 12% of the total area of the country and accounts for 70% of the country aquaculture production (Don 2008). The aquaculture sector expanded enormously the last few years. Advantages are the growing need for labor force, famine elimination and poverty alleviation. The rapid growth of fishery industry in Vietnam is putting stress on natural resources and the environment. Water pollution, degradation of land resources, soil erosion, over exploitation of natural resources and threats to the ecosystem are among the challenges (Loc et al. 2007; Nhan et al. 2008; Bosma et al. 2009; Anh et al. 2010a). The fishery is completely dependent on the Mekong River as the protection of the Mekong River is immensely important in sustaining both the environment and economy.

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[6] This chapter contains an article submitted as Pham Thi Anh, Tran Thi My Dieu, Arthur P. J. Mol, Carolien Kroeze, ,Simon R. Bush , Towards eco-agro industrial clusters in fish production: the case of shrimp processing industry in Vietnam, to Journal of Cleaner Production

Fishery processing factories produce waste streams of diverse composition and concentration. Frequently, operations are run on a seasonal basis, and with simultaneous production lines for different raw materials. The main environmental concerns related to these industries could be described as (1) the use of large amounts of fresh water for processing, such as for washing raw material and products, cleaning of machines, containers or flushing the working floor, de-icing, thawing and salt soaking; (2) the production of large amounts of wastewater, since all the water used is discharged; (3) solid waste production from fish and shellfish operations, consisting of flesh, shell, bone, cartilage and viscera; (4) consumption of energy for machineries, freezing, cold storage, heating, drying, and water pumping, which contributes to increased air pollution and climate change; and (5) odor and aesthetic damage. Odor problems are commonplace due to spoiling debris and offal, and improper disposal of solid waste. Discharge of wastewater containing high levels of solids, spoiled offal, oils and fat from the fish can spoil the natural beauty of surrounding beaches and cause the pollution for fresh and marine water bodies. Islam and colleagues (Islam MS et al. 2004) identified effluents from fish and shrimp processing industries as a potential source of coastal and marine pollution.

Industrial ecology

The integration of various environmental protection approaches in an industrial system has been studied and incidentally implemented under the notion of industrial ecology. The idea of industrial ecology has been described in different ways in the literature by for instance (Ehrenfeld 1997), (Boons and Baas 1997), (Krrishnamohan and Herat 2000), and Dieu (2003). But all emphasise the ideas of reduce, reuse, and recycle material and energy to design sustainable industrial systems. Industrial ecology, as a broad framework for thinking and acting in the realm of sustainability, is based on the metaphor of ecological systems in looking at industrial systems, and improving the design of individual firms and larger, complex industrial systems (industrial parks, clusters, networks, chains) (Ferrão 2007). Industrial ecology combines and integrates notions of cleaner production, waste prevention and minimization, reuse and recycling, life cycle analyses, and the like. With respect to food processing in Vietnam ideas of industrial ecology have been methodologically operationalized by Dieu (2006). Mol and Dieu (2006) applied the idea of industrial ecology on the Vietnamese tapioca industry and designed a physical-technological model and a network model to minimize waste in this food industrial system.

Designing an integrated model of pollution prevention for industrial systems usually starts with analyzing the material and energy flows in such industrial systems (Dieu 2003). These flows can cause emissions, waste and exhaustion of natural resources. Subsequently, various physical-technological and management possibilities are identified for reducing these emissions, waste and natural resource use in an industrial system. The identification and design of measures and options of prevention, (external) recovery, recycling and reuse leans heavily on cleaner production methodologies. The remaining waste often needs proper treatment before discharging into the environment, usually through end-of-pipe treatment technologies. Together, these steps lead us to a physical-technological model for low-waste industrial systems. Such physical-technological models need to be combined with an analysis of actors and institutions that do and can govern existing industrial systems into eco-industrial systems. Hence, the last step involves an analysis of the social and institutional environment in which the industrial system is embedded, in order to assess the feasibility and potential strategy of moving such an ideal-typical industrial ecology model into reality. Ecological modernization theory has proved to be a valuable starting point for such institutional analyses (Koppen and Mol 2002; Mol and Dieu 2006; Mol et al. 2009) .

In Vietnam, shrimp is farmed in the brackish water along the coastal areas in the Mekong delta, and mostly in Ca Mau, Bac Lieu, Soc Trang, Ben Tre, Tra Vinh, and Kien Giang provinces (MARD 2009a). The activities of fish and shrimp farming and processing can cause problems to the environment, directly or via related activities to support the production chain (Islam MS et al. 2004; Anh et al. 2010a). In the Mekong delta, we can find the whole production chain of aquaculture production (Loc 2006; Khoi 2007). The fishery sector has a relatively strong supply chain in which various industries are closely linked. The supply chain starts with shrimp farms and continues up to the frozen shrimp processing industry with various other allied production facilities and services connected. These various industries in the supply chain are clustered geographically together in the Mekong delta, and thus form an agro-industrial cluster: a network of supply chain industries in geographical proximity and with material exchange. This paper will analyze this cluster, illustrate how such an agro-industrial cluster can be designed in more sustainable terms using ideas of industrial ecology, and identify the actors and institutions that may help to realize such an eco-agro-industrial cluster of frozen shrimp production in the future.

Hence the purpose of this study is apply the idea of eco-agro-industrial clustering for reducing pollution, protecting natural resources and improving the competitiveness of the shrimp production and processing sector in the Mekong delta, Vietnam.

In the Mekong delta shrimp production system, each processing industry has its own material supply sources. This supply of shrimps is governed by contracts between processor, brokers and many farmers. Each processor sources material supply from many farmers, which can be located in different provinces, though usually within the Mekong delta area. As transportation might be a crucial issue in eco-industrial clustering, we selected Soc Trang province as the case for ecologizing shrimp production. Soc Trang is one of the provinces in Vietnam with the highest production of shrimp in terms of both farming and industrial processing. In 2008 it had a production capacity of 52 ktons fresh shrimp by farming almost 48 thousand hectares (MARD

2009a). And Soc Trang processes around 34 ktons of frozen shrimp per year (DARD Soc Trang, 2008).

The paper will be structured as follows. Section 2 deals with the shrimp production chain and presents a material balance of frozen shrimp processing. Section 3 focuses on options in constructing an eco–agro-industrial cluster for shrimp processing industry. Section 4 focuses on designing an eco-agro-industrial cluster for frozen shrimp industry in Soc Trang province. Section 5 analyzes the governance of the eco-agro-industrial cluster for shrimp production, focusing on actors and institutions. The last section presents the conclusions.

4.2 Shrimp production chain and material balances of frozen shrimp processing

4.2.1 Shrimp production network

The shrimp production network starts with the shrimp hatcheries. From the hatcheries the shrimp larvae are transferred to the shrimp grow-out farms, where after 90 to 120 days shrimps are harvested. A broker or middleman collects shrimps from around 100 to 200 farms in the area, depending on the quantity of the collected shrimps. The broker delivers the collected shrimp to one processing company. The shrimps are often frozen for 1 to 2 days before bringing them to the processing industry. Soc Trang has 9 fish processing industries with in total 13 shrimp processing factories. Current locations of the shrimp processing industries in Soc Trang province are shown in Figure 4.1. The most common export products of shrimps are frozen shrimp, for which shrimps are processed into Individual Quick Frozen (IQF) shrimps. We may distinguish four phases in the frozen processing: (I) pre-treatment; (II) de-heading; (III) trimming and (IV) freezing, packing and storage (Figure 2). We may refer to these phases as processing sub-systems. Two other sub-systems need to be mentioned: (V) ice production for chilling shrimps during processing; and (VI) cleaning in all steps during and after the processing.

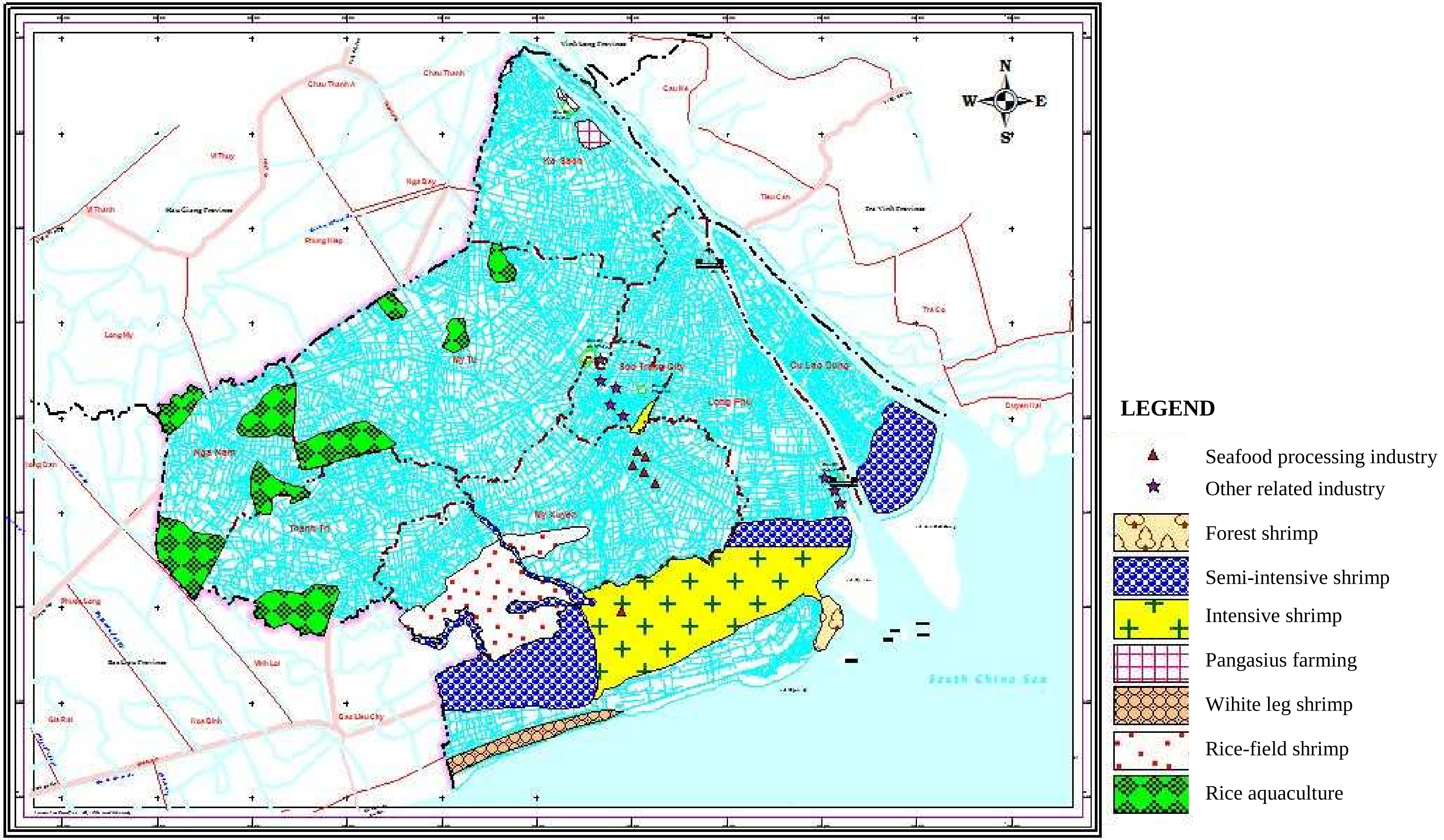

Figure 4.1 Current location of the shrimp processing industries in Soc Trang province

(source: Soc Trang (DARD 2008) and this study)

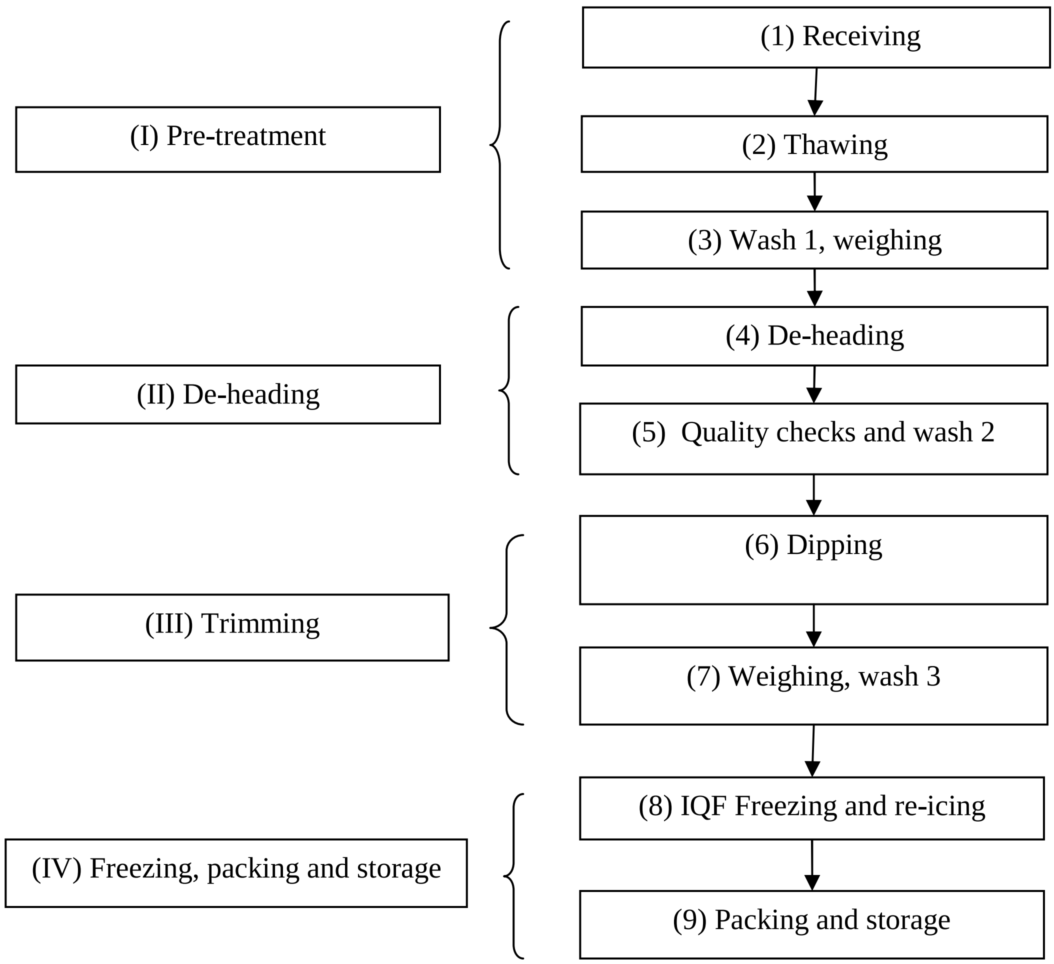

Figure 4.2 Schematic overview of frozen shrimp processing as typically applied in Vietnam

Figure 4.2 shows the typical method for processing Individual Quick Frozen shrimp. The pre-treatment of shrimp involves three steps. (1) Shrimps are received in plastic bags in frozen form. If processing does not start directly, the shrimps are stored in the freezing room. (2) The shrimp is thawed by water in a 400 litter container, where the water level is half of this volume. Next (3) shrimp is washed in another container to release the impurities, and shrimp is weighed before going to the de-heading phase. This second phase includes 2 steps: (4) the shrimp is de-headed and put in a basket, with about 5 kg/basket. (5) This semi-product undergoes a quality check and has a second wash in water, for 3 times. The next trimming phase includes 2 steps: (6) shrimps are dipped in a solution with additives and ice, and graded to have better form. And (7) shrimps are weighed and have a third wash. At the last phase, (8) shrimps undergo the IQF freezing and re-icing and (9) the frozen shrimp product is packed in plastic bags of 450g, put in a carton box and placed in a storing room at -18^{o}C to -20^{o}C, ready for transport. All water for washing contains ice to ensure the temperature of water is low (often < 7^{o}C) to maintain the shrimp quality during processing. It also contains chlorine for hygienic purposes. All production conditions have to follow required sector standards on fishery processing establishments- HACCP-based quality management program and basic hygiene and food safety conditions (MOFI 1998a; MOFI 1998b).. The final product can be exported or consumed in the local/national market. By-products like shrimp heads can be used in as animal feed, while shrimp shells can be processed to chitosan (a polysaccharide used in agriculture, food industry and water treatment, among others). Other wastes from the shrimp processing industry, including inorganic solid waste and wastewater, have to be treated according to Vietnamese regulations.

Among the considered sectors in the shrimp production network, shrimp farming and shrimp processing are located in Soc Trang province while the others such as hatcheries, animal feed processors and chitosan processing units are located in other areas or provinces. Shrimp farmers are mostly small scale, and brokers have to collect shrimp from many farms in different areas and provinces. The existing links among these actors are quite weak. Better technologies, policies and contracts are required for improved interaction.

4.2.2 Material balance of processing one ton of raw shrimp

We take an environmental systems analysis approach here, as Anh et al (2010cb) did for pangasius processing. The key method we use for material balances is material flow analysis (Fujie and Goto 2000b). Material flow analysis studies how materials and energy flow into, through, and out of a system. Specifically, material flow analysis refers to accounts per physical units such as tones, resulting from the extraction, production, transformation, consumption, recycling, and disposal of materials within a system. (Bringezu et al. 1995) (Kandelaars 1999), (Bouman et al. 2000), (Cooper 2000) and (Brunner and Rechberger 2004a) provide overviews and analyses of material flows.

The data needed for our analysis was obtained from literature, site visits and in-depth material balance studies for one frozen shrimp processing plant in Soc Trang province. In this company, only frozen shrimp is produced. Based on observations, interviews, measurements and internal documents, we accounted the inputs and outputs of materials for the processing of one ton of raw material (shrimp). The most important inputs include raw shrimp, water, salt, chlorine, and energy (electricity and fuel). The most important outputs include frozen shrimp products and non-products (wastewater, solid waste and by-products). The material balance was partly based on repeated visits during a three month study period in the year 2008 at the plant in Soc Trang province. The information has been checked with the officers of the factory through monthly bills of water use and electricity use. In addition, wastewater from shrimp processing were sampled and collected from the Environmental department of Soc Trang province of six different shrimp processing plants. These samples were analysed following the standard methods of water sampling and analyzing (APHA 2005) on the following parameters: TSS, COD, BOD_5, total nitrogen and total phosphorus.

4.2.2.1 Inputs and outputs

Inputs

Raw material: The used raw material was standardized at 1000 kg of shrimp

Freshwater: The volume of water used was calculated from the survey data for different steps in the process. The inventory includes various activities, such as the amount of water used in each washing basin and water for cleaning. The average water use for processing one ton of raw shrimp is 15 m^3.

Energy: Electricity is used in most steps of the frozen shrimp production to operate machinery, for lighting, air compressing and cold storage facilities. Electricity use only includes electricity used during the production process. It excluded electricity used in wastewater treatment plant or other electricity used in the industry that is not directly related to the production process. Total electricity use for processing one ton of shrimp is 556 kWh.

Others: The processing of one ton of shrimp also uses 1.4 kg of Chlorine and 6 kg of salt

Outputs

Product: Processing one ton of shrimp results in 595 kg of frozen de-headed shrimp

Wastewater: The volume of wastewater is about 14.6 m^3 due to the water contained in the product and water loss. The wastewater characteristics are described in Table 1

Organic waste: The generated solid waste during processing consists mainly of head and cover of the shrimp. The collected solid waste is about 339 kg per ton processed shrimp.

Inorganic solid waste: Inorganic solid waste includes damaged plastic and carton boxes. The collected non-organic solid waste is about 11 kg during the processing of one ton of shrimp.

Others: the residual heat is discharged to the environment

4.2.2.2 Solid material balance

This balance considers the flow of all solid materials through the production process including raw materials, products, by-products and wastes. The calculated solid material balance for producing one ton of shrimp is described in Figure 4.3.

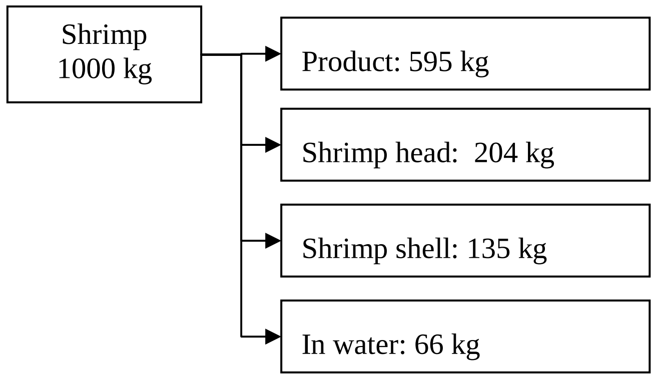

Figure 4.3 Material balances for processing one ton of shrimp.

4.2.2.3 Water balance

The volume of water use and wastewater are calculated from the survey data for different phases in the process. The inventory includes various activities, such as the amount of water and ice used in each washing basin and for cleaning. The average water use for producing one ton of shrimp is 15 m^3, including ice production. The water balance is described in Figure 4.4.

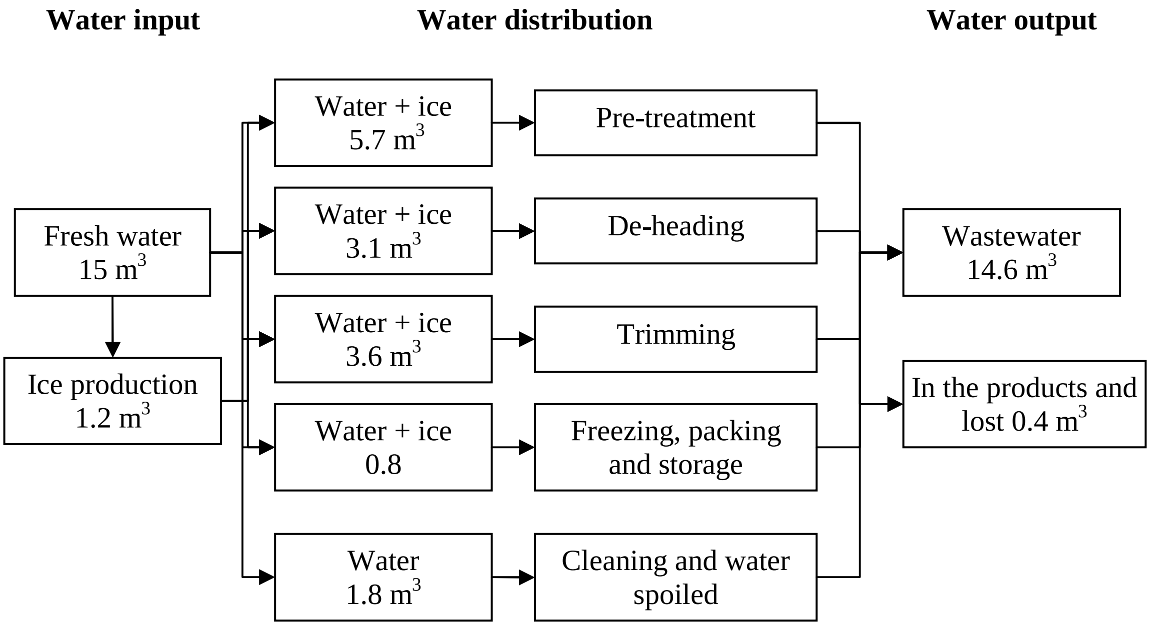

Figure 4.4 Water balance for the processing of one ton of shrimp material

Water consumption varies considerably from one processing phase to another. As required, ice is needed at some steps to keep the wash water and treatment water at a low temperature, in order to prevent the degradation of the processed shrimp. During the production process, there are three phases that consume the largest amounts of water, namely pre-treatment, washing semi-products during the processing, and cleaning.

The wastewater characteristics of six shrimp processing plants in Soc Trang are presented in Table 4.1

Comparing the measured emissions with the Vietnamese standard for industrial wastewater discharge into surface water (not being used as water supply source), all parameters in the shrimp processing wastewater are very high and exceed the Vietnamese standard. Our values exceed the national standard two (total nitrogen) to more than ten times (COD, BOD, total phosphorus). This wastewater has a high organic matter content (due to the presence of protein, suspended solids and fat), and can easily cause oxygen depletion and eutrophication in receiving water bodies if it is not properly treated before discharge.

Table 4.1 The wastewater characteristic selected shrimp processing plants in Soc Trang (this study)

		Wastewater samples in 6 shrimp processing plants						Average (min – max)	QCVN (*)
Indicators	**Unit**	**1**	**2**	**3**	**4**	**5**	**6**		
BOD_5	mg/l	950	720	1100	1020	1000	1100	980 (720 – 1100)	50
COD	mg/l	1640	1200	1490	1450	2300	1490	1595 (1200-2300)	100
TSS	mg/l	872	800	122	142	600	122	443 (122 – 872)	100
Total Nitrogen	mg/l	74	56	65	45	-	77	63 (45 – 77)	30
Total Phosphorus	mg/l	71	43	18	20	-	25	35 (18 – 71)	6

Note: (*) QCVN 24: 2009 type B, The National Technical Regulation of Vietnam on industrial wastewater (type B: not for discharging to water supply source) for the discharge flow of 50-200 m^3/second; this regulation is valid from January 2010.

4.2.2.4 Energy balance

As described above, electricity is used in most steps of shrimp processing. The electricity use was calculated during the production process according to the capacity of the equipment, machines, and lights. The total energy use for processing one ton of shrimp is about 556 kwh. The residual heat is discharged to the environment. There is no energy generated during the current production process.

4.2.3 Material balance of frozen shrimp processing industries in Soc Trang province

As mentioned above, around 50,000 tons of shrimp is processed in Soc Trang province per year. According to our in-depth study on the material balance of shrimp processing, these factories should use about 750,000 m^3 of fresh water/year and create around 730,000 m^3 of wastewater which contains BOD, COD, TSS, TN and TP. Also some 16,950 tons of solid by-products are produced, including shrimp head and shell. The material and energy balance for whole shrimp processing in Soc Trang can thus be derived and is described in Figure 4.5.

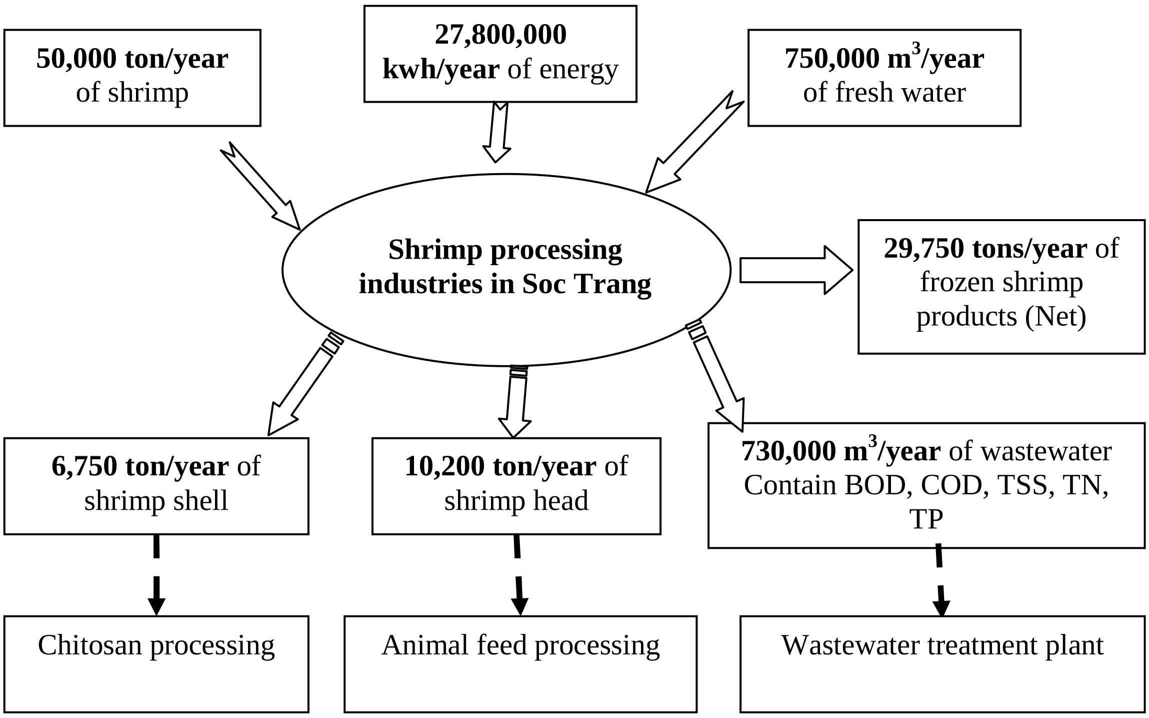

Figure 4.5 Material balance for shrimp processing in Soc Trang province

(Notes: Based on the literature and data collected from selected industrial plants (Fig. 4.3 and Fig. 4.4), around 20,000 m^3 water in product and lost and 3,300 kg of shrimp material in wastewater)

The raw material inputs consist of shrimp, fresh water and energy. Shrimp is purchased mainly from shrimp farming in Soc Trang province. The water supply for shrimp processing comes from underground water sources. Solid non-products consists of shrimp head and shell and are sold to other enterprises for livestock feed production or Chitosan production in other provinces. The wastewater has to be treated. By the Vietnamese environmental law companies are not allowed to discharge wastewater with this quality into the environment.

Considering the role of various industries in the shrimp production network as analyzed above, the shrimp processing industries are proposed as the key industries in an eco-agro industrial cluster of frozen shrimp production. These industries interact with up- and downstream industries and sectors and form as such a core agro-industrial network of material exchange. Hence, the next section analyses this industrial network/cluster in identifying options for improving the environmental performance of this cluster.

4.3 Options in constructing an eco-agro-industrial cluster for shrimp processing industry

The combined technologies for reduction, reuse, and recycling of non-products and for waste treatment are important to transform an agro-industrial cluster into an eco-agro-industrial cluster. The possible options are: (1) onsite prevention and minimization of the generation of non-products; (2) offsite recycling and reuse; and (3) waste and wastewater treatment (Dieu 2006; Nhat 2007).

4.3.1 Onsite prevention and minimization of non-product generation

The data presented in section 2.2 are used as guideline and inspiration to select appropriate possibilities for prevention and minimization of the generation of non-products (including waste and by-products) within individual shrimp processing industries. Shrimp processing consumes large quantities of water and energy, and discharges significant quantities of organic material, both as wastewater and as solid waste. However, there is relatively little use of hazardous substances and most of solid waste is organic material from the shrimp, which can be recycled for animal feed or other products. This study focuses on reducing water pollution, solid by-products and electricity use by different cleaner production measures.

In general in shrimp and fish processing industry, prevention and minimization of waste generation is often considered as a cleaner production technology and there exist several guidelines especially for these processing industries worldwide (Caravan 1991; Jesperson et al. 2000; Casani et al. 2006). In Vietnam, successful cleaner production demonstration projects in fishery from the Cleaner Production Center (VNCPC) should have convinced processors that it is not difficult to improve their production efficiency in terms of technical feasibility and costs. Nevertheless, cleaner production has not been widely accepted and implemented yet in Vietnamese (fish processing) industries, despite substantial promotion by the government, academic institutions and consultancy firms (Mitchell 2006).

Water pollution can be diminished by reducing water consumption, reducing pollutant loadings of shrimp processing effluent, and by installing end-of-pipe treatment for wastewater. For reducing water consumption and pollutant load in shrimp processing effluent, industries are encouraged to apply cleaner production technology by governmental agencies or consultant firms. There are several types of cleaner production opportunities: good housekeeping, process optimization, raw material substitution, new technology and new product design (UNDP 1994). Thrane et al (2009) have shown that in reducing water consumption, most of the easy improvements obtained in the beginning are the result of better housekeeping practices and mainly relate to more efficient cleaning procedures. For instance, to install a high pressure washer requires an investment of about 1000 USD, while the savings can be about

1,900 USD per year (Dan et al. 2003). Large water use reductions can be obtained by making cleaning staff aware of water consumption and spoilage, for example by encouraging them to register their water consumption each day. This only requires an investment of a few water meters, and paper and pencil for recording.

Other opportunities for reducing the pollutant load of shrimp processing wastewater focuses on avoiding the loss of raw materials and by-products to the effluent stream. This can be obtained in several ways such as by using good practices in de-heading and trimming, including the use of sharpened knives, preventing small fragments of shrimp being added to wastewater flows and collecting waste in a dry state by using dry cleaning methods. Improvement of housekeeping, optimization of existing processes and use of more energy-efficient equipment and heat recovery systems can reduce the energy use in fish processing.

4.3.2 Off site reuse and recycling of non-products

For non-products that are unavoidable, including shrimp shell, shrimp head, packaging material and wastewater, possible solutions to reduce and eliminate their impacts on the environment are reuse and recycling in other suitable processes. This section emphasizes on analyzing the possibilities for offsite reuse and recycling of non-products and the creation of a material flow network. In developing and constructing a material flow network, one should keep in mind that "an industrial ecosystem is a dynamic entity; the market conditions will change in coming years, causing them to introduce new products, and cease the production of others. New material will be introduced; old familiar ones will be disappeared. Companies will come and go too. So this challenges of "niche filling" and of recruiting firms with particular product and/or by products will never end" (Lowe 1997).

All generated shrimp shells, shrimp heads and inorganic solid waste are collected right after each production batch, stored and brought to recycling processors. Some manual labor is needed, which is always available in every enterprise. From an environmental aspect, these by-products do not cause any serious problem, except for smell due to the processing of shrimp and these non-products. Currently, the shrimp shell can be used to produce Chitin and Chitosan. Chitin and Chitosan have a wide range of applications, among which in environmental and biomedical engineering and the pharmaceutical industry (Ravi Kumar 2000). Shrimp head can be used in the animal feed production industry. Together with other material as wheat, soybean, bran, spinach, Vitamin, fish powder, the animal feed will be processed. Other inorganic materials such as packing material is often sold to collectors who transport it to material recycling industries off site (such as plastic factories and paper factories).

4.3.3 Waste treatment

After applying cleaner technologies to reduce the water consumption and wastewater generation, and maximizing recycling and reuse of non-products, a problem remains in shrimp processing industry with wastewater. This wastewater needs to be treated. Several techniques for treating wastewater from seafood processing industries have been studied, analyzed and mentioned by for instance, the European Commission (2006), Hung (2004) and Sridang et al (2006). Wastewater treatment methods can be based on physical, chemical and/or biological processes. Biological processes are usually used – in conjunction with physical and chemical processes – when the main objective is reduction of the organic and nutrient content of wastewater (United Nations 2003). Anaerobic treatment techniques have been applied successfully in seafood processing wastewater, obtaining high COD removal efficiencies (75-80%) at volumetric loading rates of 3-4 kg COD/m^3.day (Balslev-Olesen and Lyngaard 1990; Mendez 1992). Hung (2004) concluded that 60-70% of the biogas produced by a balanced and well functioning anaerobic system consists of methane, with the rest being mostly carbon dioxide and minor amounts of nitrogen and hydrogen. This biogas is an ideal fuel for producing low cost electricity and providing steam for use in the stirring and heating of disinfection tanks. The greenhouse gas methane can be effectively used, rendering great potential for Cleaner Development Mechanism (CDM) initiatives under the Kyoto protocol. Based on the average COD in Table 1 and calculations following Show and Lee (2008), we can estimate the amount of methane generation from all 13 shrimp processing industries (with 50,000 tones shrimp/year) to be about 110 ton/y.

Casani et al (2006) evaluated the microbiological safety issues associated with water recycling during the production of shrimp (Pandallus borealis) in brine, and they indicated how the hazards may be effectively controlled using a HACCP Approach (*Hazard Analysis and Critical Control Points).* Following these procedures, process water recovered from peeling during shrimp processing and treated by means of reverse osmosis could be recycled within the same food unit operations.

The characteristics and amount of waste, and the requirement of pollution reduction are keys in seeking the proper waste-water treatment technologies. Experiences from the existing waste treatment systems in Vietnam should be taken as points of departure, as they are practical evidences of failure or success of applied techniques in that specific geographical, socio-economic and climate setting. Each shrimp processing plant and main recycler, such as Chitosan processing industry or animal feed processing industry, have to establish a wastewater treatment system. The amount and load of wastewater from the shrimp processing industry that needs to be treated depends very much on the successes in installing any of the other options.

4.4 Designing a frozen shrimp eco-agro-industrial cluster in Soc Trang province

There are three basic objectives in designing such an eco-agro industrial cluster (Yang and Lay 2004): first, consumption of energy, scare resource use and generation of waste should be minimized; second, the use of industrial waste and discarded products as input for industrial process (reuse and recycling) should be maximized; and third, the cluster should be diverse and resilient from unexpected external 'shocks'.

In our model, the shrimp processing companies in Soc Trang are used as starting point for model development. The existing shrimp hatchery and shrimp grow-out farms in Soc Trang which surround the processing company can remain at the current locations. A feed production enterprise, a chitosan processing plant, a composting plant, and a wastewater treatment system all need to be newly (re) located in the eco-agro-industrial cluster, processing around 50,000 ton of shrimp material in Soc Trang per year.

The cluster designed in Figure 4.6 is more environmentally sound than current practice, in several ways. First, it is more energy efficient because of biogas production. Second, less waste is produced, because part of the waste is processed to animal feed and chitosan. Third, it is less polluting because the wastewater is treated.

From the material flow balance of the proposed eco-agro industrial cluster presented in Figure 4.6, it is obvious that the size of the shrimp processing capacity of the province is decisive for the capacity of the other elements of the model. The most important factor in establishing these recyclers is the availability of consumers and market demand for their products, and the outlook of profits for capital investors.

If one of the fish processing industries is interested in putting the proposed model to work by investing in these new elements, the chances of success increase if the fish processing industries have no ambition to own and operate other elements than frozen shrimp processing, the fish industries should seek other owners, who want to participate in this system as recyclers. In this case, the shrimp processing industry has to create the relationship with recyclers.

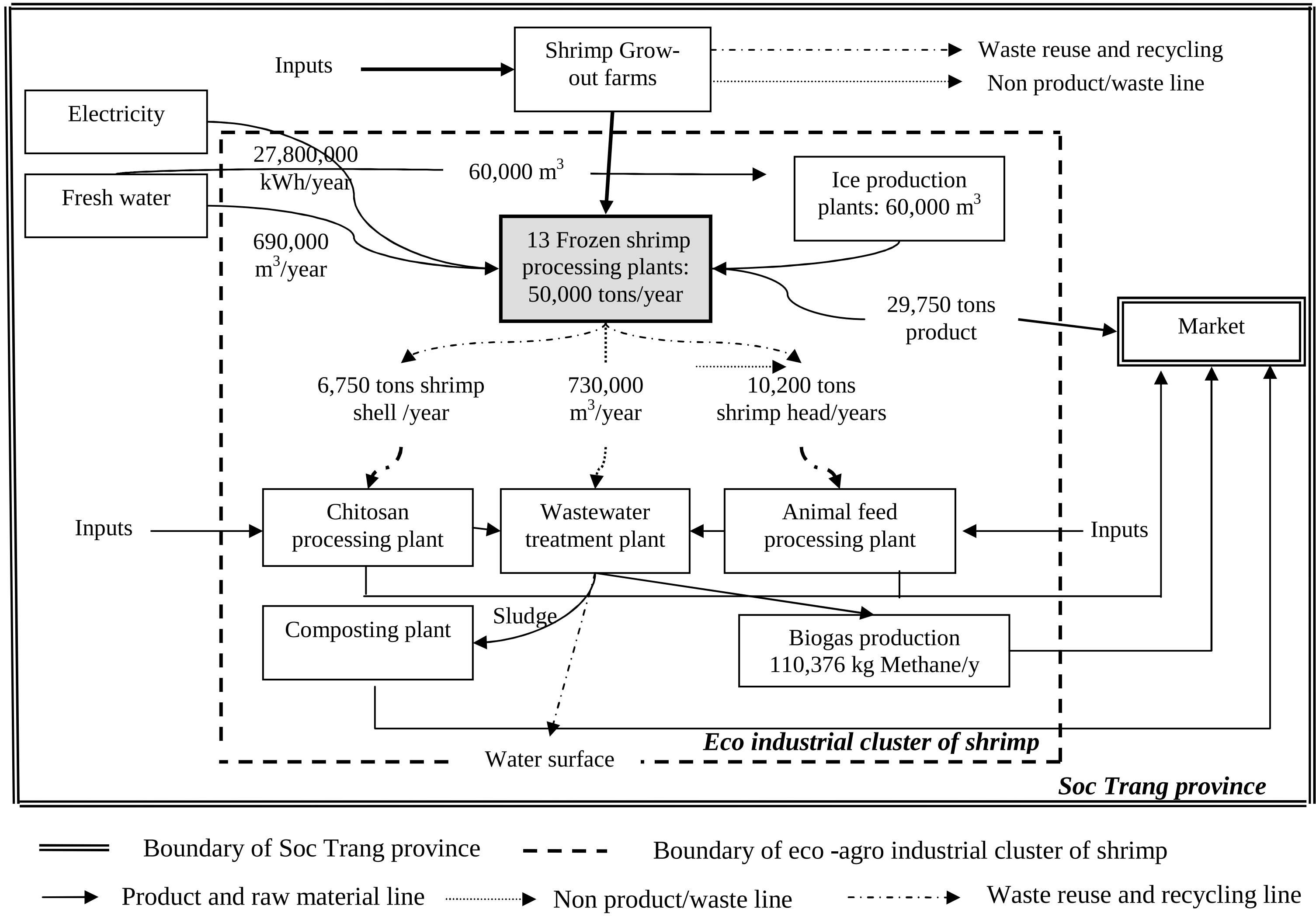

Figure 4.6 Design of an eco-agro industrial cluster for shrimp processing in Soc Trang province

4.5 The governance of eco-agro industrial cluster of shrimp in Soc Trang provinve: Actors and institutions

In order to put such a proposed eco-industrial cluster to work in shrimp production in Soc Trang province, a network analysis of institutions and interactions that govern shrimp production has been carried out, using a so-called triad-network analysis (Mol 1995). The triad-network model combines three analytical perspectives and rationalities (an economic, a political and a social-cultural) with three distinct actor-networks (an economic, a policy and a societal network) (see Figure 4.7). Each of the three interdependent networks combines a specific analytical perspective, distinctive institutional arrangements and a restricted number of interacting (collective) actors that are considered to be most important regarding that perspective and rationale.

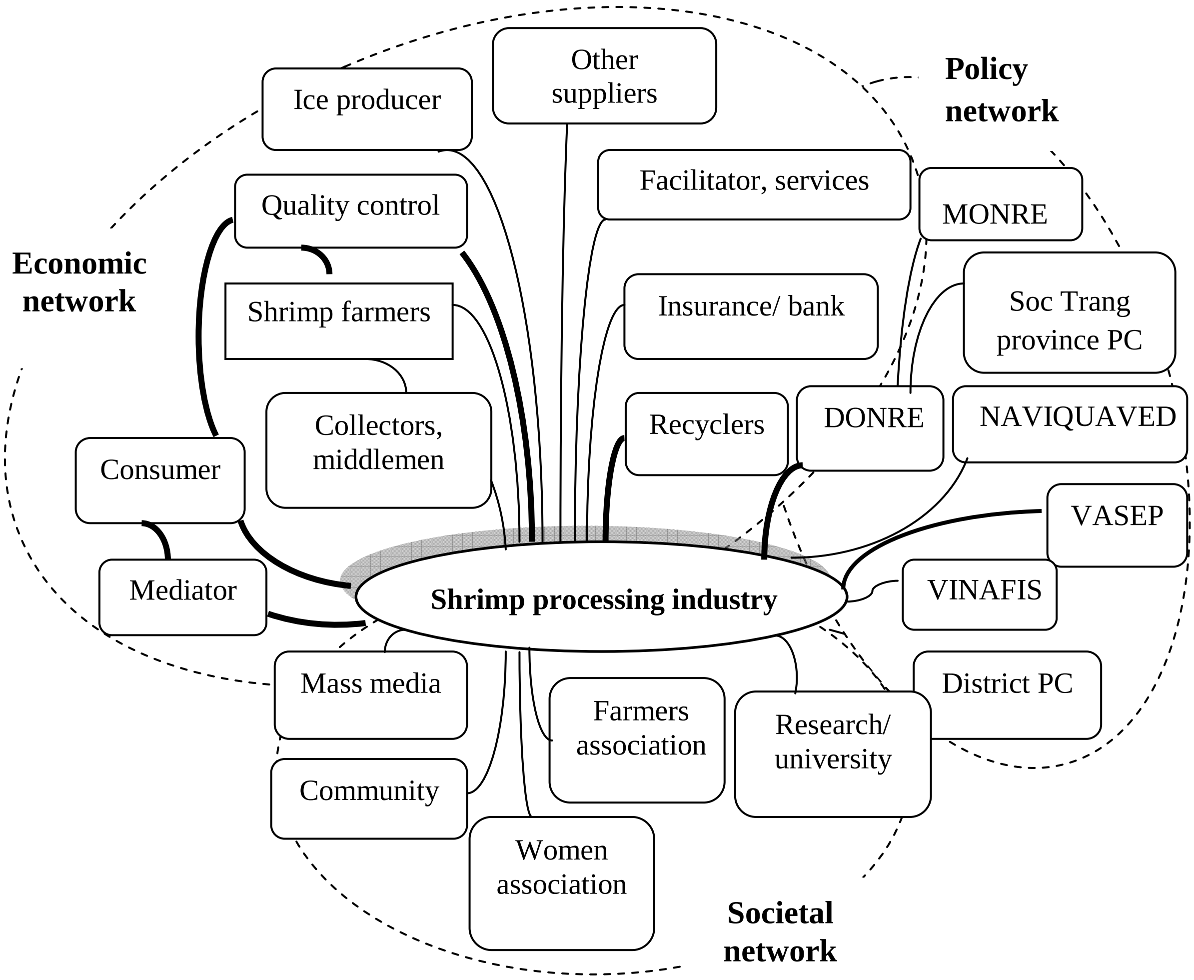

Figure 4.7 Networks embedding shrimp processing industry in Soc Trang province (main relations for eco-industrial clusters in bold lines)

4.5.1 Economic network

Economic networks basically focus on economic interactions via economic rules and resources between economic and market agents in and around shrimp production. Economic network studies analyze the relationships between frozen shrimp producers and other economic agents in the agro-industrial cluster, the network structures in terms of power and resource dependencies, and the economic processes of continuity and transformation.

There are two parties involved in getting the grown shrimps to the processing company: intermediate traders or middlemen and collectors. Middlemen collect different harvests from the smaller farmers, while the collector bids on supplies of intermediate traders, and subsequently sells larger volumes to the processing industries. The processing industries process the shrimp into consumable products, and sells to local or export markets (consumers). Besides, the value chain has quite a number of suppliers (ice producer, packaging material providers, energy and water providers), recyclers (animal feed, paper and plastic, and chitosan plants) and other service companies such as transporters, credit institutions, quality assurance and certification organizations and insurance companies.

With the existence of the large amounts of small scale shrimp farmers and their constraints in complying with increasingly stringent food safety and sustainability standards, the small farmers sometimes organize themselves into farmer groups or cooperatives, through which small farmers receive support in farming techniques, knowledge, and information, and they share production and certification costs

From an economic point of view a powerful party in the value chain is the party that trades the raw material to the processing factory. The farmer needs to get rid of his harvest and tends to accept a lower price if necessary and the processing factory has often no direct access to the raw material so it tend to buy for a higher price. The different between the two prices can be significant. Direct contracts between farmers or farming cooperatives and processors would not only allow for better prices, but also enables the eco-industrial cluster, as processors can help farmers in investments, production techniques and improved product quality (hence less waste). These direct relationships between farmers and processors become also relevant with the increasing role of (international) standards.

The processing industries often export their products to other countries and mediators act between the domestic and the international side of the value chain. These oversea customers, such as restaurant and supermarket chains, receive shrimp products via mediators and international traders, and they will deliver the shrimp products further to their outlets and to end consumers.

Foreign customers prove to be an important powerful actor in determining not only prices, but also specifying production requirements. International traders and mediators articulate these requirements towards processors and farmers, often codified in standards and certification schemes. Many different quality and sustainability requirements and standards are currently being developed and implemented, having consequences for both farmers and processing industries. There are both national (Best Management Practices, Good Aquaculture Practices, Codes of Conducts) and international (e.g. Naturland, Shrimp Aquaculture Dialogue) standards that are important for moving towards an eco-industrial cluster. These standards contain rules on use of chemicals, antibiotics, wastewater and waste treatment, and hygiene. Currently, however, there are too many different standards and certification systems in development, which makes the future uncertain and unclear for processors, farmers and also customers.

Enabling the establishment of industrial recycling companies (animal feed, Chitosan, sludge composting) might require further collaboration between shrimp processing firms, for which an association of shrimp processing companies would be instrumental. While in developed countries and increasingly also in China credit institutions and insurance companies play a role in greening industrial processors, this is not the case in contemporary Vietnam. Credit from the Agri-Bank (the Bank of Agriculture and Rural Development) and other Vietnamese banks have no environmental conditionality.

4.5.2 Policy network

Policy network studies analyze the interdependencies between authorities and industrial actors, the ‘rules of the game’ which put these policy networks to work, and the resource dependencies (regarding power, knowledge, information etc.) between the various actors and agents dominant in these policy networks. The relationship and interactions between shrimp processing companies and the environmental management agencies and authorities are the focal point of analysis. The current legislation related to the environment, which may influence environmental innovation of the company and the proposed industrial ecosystem, is also analyzed.

The Ministry of Natural Resource and Environment (MONRE) is the highest national environmental agency in Vietnam, with decentralized DONRE branches at the provincial level. Following the Law on Environmental Protection these agencies are responsible for improving the environmental performance of industries via Environmental Impact Assessment appraisal and the promulgation of environmental decrees, standards and programs.

Soc Trang DONRE is a crucial organization responsible for policy-making, control and enforcement of environmental management activities of the industries in Soc Trang province. Soc Trang DONRE participates in the decision-making about industrial locations, plays an important role in environmental impact assessments of enterprises, approves Environmental Standard Registrations and issues environmental licenses for enterprises, and inspects of the environmental performances of enterprises. At present, Soc Trang DONRE has to manage all existing industries and industrial zones in Soc Trang Province. With limited human resources and finances, it is not surprising that (illegal) discharge of (untreated or improper treated) wastewater into the environment still takes place, also with respect to fish processing industries. In addition, applied regulations are strongly based on environmental standards for water, wastewater, air, and soil, while more modern environmental protection strategies such as cleaner production, industrial ecology and industrial development master plans have hardly been considered yet, let alone been implemented. There is no policy for advancing recycling industries related to industrial production. Hence, these governmental agencies currently play little role in advancing our industrial cluster model around fish industries, but could potentially become relevant in the future. In order to force fish companies to pay more attention to production efficiency and environmental performance, Soc Trang DONRE could request companies to include material and energy information (including wastes) in company (environmental) reports. Such information might motivate and convince processing companies to conduct cleaner production, waste exchange, reuse or anaerobic treatment in order to gradually improve their environmental performance. This would also change the role of Soc Trang DONRE, from a rather powerless inspecting and enforcing agency to a trustful source of information and guidance on environmental protection improvement.

Government policies for fishery development are defined in the Fisheries Law and a considerable number of decrees, ordinances, decisions, circulars and regulations. The Ministry of Agriculture and Rural Development (MARD) – and its provincial and local branches – is responsible for designing and implementing guidelines, regulations and standards for sustainable production of aquaculture. But the Fisheries Law and these agencies have no responsibility for sustainable industrial processing of fish, which falls under the environmental ministry. But in accordance with the Fisheries Law and Government policy, MARD—often together with foreign and domestic private organizations—plays an important role in bringing international principles and (product and process) standards to the local farmers and processors, and help them in preparing to fulfill these standards and principles. The National Fisheries Quality Assurance and Veterinary Directorate (NAVIQUAVED) have responsibility for quality certification of fish products for export. As such NAVIQUAVED supports the whole chain in terms of checking, controlling as well as certifying food safety, quality and sustainability for fish products, ranging from inputs to breeding fish to finished seafood products.

In some countries and sectors industrial associations play a role in private environmental governance. The Vietnam Fishery Association *(*VINAFIS) is a small association and is most related to the farmers**.** The Vietnam Association of Seafood Exporters and

Processors (VASEP) is a much larger organization, which promotes the interest of processors and exporters. Both organizations try to influence governmental policy-making and regulations and spread information to farmers and processors on these governmental requirements and regulations. VASEP also provides market information and training for support aqua-product processors and exporters regarding market developments, international trade, quality requirements and standards of international traders and labeling and certification organizations. As such VASEP plays an important role in spreading knowledge and information for construct eco-agro industrial clusters for shrimp farmers and processors, as far as this is related to existing public and private requirements.

4.5.3 Societal network

Societal network analysis aims at identifying relations between industrial processors and civil society organizations and arrangements associated with what is usually called 'the life world'. The societal networks of the eco-industrial cluster in Soc Trang province consist of resident communities (mainly farmers), mass media, Youth Union and Women Association. In Soc Trang province, the shrimp processing industries, shrimp farmers and residents are located close to each other, but at the moment local communities hardly play a role as informal regulators (Phuong and Mol, 2004) in stimulating shrimp processing companies to reduce emissions. Neither do the Youth Union and the Women Association show major interests in more sustainable fish processing in Soc Trang. At present, the main mass media in Soc Trang province include television, radio, newspapers and internet access. These media do have special programs on fish production which include environmental issues. But their main focus is on aquaculture farmers, and not on industrial fish processing. In Soc Trang, raising public awareness is missing with respect to the environmental performance in fish processing, environmental problems caused by industrial processors, and options for reuse and recycling of waste. The media has not reported incidents of citizens complaining on industrial pollution by fish processing companies; hence models of community-driven environmental regulation (Phuong and Mol, 2004) are at the moment not working for fish processing industries in Soc Trang.

In the absence of strong civil society actors, research institutions and universities sometimes seen as active advocates of environmental improvements (see Mol, 2009). Research at research centers and universities contribute at the moment are in highlighting the industrial emissions and potential options for reducing these emissions, including ideas of industrial ecology, cleaner production and industrial clustering (see Dieu, 2003, 2006; Dan et al, 2003; Nhat, 2007). In addition, the Vietnam Cleaner Production Centre disseminates ideas of cleaner production to industries (and authorities) via guidance manuals on cleaner production assessment and video tapes, brochures and leaflets. Governmental pressures, market demand for sustainable fish products or economic profits are needed to move fishing processing industries towards using these ideas of research centers. At the moment, processing companies do not have sufficient experience in adding value to their products through sustainable production and attract their customers with sustainability standards and not only via prizes. Therefore, in their cooperation with processing industries research institutions should not restrict themselves to technical option but also include ideas of adding value to products through sustainable processing designs and how companies can use and communicate such newly acquired competitive advantages in a globalizing market.

Soc Trang environmental agencies, fishery agencies and authorities could collaborate with the television and newspaper media to develop a program to introduce good practices in reuse and recycling of waste, cleaner production and environmental performance in fish production. This demonstrates and encourages fish producers how to consider both production and environmental improvement, and keeps them informed about experiences and best practices in environmental protection activities. Moreover, it helps in legitimizing the growing fish sector towards the wider public and other sectors, now that natural resources in Soc Trang are getting scarcer and need to be shared.

4.6 Conclusions

This study illustrates how eco-agro-industrial clustering may lead to reducing pollution, protecting natural resources and improving the competitiveness of the shrimp production and processing sector in the Mekong delta, Vietnam.

This study illustrated how ideas of industrial ecology can be used to green fish production industry in Vietnam through eco-industrial clustering. The cluster that we designed in Figure 5 is more energy efficient because of biogas production. Moreover, less waste is produced, because part of the waste is processed to animal feed and chitosan. Finally, it is less polluting because of wastewater treatment. We assume in our design that all industrial enterprises participating in the model implement cleaner production measures to prevent and minimize the generation of non-products from their production processes. The economic feasibility of the cluster depends on the extent to which the benefits of energy savings, and of animal feed and chitosan production balance the investments needed. We argue that the designed eco-agro industrial cluster for fish production in Vietnam may be economically feasible if the valuable (reusable) materials generated from the production processes are indeed reused and recycled. Moreover, the large agro-(food processing) industrial sector together with the large proportion of the land used for agricultural production opens favorable conditions for eco-agro industrial cluster models and practices in Vietnam.

Eco-agro industrial clustering may also be interesting for other major fish producing provinces in the Mekong delta, such as Ben Tre and Tra Vinh provinces. The material balances from this study can be used for a rapid assessment of the feasibility to apply this model for industrial shrimp production in other places in Vietnam. The future implementation of an eco-industrial cluster for shrimp production should not rely too much on the role of environmental authorities, given their priorities and limitations in resources. Although without 'support' from environmental authorities a treatment system is not very likely to be established at the clustered fish processors, a joint proactive (financial) request might make the best chance to implement an energy generating treatment system (either at Vietnamese authorities or via foreign assistance). Environmental authorities will not be very relevant in triggering the other elements of our eco-industrial cluster. Overall, establishing further cooperation between processing industries – perhaps also via VASEP – seems to be promising in implementing further reuse and recycling, and establishing the necessary elements for our designed eco-agro-industrial cluster (the composting plant, Chitosan plant, animal feed company). In addition, emerging export market demands for sustainable products might also trigger Vietnamese fish producers into such collaborative structures and (elements of) the designed eco-industrial clustering. Most likely that will go together with necessary changes in shrimp farming. Hence, our eco-industrial cluster model will have to be coupled with a supply chain model, in which shrimp farmers are included.

Summarizing, we analyzed approaches towards eco-agro industrial clustering in shrimp processing industries in Vietnam. In an earlier study, we analyzed approaches towards reducing pollution by shrimp production in ponds (Anh et al. 2010a). Both studies indicate that there is ample opportunity to improve the environmental performance of shrimp production in Vietnam. Our study may serve as an example for other shrimp producing regions, but also for other fishery sectors.

Chapter 5 Multi-level environmental governance in Vietnam: Water pollution reduction in pangasius and shrimp aquaculture[7]

ABSTRACT

Water pollution is one of the key environmental problems associated with shrimp and pangasius aquaculture in Vietnam. Several studies exist on the causes and effects of water pollution, and on possible solutions for pollution control of these two economically important species. However, only a small number of Vietnamese farms apply these reduction options. This is largely due to current limitations in the management and governance of aquaculture. Three interdependent levels of governance can be distinguished: international, national and community governance. The purpose of this study is to analyze and understand this system of multilevel governance of water pollution in aquaculture in Vietnam, and to identify the potentials and drawbacks in improving the environmental performance of the aquaculture sector.

Key words: Governance, aquaculture, actor, stakeholder, shrimp, pangasius

5.1 Introduction

Brackish water black tiger shrimp (*Penaeus monodon*) and freshwater striped river catfish (*Pangasius hypopthalamus*) account for approximately 50 percent of the total production of aquaculture in Vietnam, significantly contributing to the country's top ten ranking amongst global seafood exporters (Trong 2008; FAO 2009b). Shrimp production has transformed coastal areas, with the proliferation of rice and mangrove integrated pond systems ranging from extensive to intensive systems, via improved extensive and semi-intensive systems (see Joffre and Bosma 2009; Sakamoto et al. 2009). In contrast, pangasius production is limited to inland rice cultivation areas, having shifted from river-based cages and pens to intensive pond systems in response to improved efficiencies over the last decade (see Phuong et al. 2007).

The rapid growth and intensification of shrimp and pangasius aquaculture in Vietnam has led to a series of concerns over environmental and social sustainability. One of the key environmental concerns common to both production systems is the impact of pond effluent on water quality. Many studies have analyzed the causes and effects of water pollution from aquaculture in Vietnam, especially focusing on nutrient loading and chemical and drug contamination, and proposed technical solutions for mitigating and

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[7] This chapter contains an article submitted as Pham Thi Anh, Simon R. Bush, Arthur P. J. Mol and Carolien Kroeze, Multi-level environmental governance in Vietnam: water pollution reduction in pangasius and shrimp aquaculture, to Journal of Environmental Policy and Planning

preventing these problems (Tuan et al. 2005; Trai et al. 2006; Long and Toan 2008; Bosma et al. 2009). Key socio-technical strategies for water pollution reduction at the farm level include (1) waste prevention and minimization and/or (2) treatment and reuse of effluent streams (Anh et al. 2010b);. However, despite growing attention in both state and international policy, the successful implementation of these strategies in shrimp and pangasius has so far been limited in Vietnam.

The expansion of shrimp and pangasius production to meet export demand and the diversity of farmers involved, with different capacities and levels of capitalization, has meant that many technical solutions have proved ineffective. In An Giang province (see Figure 1), one of the largest producing regions of pangasius in Vietnam (MARD 2009a), less than 10% of the farms have complied with government policy to build sedimentation ponds (Hoa 2008), while a small percentage of farms have voluntarily developed systems for wastewater reuse. Other reduction options, such as ozone aeration technology and constructed wetlands, are only applied at pilot sites. A key reason that farmers of all sizes have so far resisted implementing water pollution reduction strategies is the economic risk they face in international markets (e.g. EJF 2003; Bush et al. 2009). However, many of these technologies have been implemented in other Southeast Asian countries by farmers with similar levels of risk and technical experience (Schuur 2003; Wang and Han 2007) It therefore appears that the limited implementation is caused, in part, by a implementation failure of Vietnamese state policy.

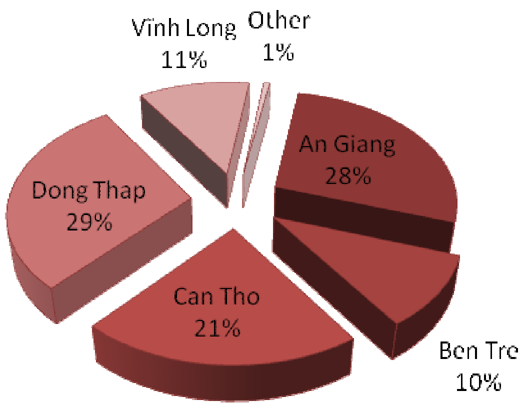

Figure 5.1 Provincial pangasius production in Vietnam (MARD 2009a)

This paper examines a number of ongoing international, national and community level governance initiatives to overcome current state failure by promoting sustainable shrimp and pangasius aquaculture in Vietnam. Our analysis focuses on the performance of new multilevel combinations of state and non-state governance initiatives in steering producers to invest in water pollution mitigation measures. At the international level we analyze the WWF-led Aquaculture Dialogues, designed to create industry-based consensus over environmental standards of production to be implemented through the nascent Aquaculture Stewardship Council (ASC). At the national level we focus on the development and adoption of voluntary production standards, which should complement poorly implemented water related laws and regulations. Finally, we examine the potential of cooperative forms of aquaculture production at the producer level, both with and without external support, in response to the direct impacts of degrading water quality. In investigating governance initiatives at these three levels, we illuminate how public-private multilevel governance complexes are starting to address conventional state failure in water pollution problems in Vietnam's aquaculture. In order to do so, we first introduce the applied multilevel governance perspective.

5.2 Multi-level governance of place-based aquaculture

When focusing on the issue of water pollution, shrimp and pangasius aquaculture in Vietnam can be interpreted as a system-to-be-governed (Kooiman and M. Bavinck 2008; Chuenpagdee and Jentoft 2009), as a system that is in need of change to fulfill increasing demands of sustainability. The core of this system-to-be-governed is place-based, where aquaculture farmers localized in tidal and riverine hydrological ecosystems of the Mekong River Delta produce shrimps and pangasius predominantly for international markets. In contrast, the governing system, where claims and interventions on sustainability are articulated, consists of a multi-level system of institutions, organizations and steering mechanisms. These institutions, organizations and steering mechanisms can be interpreted as a nested governance system. Following Elinor Ostrom’s work Marshall (2008) argues nested governance exists when smaller organizations and governance institutions become part of a more inclusive system of governance, without giving up their essential relative autonomy. While Marshall sees nested governance as a preferable normative model for governing common pool resource problems, we would rather use the idea of nested governance analytically. The nested governance concept helps us to understand how lower/smaller levels and ‘sub-systems’ of governance are embedded in larger systems, keeping at least partly their own logic and rationality in dealing with problem solving. By the same token nested governance has clear interdependencies among the constituent parts.

Working within an interactive governance framework, Chuenpagdee et al. (2008) note the importance of the multiple dimensions of aquaculture in the broader context of coastal areas and the influence of international agreements. Hence, for them the challenge of governing sustainable aquaculture comes largely from its integrated nature within complex coastal and riverine ecosystems. Their approach normatively addresses governance as a process of ‘best fit’ between the governance-system and the system-to-be-governed. Challenges to such an approach arise when flows of feed, seed and water lead to transient and spatially diffuse impacts such as disease transmission and water pollution (see Folke et al. 1998; Bush et al. 2010). By the same token, different levels of governance focus on different scales, and hence different boundaries. As such, it may prove that each level of governance, or combinations of these levels, define the boundary around the object of governance very differently, making normative 'best fit' approaches complicated.

Using the notion of nested hierarchies allows us to identify specific governance arrangements at different nested levels – for example, local, national and international – and determine how these different governance systems can together steer a system-to-be-governed to generally agree upon outcomes. How these outcomes are defined and translated into institutions that guide the practices of, for example, aquaculture farmers, may differ between nested governance 'sub-systems'. The overall governance system is therefore made up of any number of sub-systems, with their own logic, norms and principles (Kooiman and Bavinck 2005), and operate over different time frames (Gibson et al. 2000; Cash and Moser 2001), to collectively steer the system-to-be-governed. Within each subsystem networks of state and/or non-state actors and institutions are active. By focusing on specific environmental challenges within aquaculture, such as the promotion and implementation of water pollution mitigation technologies, we are able to understand how these governance sub-systems look like and how they interact with and mutually strengthen each other (or not). With such an inductive approach we can further contribute to a less normative understanding of multilevel governance.

5.3 Methodology

The methodology for this study is based around our participation in a range of activities at all three levels, where institutions and steering mechanisms were designed and created. At the international level, the aquaculture dialogues organized by WWF are the main frame in which Vietnamese shrimp and pangasius aquaculture are governed. From 2007 to 2010 various stakeholder meetings were held as part of the Shrimp Aquaculture Dialogue (ShAD) and Pangasius Aquaculture Dialogue (PAD), and involved a large number of diverse local and transnational actors. Although the Aquaculture Stewardship Council (ASC; the final steering mechanism for the implementation of these standards) is not yet fully functional, the contours of an institutional system are emerging, be it to a different extent for shrimp and pangasius.

At the national level, independently from WWF and simultaneously, the Vietnamese Government took the initiative to organize a series of stakeholder meetings to identify technical and management approaches for pangasius and shrimp production. One of the stakeholder meetings was held in An Giang province with participation of a large number of actors from different provinces in the Mekong delta. The meeting focused on the participation and concerns of different actors for improving the environmental performance of aquaculture production. In addition, the participants dealt with the experiences of the Vietnamese government in adopting BMP, GAP and CoC standards for aquaculture, as complement to existing laws and regulations.

At the community level, formation of producer cooperatives in the shrimp sector started in 2002 and continues up to the present. These producer cooperatives focus on both economic and environmental improvement. The experiences gained in these cooperatives in the shrimp sector in Soc Trang and Ben Tre provinces in the Mekong delta to a certain extent served as a conceptual model to the pangasius sector.

With respect to the pangasius sector observations were made during local stakeholder meetings designed to develop cooperative structures for farmers and communities in the beginning of 2009. During these meetings attention was given to better understanding the environmental problems caused by pangasius farming and to assess cooperation in water resource management at the community level. The meetings were held in Hoa Lac village, located in Phu Tan District of An Giang province, and included pangasius farmers, rice farmers, local government officials, environmental experts, and women and farmer associations.

Participant observation and involvement in stakeholder meetings, in-depth (often informal) interviews with all involved actors groups, and access to public policy documents and the wider project-based 'grey literature' were all part of our data collection methods related to all three levels.

5.4 International governance through the WWF aquaculture dialogues

5.4.1 A global initiative

Initiated by World Wildlife Fund (WWF), several species-specific roundtables, referred to as "dialogues," are being implemented to develop science-based standards and certification schemes for aquaculture products. The dialogues consist of a large variety of stakeholders. Since the start of these dialogues in 1999, 12 species have been identified for review, based on the degree of impact on the environment and society, and the extent to which they were traded internationally. The key characteristics of these dialogues are: 1. involvement of a broad and diverse set of stakeholders; 2. deliberation and debate through a transparent process; 3. science-based decision making; 4. consensual decision making; and 5. measurable and performance-based criteria and standards (WWF 2008a). When finalized, these standards will be given over to the ASC, an independent certifying body similar to the Forest and Marine Stewardship Councils (see Cashore et al. 2004; Gulbrandsen 2009), which will be responsible for implementing the certification scheme.

In a 2007 benchmarking study of environmental and social standards for aquaculture WWF argued that all standards developed up to then lack an effective and credible regulatory framework, have internal governance arrangements with limited transparency, lack multi-stakeholder participation, and further, insufficiently cover key issues for specific species and lack of meaningful measurable and verifiable criteria (WWF 2007). In response WWF developed the Shrimp and Pangasius Aquaculture

Dialogues (ShAD and PAD) on the basis of the ISEAL Code of Good Practice for Setting Social and Environmental Standards. The details of the entire process were outlined for each of the 12 dialogues in a "process guidance document" (WWF 2008a) . WWF argues that the dialogues represent a more interactive approach to standard development for aquaculture than any of the alternative competing standards.

5.4.2 Comparing PAD and ShAD

Although part of the same global WWF programme, both PAD and ShAD differ considerably with respect to geographic scope and, as a result, to the relative contribution of the aquaculture industry in Vietnam. PAD has emerged as a largely Vietnamese dialogue given the fact that 90% of pangasius is grown in this country. Involvement from China, Bangladesh and Indonesia has been invited but, even by the admission of the organizers, has proven limited given the dominance of Vietnam. In contrast ShAD has to deal with considerable diversity in reaching consensus over the standards, with two dominant shrimp species (*Penaeus vanamei* and *Penaeus monodon*) produced in a variety of production systems with varying intensity, across more than 35 countries (FAO 2010). Though Vietnam is the fourth shrimp producing country in the world with 12% of world production (FAO 2009b) its involvement has been relatively limited.

The aquaculture dialogue standards are made up of issues (in the case of PAD) or principles (in case of ShAD), which are in turn comprised of criteria and verifiable indicators. The criteria provide specific direction on how to reduce each impact and the indicators address how to measure the impact. Standards are therefore quantitative performance parameters that evaluate whether an issue/principle is achieved (WWF 2009a). The draft standard of PAD was developed through discussions with a broad and diverse group of stakeholders (PAD participants). The Process Facilitation Group (PFG) is charged with managing the PAD process, a Technical Working Group (TWG) is charged with drafting the principles, criteria, indicators and standards, and PAD meetings where final decisions concerning the PAD standards are made by consensus by the participants at the meeting (WWF 2009d). The ShAD process is managed by a Global Steering Committee (GSC), with input and recommendation from three Regional Steering Committees (RSCs): Africa, Asia and Americas. The GSC makes all final decisions related to the ShAD. Its main task is creating one global standard for shrimp aquaculture (WWF 2010).

All of the standards generated through the aquaculture dialogues are open for (global) public comments for 60 days. The technical working group (TWG) and process facilitation group (PFG) subsequently revise the standards which will then again be open for a 2nd round of public comment during 60 days, followed by a final revision by and TWG. Finally the standards will be presented to the full group of participants for final approval. The PAD standards are expected to be completed by 2010 and the ShAD standards by 2011. The following analyzes the recent draft standards of PAD (April 2009 WWF 2009b) including the first round and second round of public comments on PAD (June 2009 and January 2010) and the subsequent 4th and the 5th PAD meetings (August 2009 and March 2010) organized in Vietnam. The PAD standards are now close to being finalized. In addition we discuss the first draft of the ShAD standard open for 1st public comment (January 2009 WWF 2009g)

Our key question is to what extent both sets of standards can foster improved compliance and adoption of technological options to mitigate water pollution in Vietnam. Table 5.1 compares the PAD and ShAD standards with the available options for pollution control at the farm level from our previous studies (Anh et al. 2010b),.

There are significant differences between the two standards. Related to the water use reduction option, PAD standard mentions a water abstraction not exceeding 5,000 m^3/ton of fish production. Vietnamese pangasius farmers estimate water use to be much higher although there are no accurate measurement methods available at the farm level. ShAD standard does not allow ground water use for diluting salinity in ponds, which is at the moment not happening in Vietnam. No water use reduction indicator has been proposed for shrimp farming yet. Feed use reduction indicators are proposed in both standards. Both standards have indicators for chemicals and drugs use reduction, and on treatment and reuse of waste streams. However, there are different shrimp farming systems and different types of shrimp and these indicators have not been specified for specific shrimp farming systems yet. Though PAD has progressed further than ShAD in developing a completed standard, its criteria are still not clear to many stakeholders as became apparent during the two rounds of public comments in August 2009 and March 2010.

Table 5.1 Proposed technical options for reduction of water pollution at farm level related to PAD and ShAD standards.

Proposed options at farm level [1]	Related to PAD indicators and standard[2]	Related to ShAD indicators[3]
I. Waste prevention and minimization at source		
Water use reduction: techniques for cleaning water, so that less refreshment is needed	Amount of water abstracted must not exceed 5,000 m^3/ton of fish production	No use of ground water for diluting salinity in ponds allowed
Feed use reduction: Use pellet feed and optimize use of feed Farmers need information exchange	The fish feed equivalence ratio must be 0.5	A fish feed equivalence ratio is used (will be defined). Good pond management should encourage natural productivity and reduce the use of artificial feed
Chemicals and drugs use reduction through correct use of chemicals and medicine (appropriate doses and frequency)	Legislation or regulation on the use of veterinary medicines and chemical must be followed ; treatment recording compulsory	No prophylactic use, no banned antibiotic; treatment recording
II. Treatment and reuse of waste stream		
Treatment and reuse of sediment	No direct discharge of sludge into public water bodies allowed There must be evidence of sludge repository and of sludge being used; Criteria of Total Nitrogen (TN), Total Phosphorus (TP) in the sediment are applied; reuse of sludge is promoted	No direct discharge of sludge into public water bodies allow reuse of sludge is promoted
Treatment and reuse of wastewater	Use criteria of Dissolved oxygen (DO), TP, TN in the water discharge	Use mass balance of TN and TP from water input and output

(1) From Anh et al (2010 a,b)

(2) From (WWF 2009b)

(3) From (WWF 2009g)

5.4.3 Stakeholder negotiations on PAD standards

To understand the PAD process, the development of its criteria and the influence of global networks on aquaculture in Vietnam, we analyze the negotiations that took place over five PAD meetings from 2007 to 2010, including the contributions from the two rounds of public comments. Comments from 143 people were received during the first round and from 171 people during the second round (see Table 5.2). We will review the more general and issue-specific comments of both rounds.

Table 5.2 Public comments (1st and 2nd round) in general and on specific issues (issue 2,3,5 and 6) of PAD.

Items	Units	1st round	2nd round
Total stakeholders	Person	143	171
Total comments	Comment	642	458
Comments on seven issues	Comment	502	393
Issue 2: Land and water use	%	11.2	20.8
Issue 3: Water pollution and waste management	%	20.1	24.2
Issue 5: Feed management	%	18.5	19.3
Issue 6: Veterinary medicines and chemicals	%	10.7	10.3

The general comments of the first round mainly focused on questions like “do we need PAD standards?”, “will this create consumer confusion?”, “will farmers benefit from the standards?”, “why do standards aim at the top 20 percent of performers?” and “how are the top 20% farmers identified?” The first three questions were answered during the first PAD meeting in Vietnam in September 2007, but emerged again when stakeholders had become aware of several other certification schemes in aquaculture and fishery (FAO 2007a). With respect to the last two questions, the TWG stated that PAD will use existing studies to establish the median for each indicator, which subsequently will be adopted as standard requirements. TWG took as point of departure that approximately 20 percent of the farms will eventually be able to perform better than the median for all indicators (WWF 2009e) and comply with the strict requirements of the highly competitive export market. Implicitly, PAD presupposes that 80% of the producers will not reach the set standards and thus will have difficulty to access the world market.

Improvement of the performance among these producers will have to be addressed indirectly through an outreach program (WWF 2009c). We conclude that the PAD approach focuses on larger, most efficient and export-oriented farmers. In the second public comment round no fundamental objections were raised regarding the second draft document. PAD participants generally agreed on the criteria, indicators and standards, but asked for greater specificity of indicators and clearer definitions of terms. These are to be addressed by the PFG and TWG in the finalization of the standard documents.

Beside these general comments, comments were raised on all seven proposed issues. We will especially focus on issues related to water pollution from pangasius aquaculture. In the first round participants raised numerous questions about issue 2 (land and water use) on water abstraction, ecosystem impacts, farm location and design: What is the rationale for the water abstraction indicator of 5000 m^3/ton of fish production proposed by the TWG?; what criteria are being applied for using ground water?; why only consider wetlands and not other ecosystems when assessing impacts?; how to deal with land already designated as protected area?, what are aquaculture development plans and who should develop them? These questions were discussed and answered during the fourth PAD meeting. In the second round, some comments still focused on criteria and indicators related to the water use, ecosystem impact and the justification of the 5,000 m^3/ton of production.

Issue 3 (water pollution and waste management) received most comments. While stakeholders agreed on minimizing the negative impact of pangasius farming on water resources, farmers and other stakeholders did not understand the technical physical-chemical water quality parameters. It was agreed upon that training to farmers on these parameters and the environmental impacts of farming was considered necessary.

Issue 5 (feed management) mainly concerns fish and feed producers. The proposals for feed management were considered complex and hard to implement, and raised contradictory views between large-scale farmers and feed producers on one side, and small-scale farmers on the other (for instance on homemade feed vs. pellet feed). The prohibition to use raw fish as feed ingredient, and the requirements to calculate the feed conversion ratio means that small-scale farmers using homemade feed will be unable to comply with this standard. Participants argued that external support from Government, NGOs and private sector should ensure facilities for analysis of feed ingredients and farmers is informed about the sources of alternative and better quality feed ingredients so that they can comply with the PAD standards.

Issue 6 (veterinary medicines and chemicals) raised diverging points of view among stakeholders, but also common suggestions. Except government officials, all groups suggested a clear black and green list of forbidden and allowed drugs. Most commentators suggested permitting the use of pro-biotics, prophylactics and vaccines, in addition to antibiotics and chemicals. Producers and government officials highlighted the dilemma that application of pharmaceuticals would require advice by veterinary experts but that these are insufficiently available in rural areas. Certifiers, NGOs and academics suggested the training of farmers in the efficient use of antibiotics and chemicals.

It is difficult to arrange the different perceptions of participants on the PAD standard. In general, the indicators for water use, water pollution, feed management and medicines and chemicals use seemed difficult to understand for all stakeholders in the first public round. The 4th PAD meeting discussed how to deal with this and the Technical Working Group of PAD was instructed to further develop standards that are more understandable for all stakeholders, especially for (Vietnamese) farmers. In the second public round, debates focused more on the details of the criteria and indicators. The information seemed clearer for the participants, generating more consensuses. These dialogues contributed to knowledge sharing, communication and social learning among aquaculture interest groups, including the development of new institutions and new analytical tools. The question remains whether such processes of collaborative inquiry will lead to more sustainable fisheries management decisions. As Belton and Little (2009) and Belton et al. (In Press) argue for the Tilapia Aquaculture Dialogue (TAD), the collaborative process was captured by industry and the vision that large scale is more responsible in aquaculture. But this has not been the case with respect to pangasius. By including many actors and stakeholders through dialogues, the challenges, concerns, and difficult choices in fisheries governance became 'owned' by large numbers of actors in the fish chain.

Still, with its focus on 20% of producers, PAD leaves the other 80% of mostly small scale farmers behind. Thus, it excludes a large part of the current farming community that is and will be unable to comply. This 80% of aquaculture producers also need to produce food in a safe and environment-friendly manner. In many remote areas international governance arrangements, exporters and private extension agents are absent and only government extension services are present. Here farmers need other forms of assistance from national and local governmental authorities and through producers’ cooperatives.,

5.5 National governance

At the national level, government policy, institutional support and human capacity building are providing a strong foundation for aquaculture development (FAO 2009a). Most farms and community activities are influenced by national level policy, legislation and institutional support. The spectacular growth of pangasius and shrimp aquaculture has challenged the government with respect to increasing compliance of farmers with production standards. The next subsection analyzes the government policies in aquaculture. The governmental approach has blurred boundaries between voluntary and compulsory standards.

5.5.1 Emergence of voluntary standards

Government policies in Vietnam continue to be highly supportive of aquaculture development. This strong government support, combined with the dynamism of Vietnam's farming community, is the principal driver behind the sector's substantial growth (Trong 2008). Government policies for aquaculture development are defined in laws and a considerable number of decrees, ordinances, decisions, circulars and regulations. The main policy document for Vietnamese fisheries is the National Program for Aquaculture Development – Master Plan 1999-2010 (Decision No. 224/1999/QĐ TTg dated Aug. 12, 1999 by the Prime Minister). In 2006 this plan was amended in response to the growing international concern over environmental impacts of aquaculture with a new aquaculture development plan and seafood export promotion program; nominally to 2010, with a 'vision' to 2020 (Dung 2006).

A central component of the Vietnamese aquaculture plan and export promotion program is the ongoing expansion of the sector, with a target of 9% annual growth, and 100% compliance of processing companies and 50% of farmers with international standards by 2010. Both the plan and program build directly on the design and implementation of Codes of Practice (COP) designed to provide practical guidance in achieving the principles set out in the FAO Code of Conduct for Responsible Fisheries (CoC, FAO 1995) and more specifically in the 'International principles for responsible shrimp farming' (FAO et al. (2006). The implementation of these international standards was intended to have a voluntary character, meaning that farmers agree on their application without being controlled by the government.

The first COP initiative in Vietnam was the development of Good Aquaculture Practices (GAP) in 2002 by the National Fisheries Quality Assurance and Veterinary Directorate (NAVIQAVED) and the US Food and Drug Administration. The GAP standards focused on improving the food quality and safety aspects of fisheries production, including the reduction of water pollution, and traceability to consumer markets (NAVIQAVED 2006). Recognizing the high technical capacity required to implement GAP, and the predominant focus on intensive production systems, the government, as part of a larger NACA/SUMA (2005) managed project, developed Better Management Practices (BMP) as an alternative COP. BMP is similar to GAP, addressing improved food safety, quality and the reduction of water pollution, but it is seen as more suited to extensive and semi-intensive systems.

5.5.2 Adoption of BMP and GAP standards in aquaculture

During the six years after the launching of the GAP and BMP standards there have been many projects and support from the government and non-governmental organizations (Khang 2008; Tien and Griffiths 2008). These projects focused on training farmers, and supporting equipment to provincial Department of Agriculture and Rural Development. In addition, pilot sites were set up for certifying eight enterprises and four farming areas (in Ben Tre, Soc Trang, Bac Lieu and Ca Mau) for GAP, and preparing documents on detailed guidelines for the further dissemination of the standards. The implementations of BMP and GAP have shown positive results. NAVIQAVED (2006) reported that the productivity of shrimp from GAP-farms was 20 to 30% higher than from non-GAP farms. In addition, the certification of hatcheries and nurseries meant that pathogens were controlled so that outbreaks could be prevented in time. The use of antibiotics decreased and chemical use declined even with 30-60%. Wastewater and solid waste have been treated. Costs were about 5-10% lower due to reduced Feed Conversion Ratio (FCR), and chemicals and antibiotic use, and farmer benefits increased with up to 15%. Still, the results have been limited due to poor diffusion.

In 2008 about one percent of the shrimp farming area and less than one percent of pangasius farms have been certified (Tien and Griffiths 2008). Both the shrimp and pangasius sectors are dominated by small scale producers. In pangasius approximately 89% of the producers are small holders, who collectively contribute 11% of the Vietnamese pangasius export value (Loc et al. 2010). In the shrimp industry 95% of farming area is occupied by extensive, improved-extensive and semi-intensive farmers, contributing two third of total shrimp production (Bindels 2009).

The implementation of these voluntary standards has been hampered by high costs and a lack of market incentives to farmers. In response, the government shifted these standards from voluntary to mandatory compliance. The Government outlined a series of deadlines for implementation BMP and GAP. Intensive farmers, which imply all pangasius producers, were expected to take up GAP in January 2009, while all other aquaculture farmers were expected to comply with BMP standards by January 2010. Despite international pressure the government has been unable to make the transition to mandatory standards by either of the two deadlines. As Ha and Bush (Forthcoming) note, this is largely because of a lack of major institutional restructuring of the fisheries within the Ministry of Agriculture and Rural Development (MARD), the lack of capacity to punitively enforce standards and, perhaps most tellingly, the lack of market incentive.

Moving from the experimental area of certified shrimp farming to wider full-scale implementation of certification systems is unlikely to occur through mandatory compliance with production standards. As outlined above, the government has neither the capacity nor, in recognition of the low levels of capitalization of many farmers, the will to do so. As noted by Loc et al. (2010), and supported by studies elsewhere (Delgado et al. 2003; Belton et al. 2009), without market incentives or government subsidies farmers are unlikely to meet the high costs of compliance.

In addition to market incentives farmers also require a stronger set of national institutions to ensure confidence in the adoption of the standards. Loc et al. (2010) found that, in contrast to many land and environmental regulations affecting aquaculture in Vietnam, the vast majority of farmers are aware of the BMP and GAP standards, especially as they relate to drug and chemical use. They also found that one of the main factors preventing farmers adopting these standards is the poor enforcement of contracts with processing companies. It therefore appears that the Vietnamese government has an important role in bringing international principles and standards to the local farmers; codification in legal documents seems not enough.

5.5.3 Aquaculture stakeholder meeting in An Giang province

In December 2008 a meeting of all sector stakeholders was convened in An Giang province to discuss environmental impacts of aquaculture in the Mekong Delta. Participants included government staff, scientists, pangasius and shrimp farmers, processors, and representatives from the farmer's and women's union. The meeting was the first government-led forum on the causes of and potential solutions for water quality issues surrounding aquaculture. Through such meetings the government aims to build recognition of GAP and BMP standards, and facilitate the transition from their voluntary to compulsory implementation.

The meeting included two parts. The first consisted of plenary presentations by provincial politicians and environmental experts on aquaculture development, including environmental problems and technical and managerial solutions. In the second part of the meeting discussion turned to the advantages and disadvantages of different technical and management approaches. The meeting proved instrumental in stressing the political priority and feasibility of pollution control in aquaculture in Vietnam. All stakeholders agreed on the problems caused by pangasius and shrimp production, especially on existing and potential water pollution, while government officials agreed on the weak implementation of pollution control and waste treatment in aquaculture farming and processing industries.

The discussion around technical and managerial approaches to mitigate pollution led to more contentious debate. Two key issues stood out. First, no consensus was reached over the specific technical requirements placed on farmers for water pollution mitigation. In line with GAP and BMP standards government officials reiterated the need for farmers to build sedimentation ponds to treat wastewater from aquaculture ponds. During the stakeholder meeting, farmers expressed their preference for using their land for rice or aquaculture production rather than for wastewater treatment (Anh and Mai 2009a). Farmers with smaller land holdings voiced their concern that such treatment options were simply not possible. A more general concern of all participants was the limited knowledge of farmers on technical options for waste minimizing and treatment. Farmers and rural communities agreed on the importance of cooperation between the aquaculture sector and the irrigation sector. Government support was needed to establish farmer cooperatives for aquaculture production and water resource management.

The second concern raised in the meeting related to the need for financial incentives to implement pollution mitigation measures in line with GAP and BMP standards. Farmers noted their desire for improved contract conditions with processors to invest in water pollution technologies. The discussion highlighted the need for market ownership of standards, translated into economic incentives (market access, improved contract conditions or price premiums) to be effective. Such concerns are more pronounced in the pangasius sector where there has been a 30 to 40% decline in the number of small farmers due to poor economic performance (Loc et al. 2010). Not surprisingly processing companies were reticent to agree with sweeping changes to contracts or buying practices. However, they did note the potential of farmer organizations as a means of increasing compliance with water pollution standards as well as meeting their own requirements for improved product safety and reduced transaction costs.

5.6 Community-based governance

The shortcomings of international and national standards have increased the attention given to community-based initiatives to mitigate water pollution from aquaculture. The assumption is that improving cooperation between farmers, especially smaller 'household-scale' farmers, will improve their capacity to organize and invest in pollution mitigation technologies. Community-based cooperative arrangements have a long history in Vietnam, ranging from state sponsored production cooperatives (*hop tac xa*) to more informal production groups (to hop toc or to lien ket, see Fford and Huan 2001). A full discussion of the success and failure of these various models is not possible here (see for example Beresford 1990; Kerkvliet 1995; Luttrell 2001). Instead we focus on the relevance of 'new-style cooperatives' for improving environmental performance of aquaculture production.

5.6.1 Old and 'new' style cooperatives

In Vietnam there has been considerable resistance to cooperative forms of production since the failures of collectivization in the early 1980s. This resistance has been greatest in Southern Vietnam where land holdings have been historically more uneven, and less centralized around single communities (Kerkvliet 1995). To increase the international competitiveness of Vietnamese small holders, while at the same time avoiding connotations of collectivization, the government introduced 'new style' production cooperatives through the 1996 Law on Cooperatives (Decree No. 47 L/CTN 1996). The objective of these cooperatives was to assist members with marketing services, coordination of production and, in some cases, additional administrative services.

Since the 1996 Law on Cooperatives, many old style co-operatives changed to new style cooperatives. Most cooperatives, especially those involved in traditional agricultural sectors (Table 5.3) such as rice, are a formalization of existing reciprocal labor and irrigation agreements between households (Nhuong 2004). Where new production cooperatives were formed, such as in aquaculture, poor administration, high organization costs and a lack of clear market incentives meant that many existed only on paper. As Fford and Huan (2001) note these failures did not mean an absence of cooperation in rural communities. On the contrary, the innumerable private (i.e. not state sponsorship) ‘self help’ or ‘cooperative groups’ which emerged were reformulations of (failed) production cooperatives (Kirsch 1997).

Table 5.3 Cooperatives in agricultural sectors in Vietnam (2008)

	Number of cooperatives			
Area	**Total**	**Crops**	**Aquaculture**	**Other**
Whole Vietnam	7592	7277	273	42
Mekong Delta	753	646	104	3

Source: (GSO Vietnam 2009)

In 2007 a Decree on the organization and operation of cooperative groups relaxed the state control over cooperatives, giving legal space for these smaller cooperative groups, operated “by three individuals or more who jointly contribute assets and labor to carrying out certain works for mutual benefit and responsibility” (Decree No. 151-2007/ND-CP 2007). Under this Decree both forms of cooperatives are considered legal entities, allowing them to associate, advertise and access formal credit. The primary objective of these cooperatives in state policy is economic development and poverty alleviation (MARD 2009a). However, in aquaculture these cooperatives are also instrumental in improving compliance with BMP, GAP and international safety and quality standards.

5.6.2 New goals for ‘new style’ (aquaculture) cooperatives

The loosening of state control over production cooperatives and the formalization of production groups has led to new opportunities for meaningful 'new style' cooperatives in the aquaculture sector. Many aquaculture producers see the benefits of this formalized cooperation in building closer (contractual) ties to processing companies and access to credit (e.g. Lem et al. 2004; Khiem et al. 2010). However, many have not been able to manage such arrangements without external assistance of government and international projects, or without direct sponsorship of processing companies. These ‘external’ interventions both improve efficiency (and therefore economic development) as well as safety and quality, with a focus on environmental standards.

At least two international projects have been active in promoting cooperatives to facilitate BMP standard compliance, including water quality testing, health management, awareness of government environmental laws and regulations, and action plans for upgrading and monthly monitoring (Trong 2008). The first is a project of the An Giang University (AGU), which has been involved in setting up a cooperative group of (small) household scale pangasius farmers in Chau Phu and Phu Tan district of An Giang Province (Khiem et al. 2010). The second project was set up by the Mekong River Commission (MRC) in Soc Trang province through the Research Institute for Aquaculture 2 (RIA2) (WWF 2009f). The establishment and support of these farmer clubs strengthened the preparation and implementation of management plans and management capacity of farmers in food safety and reduction of environmental risks, most notably water pollution reduction. But neither the AGU nor MRC project was able to create lasting contractual ties with processing companies, as the cooperative members has wished. This failure meant that farmers meeting BMP standards were not recognized and therefore not explicitly rewarded by a higher price in the market. This in turn raises questions about the long term viability of production cooperatives or production groups as either a mechanism for improving compliance with environmental standards or, as argued by the government, poverty alleviation.

In their attempts to ensure greater compliance and traceability in response to existing food safety standards and emerging environmental standards processing companies now sponsor and establish cooperatives. An example from the pangasius industry is the ‘An Giang Pure Pangasius Union’ (APPU), a cooperative group sponsored by AGIFISH.Co, one of the largest processing companies, in response to growing concerns over the ability of the company to meet food quality and safety standards. APPU was formed by the company to reduce the risk and transaction costs associated with sampling and testing for banned substances, which also differentiates their product to international buyers (see Bush and Belton Forthcoming). A similar model is seen in Ben Tre province for shrimp, where large scale farms are organized into cooperative groups sponsored by processing companies. As in the pangasius sector, these cooperative structures often improve product quality following requirements of the company and offer fixed contracts. In both cases farmers are given incentives through more secure market access to invest in upgrading their production to meet water pollution standards.

Smaller producers are often excluded from these forms of ‘alliance capitalism’ in Vietnam (Beresford 2008); hence compliance oriented cooperative groups for small household producers are needed. With this in mind WWF is building on the work of the MRC, in anticipation of the emergence of the ShAD (and later ASC) standards. In order to ensure that farmers will be able to comply, the ‘cooperative group’ model is extended to 21 farmer ‘clusters’ in Soc Trang, Bac Lieu and Ca Mau provinces (WWF 2008c). It is anticipated that members of these clusters will provide the necessary administrative, credit and technical framework for cooperative forms of standard compliance.

The promise of independent small-holder initiatives is already evident in the pangasius industry. Farmers in Hoa Lac village in An Giang province, who have formed the Chau Phu Clean Pangasius Club through the AGU pangasius project (see Khiem et al. 2010), designed a novel water treatment technique similar to what Anh et al (2010cb) describe as wetland filtration. The farmers remove sediments from their pangasius ponds into a common discharge area before letting their pond water drain though gravitation into to the community rice fields. Conflicts did emerge with rice farmers about the costs and benefits of pumping water and nutrients into rice fields. However, perhaps for the first time in Vietnam, the commune government supported this cooperative form of water treatment over the concerns of the rice farmers. It appears this support is a direct response to the water quality benefits and the fact that the farmers are formally registered as a cooperative group under the 2007 Decree.

5.6.3 Cooperatives between public and private governance

Our assessment of cooperative groups in the Mekong Delta shows that collaboration can indeed assist small farmers to better comply with the requirements of quality standards. A range of difficulties still remains for small farmers wishing to form cooperative groups; and farmer cooperatives also meet difficulties in the technical requirements of traceability, the high costs of certification, and the lack of knowledge and skill on technical solutions to water pollution. Nevertheless, the experience of farmer groups in An Giang, Ben Tre and Soc Trang provinces show that cooperative groups serve an important role in increase production efficiency, as well as facilitating innovation in water treatment. In addition, it appears that the registration of product labeling can improve bargaining power in the market.

The experience outlined above demonstrates the role of cooperative groups in transferring experiences of implementing BMP and GAP (and equivalent) standards between farmers as well as back to government and industry actors. This ‘bridging’ role of cooperatives has also been noted in the Thai shrimp industry (Lebel et al. 2008; Giap et al. 2010). To ensure long term impact in Vietnam cooperative groups will have to become independent of the external government and international donor support and will have to seize market preferential. While, as reflected in the An Giang meeting, processors see potential benefits of farmer organisation, they appear reluctant to provide market incentives such as contracts.

5.7 Discussion and conclusions

Following significant implementation failures of Vietnamese national regulations and laws in making pangasius and shrimp farmers more sustainable, new arrangements have been emerging involving state and non-state actors at multiple levels. This nested multilevel governance system focuses on the development and implementation of (mostly voluntary) standards and certification systems. The governance systems analyzed here show how environmental regulatory networks for pangasius and shrimp aquaculture bring together multiple actors, with increasing levels of participation (Stead 2005). These include national and international actors, private sectors, NGOs, government agencies and communities.

Different standards and certification systems function in this multilevel governance system (e.g. PAD, ShAD, BMP, GAP, CoC, Naturland). A distinction needs to be made between what might be termed 'transformative' vs. 'niche' standards. If there is going to be real change in the industry then this difference needs to be better appreciated, as well as the links between state, industry and farmers. It may not be appropriate that all certification schemes are applied by all communities in the same way, as these schemes emphasize different sorts of qualities. How communities might be best enrolled into certification networks depends on how local communities and governments are organized, and how pangasius or shrimp farming is conducted.

A key issue for local implementation success of such standards and certifications is the need for market incentives. One of the shortfalls of the GAP and BMP standards is that they have been developed under the auspices of the FAO Code of Conduct for Responsible Fisheries. Although providing an international remit for national standard development – as seen also in Thailand (Vandergeest 2007) and India (Knowler et al. 2009) – they lack market ownership. As Tien and Griffiths (2008) and Ha et al. (Forthcoming) note, links need to be built between farmers, processors and retailers to provide incentives for standard compliance. The lack of such incentives contributed to the shift from voluntary to compulsory implementation of BMP and GAP in aquaculture by the Vietnamese government. The ShAD and PAD standards may well prove successful in achieving this goal given the strong international market involvement. But the effectiveness of PAD and ShAD is yet to be seen. In the case of ShAD international involvement has been less effective, but there is a move towards integration with BMP and GAP standards and thus stronger linking up with national developments. In the case of Pangasius PAD has been effective in creating a new platform within the country, but has not yet engaged with BMP and GAP standards.

This links to questions on the possible and profitable interactions between these governance's networks. Is it possible or useful for these three governance networks to apply a harmonized certification approach to communities and farmers? We have noticed increasing linkage between these nested governance arrangements. In the process of developing PAD and ShAD, local pangasius and shrimp farmers have been directly involved in processes of the standards. However, the participation of governmental actors is still limited compared to other actors. Such harmonization would also have to cope with difference in farmers and farming systems.

Most certification networks require that the costs of certification be borne by the enterprise being certified, and involve complex, expert-driven documentation and monitoring processes that are beyond the financial and technical means of small enterprises or community-based institutions (cooperative). In this context, it needs to be noted that if most large buyers follow in making transnational environmental certification mandatory, it is likely that smaller, locally-owned pangasius or shrimp farms would be marginalized from major markets on account of lack of resources to pay for expensive certification procedures, and lack of ability to meet complex documentation requirements. The elimination of many smaller farmers would reduce the likelihood that pangasius or shrimp farming would benefit local communities (World Bank et al. 2002; Vandergeest 2007). BMP, GAP, and CoC standards and community-based processes partially displace these expensive and complex procedures and make space for small farmers. According to Corsin and colleagues (Corsin et al. 2007), the use of government officers to implement inspections would be a more cost effective strategy than third party certification, although arguably less credible because of the links that government has with producers and their direct interest in having many certified enterprises.

Chapter 6 Discussion and conclusions

6.1 Introduction

The main objective of this study is to analyze possibilities for environmental improvement in pangasius and shrimp production in Vietnam and to identify options for technological and management intervention. This final chapter formulates the conclusions out of this study. The main findings—following the research objectives as presented in Chapter 1—are reported in section 6.2. Section 6.3 compares the cases of shrimp and pangasius production, followed by a discussion on a number of methodological issues in section 6.4. Subsequently, the strengths and limitations of the present study are analyzed in section 6.5. The chapter closes with recommendations for environmental management of shrimp and pangasius production and for future research.

6.2 Main findings

In chapter 1, four research sub-objectives were formulated to achieve the overall objective of the thesis. In this section, conclusions are drawn subsequently for each of these research sub-objectives.

Sub-objective 1: To identify causes and impacts of water pollution in the Mekong delta, associated with pangasius farming and processing industry; and identify possible options to reduce these problems.

This study concludes that pangasius production is a minor source of nutrient pollution in the Mekong River, accounting for less than 1% of total TSS, Nitrogen and Phosphorus loads. However, the pollutant loadings from individual farms and processing plants may exceed locally water quality standards for Vietnam, leading to local pollution problems. On the other hand, there are also pangasius farms for which the wastewater is no source of local water pollution, because the concentrations of pollutants are below the water emission standards. This indicates that with current technologies and management schemes, it is possible to avoid local pollution problems caused by pangasius farming in Vietnam.

There are three sources of water pollution related to pangasius production: wastewater from fish ponds, sludge from fish ponds, and wastewater from processing industries. Wastewater from fish ponds is the most important source of water pollution from pangasius production, contributing between 60-90% of the total pollutant loading from pangasius production to surface waters. However, sludge from fish ponds and wastewater from fish processing have relatively high pollutants' content, which may lead to severe local environmental problems.

Several approaches for reducing water pollution problems from pangasius farming have been identified and assessed. First choice options are waste prevention and minimization in fish ponds, including a range of techniques for reduction of water use, feed use, chemical and medicines use and treatment of input water and good farm cleaning. In addition, treatment and reuse of effluent streams is possible through the application of sediment ponds. The collected sludge from these sediment ponds can be re-used as fertilizer in agriculture after dewatering. The application of such sediment ponds is restricted by available land. For pangasius processing, cleaner production technologies and wastewater treatment plants should be applied in every processing industry.

Sub-objective 2: To analyze the causes of water pollution, contaminated sediment and spread of disease from intensive black tiger shrimp farming in Vietnam and to identify possible options to reduce these environmental impacts.

The study concludes that the most important environmental problems caused by shrimp farming are associated with water pollution, contaminated sediments and the spread of diseases. Intensive shrimp farming is not always associated with waste streams exceeding emission standards. The concentrations of pollutants in wastewater vary largely among shrimp ponds, depending on the kind of shrimp farming system and the mode of operation. Intensive and semi-intensive shrimp farming in Can Gio account for about 17% of the total shrimp farming area in Can Gio. There are probably many individual ponds in this category where emission standards are significantly exceeded. But not all intensive shrimp farms are causing environmental problems. The improved extensive shrimp farming system (55% of the area) and the extensive rice shrimp farming systems (28% of the area) (Can Gio Economic Division 2007) are considered not to cause major water pollution problems. In all systems the levels of BOD_5, COD and TSS in effluent vary along periods of the production cycle.

Currently available technologies can reduce pollution from intensive shrimp farms. Two groups of technical options are identified and assessed with respect to reducing the environmental pressure of water pollution, contaminated sediment and disease spreading from individual shrimp farming ponds in Vietnam. The first group of options focuses on waste reduction and includes more efficient feed use, ozone aeration and improved farm management. For the reduction of feed input it is important that adequate and sufficient information is available to farmers and that the government can efficiently regulate the quality and composition of feed. Aeration is noted as a particularly suitable technology given the low level of expenses needed to implement it in existing intensive systems. The second group of options focuses on waste treatment, sediment reuse and the construction of artificial wetlands. Sediment reuse in agriculture may prove to be successful if the economics of its production can be justified to farmers. Wetland construction, although practiced on some farms, remains difficult to implement due to the lack of land available to farmers.

Sub-objective 3: To apply the idea of eco-agro-industrial clustering for reducing pollution, protecting natural resources and improving the competitiveness of the shrimp production and processing sector in the Mekong delta, Vietnam.

This study showed that ideas of industrial ecology are valuable in greening fishery production industry in Vietnam. Following the notion of industrial ecology a (almost) zero waste industrial cluster around shrimp production in Soc Trang could be designed, involving 13 processing industries, a animal feed plant and composting plant, a Chitosan industry and an anaerobic wastewater treatment plant. Waste of the shrimp processing industries could be reused by the other plants, leaving hardly any waste stream flowing into the environment. The application of proposed eco-agro-industrial cluster proved economically and environmentally feasible.

A limited number of actor relations within the economic and policy networks, in which shrimp processing industries are embedded, proved important to facilitate the materialization of such an industrial cluster in contemporary Vietnam. Especially international customers and product quality and certification organizations, and national environmental authorities and business associations are key actors in bringing the designed model into reality.

The approach taken in the current study is also valuable for assessing the potential for eco-industrial clustering in other provinces and other fish processing sub-sectors. However, the concrete outcomes in terms of eco-cluster design and facilitative actor networks will differ.

Sub-objective 4: To analyze current attempts—at multiple levels—to govern water pollution in aquaculture in Vietnam, and illuminate how public-private multilevel governance complexes are starting to address conventional state failures in water pollution problems in Vietnam's aquaculture.

Following the failures of conventional state governance approaches in addressing water pollution by aquaculture in Vietnam, the emergence of new approaches is of key importance. This study found that water pollution by shrimp and pangasius aquaculture in Vietnam is addressed by new governance arrangements at three distinct governance levels. At the international level the PAD (Pangasius Aquaculture Dialogue) and ShAD (Shrimp Aquaculture Dialogue) Dialogues include a large variety of actors and stakeholders to develop standards of sustainable aquaculture. Although these Dialogues are a lengthy process full of challenges and difficult choices, it does develop a sense of ownership among the participants and stakeholders and develops international acknowledged standards for certification. But the focus of these international governance arrangements is on a small percentage of producers, leaving behind a large number of small scale farmers which are unable to comply with the developed standards. For these significant groups of aquaculture farmers, national and local governance arrangement play an important.

National voluntary approaches of GAP, BMP and CoC, and local arrangements of farmer groups and cooperatives seem promising ways of including the remaining 80% of aquaculture farmers. While interesting best practices could be found of these two approaches, overall implementation of these innovative arrangements is still far from successful. Farmer cooperative groups, for instance, meet difficulties in technical requirements of traceability, the high costs of certification, and the lack of knowledge and skills on technical solutions to water pollution.

This study concludes that it seems profitable and possible to link these governance's networks and to work to harmonized certification approaches for communities and farmers. We have noticed increasing linkage between these nested governance arrangements. However, such harmonization would have to cope with differences in farmers and farming systems.

6.3 Comparing shrimp and pangasius

6.3.1 Comparing pollutant loads in wastewater from shrimp and pangasius farming

The characteristics of pangasius and shrimp farming system are described briefly in table 6.1. In general, pangasius farming and shrimp cultivation have many different in water resource, farming period, volume of water use and discharge, production capacity. These characteristics can cause other different in the pollutant load in wastewater from their system as described more clearly in figure 6.1 and 6.2.

Table 6.1 Comparing pangasius and black tiger shrimp farming systems

Item	Unit	Pangasius	Black Tiger Shrimp
Water body		Fresh water	Brackish water
Farming period	Months	6	4
Water use and discharge	m^3/ha	2,200,000	35,250
Production	ton/ha	240	5.3
Water use/ton of product	m^3/ton	9,166	16,022
Production cost	VND/kg	16,500	70,000

Item	Unit	Pangasius	Black Tiger Shrimp
Price in the national market	VND/kg	16,800	110,000

In Figures 6.1 and 6.2 we have compared the pollutant load in wastewater from pangasius farming (chapter 2) (Anh et al. 2010cb) with that from intensive black tiger shrimp farming (chapter 3) (Anh et al. 2010a), both focusing on the Mekong delta of Vietnam. From that we can conclude that shrimp farming is causing less water pollution than pangasius farming per hectare of farming area (Figure 6.1). However, per ton of product, the results are different: BOD, COD and TSS losses are highest for shrimp aquaculture because of turbulence during the ventilation in the shrimp pond. Total N, total P and N-NH3 are highest for pangasius (Figure 6.2). For both intensive shrimp and pangasius farming, it can be concluded that water emission standards are not always exceeded. This is interesting, because both shrimp and pangasius farming are generally considered to be relatively polluting, also in Vietnam. Our studies indicate that this is not always the case and that it depends very much on the technologies and management schemes applied in intensive farming systems. It would be interesting to identify more specifically the factors that affect the variation of pollution among ponds.

If we compare the pollution load per economic value for both species (Figure 6.3) it can be concluded that shrimp farming is causing less water pollution (in terms of BOD, COD, TSS, total N, total P and NH3-N) than pangasius farming per unit of economic value (Figure 6.3)

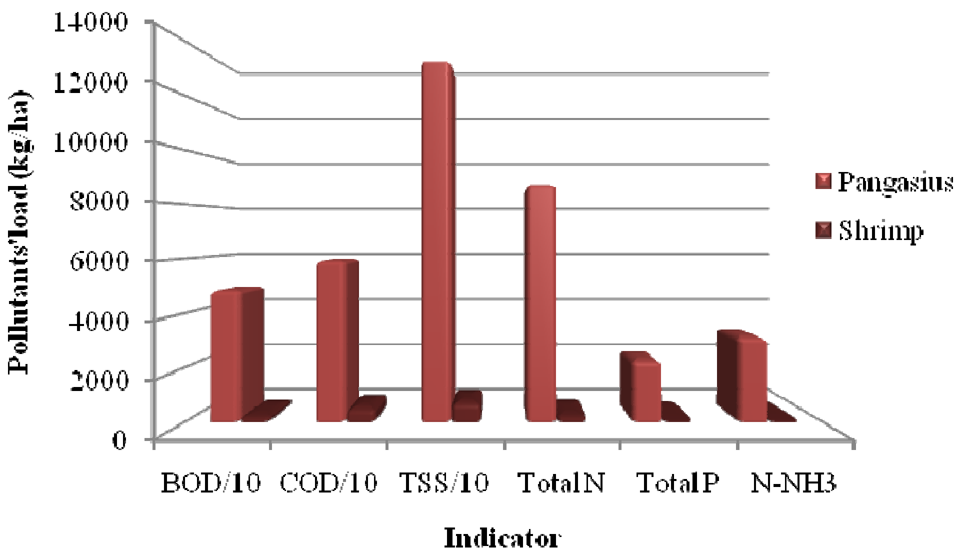

Figure 6.1 Water pollution by pangasius farming and intensive black tiger shrimp farming (excluding sludge) (kg/ha). Source: chapter 2 and 3 of this thesis.

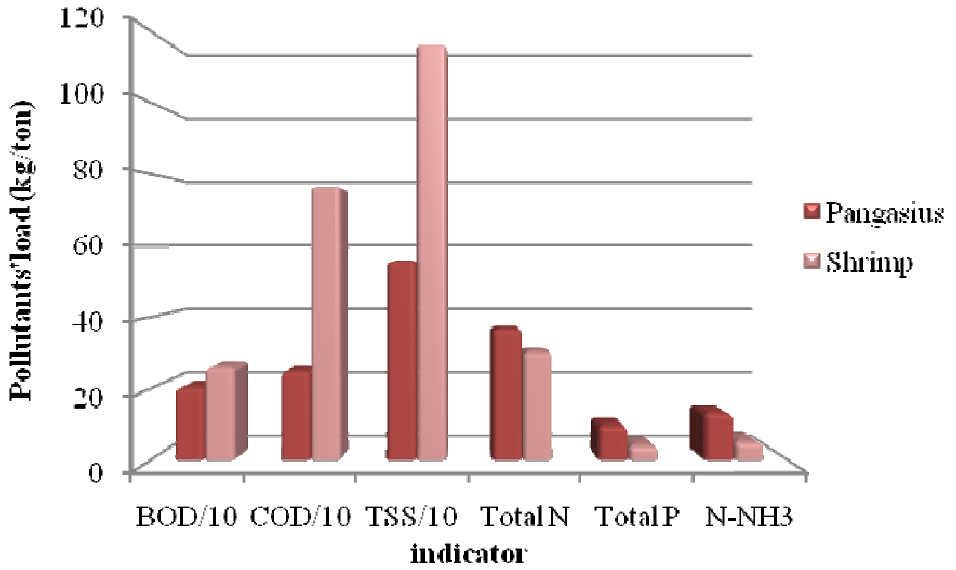

Figure 6.2 Water pollution by pangasius farming and intensive black tiger shrimp farming (excluding sludge) (kg/ton). Source: chapter 2 and 3 of this thesis.

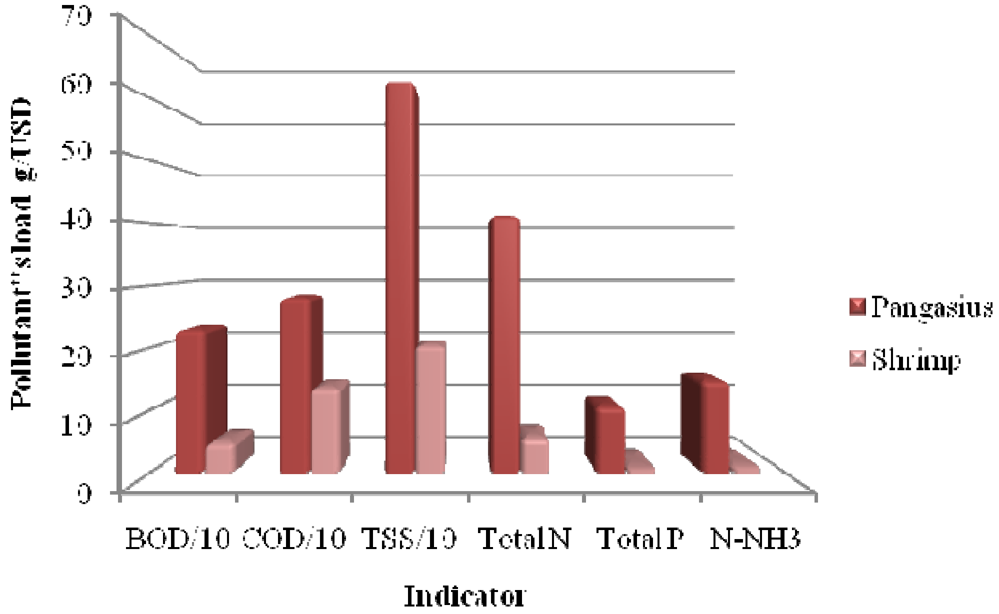

Figure 6.3 Water pollution by Pangasius farming and intensive black tiger shrimp farming (excluding sludge) (kg/USD)

6.3.2 Convergences and divergences between shrimp and pangasius governance

The fishery sector in Vietnam is a significant and fast growing component of the Vietnamese economy. In there, pangasius and shrimp aquaculture are the two largest contribution species to the production and export value of Vietnam. The export orientation of the fish products has meant the export fish processing industries in Vietnam are equipped with modern technology and are increasingly regulated by international food safety and quality standards. Industrial processing of most fish species shows remarkable similarities in term of production processes, main environmental problems, and potential solutions. There are quite some similarities between processing industries in both sub-sectors. With the rapid modernization of processing companies in response to both government and international safety and quality requirements, the fish processing industry is moving towards more modernized industrial production in Vietnam.

Through their international production chains, pangasius and shrimp aquaculture systems are both strongly influenced by global markets and several standards related to food safety, and environmental and social performance. For the purpose of economic development, the Vietnamese government has sought to reinvigorate production through a series of modernization programs with these two species. Pangasius aquaculture has become a popular form of aquaculture and the largest single species farming system by volume in Vietnam. The subsector is dominated by intensive farming systems with high productivity and large export markets. By comparison shrimp farming throughout the country has been encouraged to shift from extensive traditional systems to improved extensive, semi-intensive and intensive production models. However, shrimp production in Vietnam remains relatively ‘under-modernized’ with approximately 90% of the total farming area practicing extensive traditional production.

Intensive farming system is more often associated with environmental problems, especially water pollution. As outlined in this thesis, there are a wide range of available techniques for reducing water pollution in both pangasius and shrimp production, but currently there is only a relatively small percentage of famers applying these techniques. The effects of water pollution on pangasius are small due to high production and survival capacity of the fish. As a result, pangasius farmers have until now not had to respond to water pollution problems in their production systems – with the exception of improving meat quality in the last month of the production cycle. Farmers are also not aware of any substantial impact of water quality on the surrounding waterways and wetlands, because farmers located on major canals and mainstream areas do not observe any water quality change, and there is low pressure for reform of their production practices from the government.

This is significantly different in case of shrimp in coastal areas. As indicated above, intensive shrimp farming systems are more polluting than pangasius per kg of production and also far more polluting than the conventional extensive shrimp systems seen throughout the Delta. In fact, water pollution in intensive shrimp farming is directly linked to the spread of diseases, such as White Spot Syndrome, Monodon Baculo virus (MBV), and Yellow-Head virus (YHV) which has until now been the main limiting factor in improving economic efficiency (see also (Hoang 2006); (Joffre and Bosma 2009); (Nimrat et al. 2008)). Farmers are very aware of these risks associated with water quality and, in contrast to their pangasius counterparts, are more willing to invest in water treatment.

At the same time, with strong export orientation, both sectors have been subject to international pressure – through export markets with regard to a 'sustainable' industry via systems of standards. Led by demand in international markets farmers are increasingly pushed to produce safe, high quality, environmentally friendly and socially responsible aquaculture products. Pangasius is mostly export oriented, and the farmers depend very much on processors. However, with the current low market prices farmers do not have enough incentives for upgrading their production systems – indeed many farmers in recent years had to sell at a loss (as also reported in (MARD 2009a). With respect to environmental performance, and especially water quality, if the pangasius farmers want to continue their involvement in this industry, they will have to apply reduction options for wastewater or leave pangasius and move to farm other species. The volume of pangasius product that already meets market demand does not provide enough market incentive for both processors and pangasius farmers to install improvement options. Further research is therefore needed to determine what changing practices are possible under marginal economic conditions? Is more financial support needed from the government, should farmers be encouraged to shift to alternative species, and if so, what continued impacts will these production systems have on water quality?

In the case of shrimp, extensive or less intensive forms of farming do not need to apply the technical options to reduce environmental problems because of their relatively low environmental impacts. Besides, there also exists a domestic market for shrimp with a significant percentage (40-50% as shown in (Bindels 2009),(MARD 2009a) and(MARD 2009b). Under these conditions shrimp farmers do not feel similar pressure as pangasius farmers. The intensification of shrimp is important to reach economic goals of the country, while intensive shrimp often have high risk associated with water pollution problem and with the disease spread. The farmers cannot overcome this problem when the surrounding areas are not yet planned, even if the technology is available, or if they have already invested in water quality technologies. So, if the intensification policy of the government is to continue, then the government needs to invest heavily in improving public infrastructure in surrounding areas. It may then be more likely that farmers are more willing to invest in on-farm technologies.

Currently, there are different types of aquaculture in the Mekong delta. The development of these aquaculture systems has so far been spontaneous and, as such, few if any water pollution mitigation plans are in place. While most of international or national standards try to certify the farm, when the water source quality is poor and the surrounding areas are unplanned farmers are unlikely to have the confidence to invest individually in the on-farm technologies outlined in this thesis. This issue is particularly relevant for pangasius farmers who question why they should increase the quality of water released into their ponds while the water they take from surrounding canals is so poor. This demonstrates the lack of urgency in the pangasius industry to mitigate water quality and is in complete contrast to the shrimp industry. In the case of shrimp, farmers are much more vulnerable to water quality and disease. Farmers are very aware of the need to control the quality of water on their farms and they also realize that the poor quality of water from canals negatively affects their production. However, similar to pangasius farmers, they may well be reticent to invest in on-farm technologies if surrounding water quality is so poor. As such, water quality improvements require ongoing support by government in public infrastructure.

There is also an apparent convergence between shrimp and pangasius in terms of governance. The international influence over the industry has led to more homogenous incentives, expectations and standards with respect to water quality. This globalizing influence is felt equally for shrimp and pangasius. The national level is also creating industry wide standards and governance arrangements to steer the sector as a whole to improved environmental performance. While the international governance standard serves a small percentage of the farms, the national governance requirements for environmental performance have a potentially much wider reach and a strong harmonizing effect, if implemented fully and strictly. In particular we witness convergence in the degree to which shrimp and pangasius sectors are confronted with national policies and measures. In both cases, better planning and management is needed. As pangasius aquaculture is intensive the water and sludge discharge is considerable. Even though the environmental impact appears to be low across the Mekong Delta as a whole, our results show that local environmental impacts are likely.

But there are still many small shrimp and pangasius farmers that are unable to partake in the intensification and modernization transition due to lack of cooperation and financial support. Pangasius farms are more able to invest individually in wastewater treatment given the intensive nature of production (Khiem et al. 2008). But because there are no observable impacts they are less willing to do so. The key problem of the pangaisus farmers is selling product to the processor at a reasonable price, related to their investment. Therefore pangaisus processors can support and encourage the farmer to invest for the wastewater treatment. In shrimp, the environmental impacts are observable, but the farmers are unwilling to invest because the problem lies with the common water resources in the canals. To intensify shrimp aquaculture, the government needs to help in re-planning and construction of infrastructure for the whole area, because water is a common resource while farm investment and certification only focus on the farms level.

6.4 Methodological issues

This section will discuss two methodological issues: the use of iterations in strengthening our study (6.4.1.) and the consequences of our case study approach in interpreting results and drawing conclusions (6.4.2).

6.4.1 Iterations

In this thesis, we applied a five-step approach, as described in chapter 1. The first two steps are largely based on the environmental system analysis approach as described by Checkland (1979), Wilson (1984), and Findeisen and Quade (1997). Most importantly, after formulating the problem, the technical reduction options were identified and evaluated, quite comparable to other systems analyses (such as Pluimers (2001), Jawjit (2006), and Neto (2007)). This is presented in chapter 2 for pangasius production and chapter 3 for shrimp farming. In this thesis, two other steps have been added: steps 3 and 4 include the conceptual modeling of an eco-agro-industrial cluster for shrimp processing industry in Soc Trang province (chapter 4) and a governance analysis of aquaculture production and products (chapter 5). This leads to a new approach, integrating systems analysis, industrial ecology and governance analysis, to identify solutions for sustainable aquaculture production, which are not only technologically and economically feasible but also manageable and governable (Figure 6.4). In this section, the experiences with this approach are discussed, in particular with respect to the iterations and the sequences of steps.

First, the study included iteration between step 2 back to step 1. The initial problem formulation and the scope of our study changed, after visiting farms and processing industries and a subsequent increase in knowledge of the system. Early in the project, the focus was very much on end-of-pipe techniques for wastewater treatment only. Later on, the focus shifted towards minimization and prevention options such as sedimentation ponds. In a later stage eco-agro industrial clustering came also into focus.

Second and third, iterations took place from step 4 and 5 back to step 2. During stakeholder meetings of the PAD and ShAD dialogues, but also those organized by the Vietnamese authorities, reduction options were mentioned and suggested that first were not considered in the analysis. One example was the reuse of wastewater and sediment for the rice-field or other plantation areas. Moreover, different communities used the sediment for different types of plantation.

Fourth, there was also iteration from step 5 back to step 1. Within the governance analyses and the stakeholder meetings specific problems were formulated together with causes of problems. This resulted in a reformulation of the problem definition and different types of options for improvement. For instance, the problems related to drugs and chemical use are to a significant extent caused by lack of information, lack of management skills and lack of trained experts.

Finally, it can be argued that iterations between steps 3 and 4, and also the iteration from step 5 to step 3, would have been extremely useful. In this study, this was not possible for practical reasons and time constraints. The eco-agro-industrial cluster model described in this study (chapter 4) is still a conceptual model without a practical application, and it needs more discussion with stakeholders. Hence, the network analysis needs further verification with stakeholder perceptions and interests through, for instance, organized meetings. An extension of the eco-agro-industrial cluster towards fish—and other—farmers, and relating that to a governance analysis would be able to further assess the possible contributions of cooperatives in the Mekong delta.

6.4.2 Case study selection

This thesis took a case study approach for studying the various subsystems. One of the known problems of case studies is the question of representatives. Below I will argue how in this study the question of representativeness have been adequately addressed, making the results of this study to have wider relevance for pangasius and shrimp aquaculture and processing in the Mekong Delta than only the cases studied.

In the pangasius farming study, four pangasius farms were visited with a total of 23 ponds in My Hoa Hung commune, An Giang province – an area considered typical of larger, commercial scale farming operations (Schut 2009). Detailed information was collected through observation and interviews with farmers and technicians on the production processes and activities of each sub-system, their associated wastewater problems and the efficiency of current solutions for mitigating pollutants. Wastewater and sludge were sampled from five ponds during multiple visits to farms, at various moments throughout the production cycle. Because farmers exchange water every day the diurnal variation in the water quality is larger than the variation in the production cycle. Care was therefore taken to sample between 3-6 hours after the water in the pond changed. Sludge samples were analyzed in three settling columns, each with 10 sampling valves. The quality of the water content and settling capacity of the pond sludge were analyzed. The water quality parameters used in the analysis were BOD, COD, TSS, Total Nitrogen, Total phosphorus, and N-NH_3. More parameters, such as temperature, pH and Coli-forms, were additionally measured in *in-situ* wastewater. All samples were analyzed according to the Standard Methods of Water Sampling and Analyzing (APHA 2005). The study also included the results of a pilot study in which wastewater from a pangasius farm with a sedimentation pond was used to irrigate and fertilize rice fields in order to minimize water pollution. In all, the results from these cases can be said to have wider applicability for pangasius aquaculture systems in the Mekong Delta.

For shrimp farming, cases were selected in the region of Can Gio, the most intensive shrimp production area in Vietnam. Farms were selected for the analyses based on their production methods (only intensive farming of Black Tiger shrimp was considered). In total 33 water samples were collected from farms at the point of discharge during the shrimp production season. Samples were taken based on the production cycle, with 11 samples from ponds of less than one month old, 12 samples from ponds two to three months old, and 10 samples from ponds three to four months old. In total 22 farms were visited to collect information about farming practices and environmental problems. Virtually all the intensive farms were included in the analysis. The study therefore provides a complete analysis of intensive black tiger shrimp farming in Can Gio. As the intensive shrimp farming systems in Can Gio are typical for other areas of the Mekong Delta, the study is also representative for other regions with intensive black tiger shrimp farming in Vietnam, such as Ben Tre, Soc Trang, Tra Vinh provinces. However, in other countries, such as Thailand and the Philippines, the intensity of black tiger shrimp farming may be different from Vietnam. Equally, an analysis of white leg shrimp farming would possibly lead to different conclusions (see also section 6.6 below).

For the processing industry, the study is potentially less representative because only 3 pangasius processing industries and one shrimp processing industry were visited and studied. This limited sampling size was caused by the fact that analyses of processing industries require more effort than those of aquaculture systems. In there, two of three pangasius industries and one shrimp industry are representatives of more average processing plants in the studied areas. We studied material balances in these companies by material flow analysis. It refers to account per physical units such as tones, resulting from the extraction, production, transformation, recycling and disposal of material within the system. (Kandelaars 1999; Fujie and Goto 2000a; Brunner and Rechberger 2004b).

In my governance study questions of representativeness are especially relevant for the study of farmer groups and cooperatives (as at the other two levels the number of governance arrangements are quite limited). Here, I included experiences of farmer groups and cooperatives from different provinces in the Mekong Delta. Moreover, experiences from other studies were used to verify the functioning and roles of farmer groups in collective action around common goods. But we did not perform a well structured survey among a randomly sampled selection of farmer groups in aquaculture. As the contribution of farmer groups in sustainable aquaculture is still very much in an explorative phase this would not have been useful at this point in time.

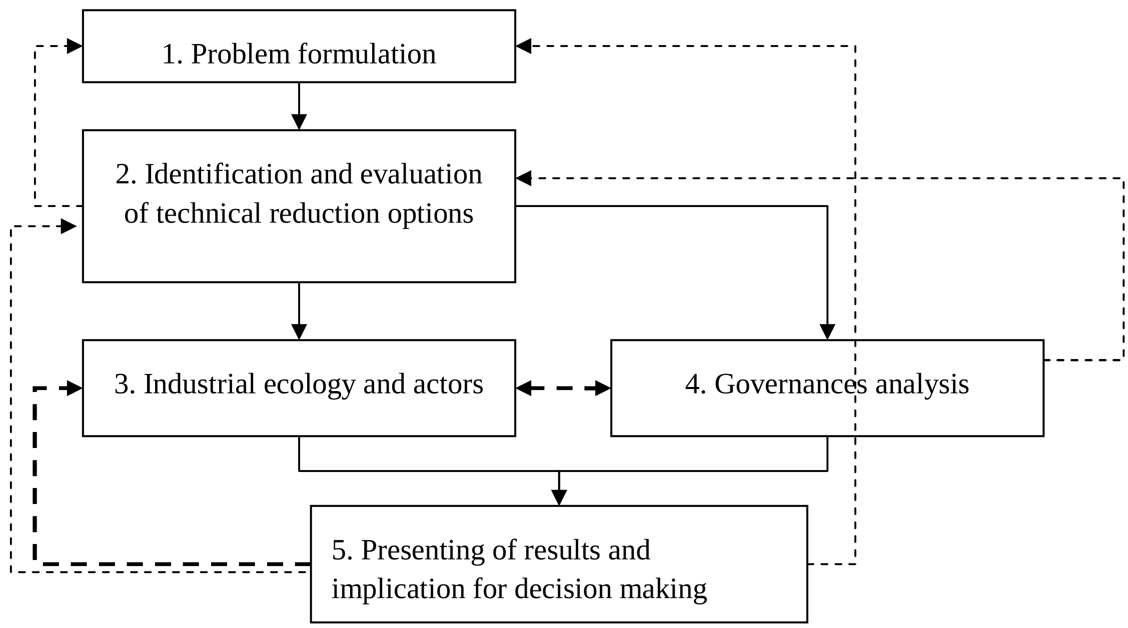

Figure 6.4 –The five step approach in this thesis and possible iterations

Iterations in this thesis   Possible Iterations for further study

6.5 Strengths and limitations of the study

6.5.1 Strengths of the study

This study is the first to systematically estimate the extent and nature of water pollution from shrimp farming and processing, and pangasius farming and processing in Vietnam. pangasius (*Pangasianodon hypopthalmus*) in fresh water and black tiger shrimp (*penaeus monodon*) in brackish water are two key-aquaculture products in Vietnam, both in terms of production as well as in terms of export value. Their production account for approximately 50 percent of the total production of aquaculture in Vietnam (Trong 2008).

A novel aspect of this thesis is that it combined environmental systems analysis with multi-level governance analysis and industrial ecology approaches. Systems analysis was combined with an assessment of eco-agro-industrial clustering for shrimp industry to minimize pollution and waste production from shrimp production in Soc Trang province. This could serve as an example for other types of fish production and processing in the Mekong delta, such as pangasius.

Moreover, this study (chapter 2 and chapter 3) used an environmental system analysis (ESA) approach, defined as a practical strategy for carrying out decision-oriented multidisciplinary research, using a broad range of analytical tools (Quade and Miser

1997). A key benefit of an ESA approach is that it aids decision makers faced with complex problems to make choices under uncertainty (Pluimers 2001); (Jawjit et al. 2006); (Neto et al. 2008), by defining a system's boundary, identifying environmental indicators and exploring solutions for mitigating impacts. The study included some experiments to test feasible technical options to environmentally improve pangasius and Shrimp farming in the studied areas (CENTEMA 2004b; Anh and Mai 2009b).

Other strength of the study is the governance analysis at three levels and the direct participation of the researcher at each level: local, national and international. As researcher, I participated in a diversity of actor network activities at all three levels, where institutions and steering mechanisms were designed, discussed, and created. (1) At the international level, the aquaculture dialogues organized by WWF are the main frame in which Vietnamese shrimp and pangasius aquaculture are governed. From 2007 to 2009 various stakeholders meetings were held in Vietnam which involved a large number of diverse – local and transnational – actors and I participated in these meetings and discussions on PAD standards (WWF 2009a); (WWF 2009e; WWF 2009c). (2) At the national level, I participated in the stakeholders' meeting which was organized by the Vietnamese government on the discussion of technical and management approaches for pangasius and shrimp aquaculture production. The stakeholders' meeting was held in An Giang province with participation of a large number of actors from different provinces in the Mekong delta. I focused on the participation and concerns of different actors for improving the environmental performance of aquaculture production. In addition, I focused on the experiences from the adoption of BMP (Best Management Practice), GAP (Good aquaculture Practice) and CoC (Code of Conduct for Responsible Fisheries) for Aquaculture by the Vietnamese government. (3) At the community level, I co-organized a local stakeholders' meeting for cooperatives of farmers and communities to better understand the environmental problems caused by pangasius farming and to identify cooperation in water resource management by community–based approaches. The meeting was held in Hoa Lac village – Phu Tan district in An Giang province and included pangasius farmers, other farmers, local government officials, environmental experts, women and farmer associations (Anh and Mai 2009a; Anh and Mai 2009b). In addition, I focused on the experiences from other community cooperatives in shrimp farming areas in the Soc Trang and Ben Tre provinces in the Mekong delta. Participant observation and involvement in stakeholder meetings, in-depth (often informal) interviews with all involved actors groups, access to grey literature were all part of our data collection methods. Besides, secondary data was collected from public policy documents, from the standards' websites and through literature review.

Finally, a strong point of the study is the relatively large sample size for the analysis of local water pollution by pangasius and shrimp farming (see 6.4.2). During the visits to farms, detailed information was collected through observation and interviews with farmers and technicians on the production processes and activities of each subsystem, their associated wastewater problems and the efficiency of current solutions for mitigating pollutants.

6.5.2 Limitations of the study

Systems analyses are never complete (Miser and Quade 1997). In Figure 6.4 the research framework as defined in chapter 1 is presented. It illustrates how the different chapters relate to each other, and how the eco-agro-industrial cluster defined in chapter 4 is based on the systems analysis presented in chapter 3. It also shows how chapters 2, 3 and 4 feed into the governance analysis in chapter 5. However, the thesis does not cover the whole framework presented in chapter 1 for both pangasius and shrimp.

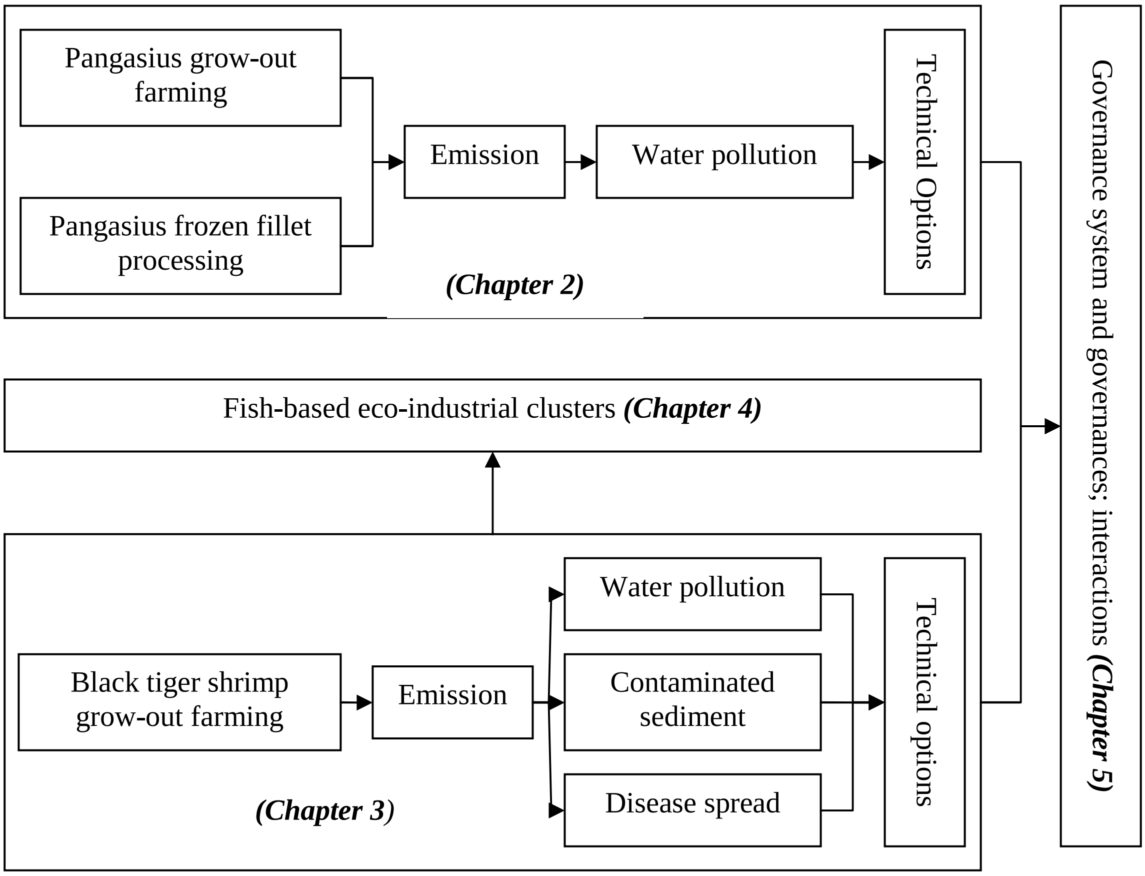

Figure 6.5 Research frameworks.

Moreover, this study did not include a full life cycle of the product. In the pangasius production system, the focus was on two sub-systems: farming and processing. In each sub-system, not all environmental impacts from these subsystems have been studied. Water pollution, as the most important local problem caused by aquaculture production in Vietnam, had a key emphasis. We excluded the effects of water pollution such as eutrophication and other environmental impacts such as global warming, and acidification.

Another limitation is related to the sampling size for sediments, and for processing industries. In both studies on pangasius farming and shrimp farming, we had small sample sizes for sediments and for processing industries. These may not be fully representative for the whole region (see 6.4.2). For wastewater we considered the sample size large enough to draw conclusions.

Finally, in studying shrimp farming, the emphasis has been on intensive shrimp farming, excluding less intensive types of shrimp farming. It should be noted that currently, most farming in the Mekong delta is of the less intensive type. However, most pollution is from the intensive farming systems, which makes our limitation reasonable from an environmental perspective.

6.6 Recommendations

Below recommendation will be formulated with respect to (i) environmental management of pangasius and shrimp production in the Vietnamese Mekong Delta, and (ii) future studies.

6.6.1 Recommendations for environmental management

To treat wastewater from the pangasius aquaculture, several simple, inexpensive and environmental friendly methods are available. Among the relatively cheap options are reduced use of chemicals and medicines, sludge treatment in sedimentation ponds and constructed wetlands and the re-use of wastewater through existing irrigation systems.

In pangasius processing, several low-cost cleaner production opportunities are currently applicable to small, medium and large processing factories including improved management techniques and low-tech technologies such as the application of anaerobic wastewater treatment, which has the added benefit of generating alternative income streams from energy generation and carbon credit schemes.

In shrimp farming, with the option of the reduction of feed, it is important that adequate and sufficient information is available to farmers and that the government can efficiently regulate the quality and composition of feed. Aeration is noted as a particularly suitable technology given the low expenses needed to implement it in existing intensive systems. Sediment reuse in agriculture may prove successful if the economics can be justified to farmers. Wetland construction, although practiced on some farms, remains difficult to implement due to the lack of land available to farmers. Coordinated treatment on communal lands, or the rehabilitation of mangrove areas for this purpose, as partly can be seen in Can Gio, may prove a more viable and low cost option.

Future implementation of an eco-industrial cluster for shrimp production should not rely too much on the role of environmental authorities, given their priorities and limitations in resources. Establishing cooperation between processing industries and increasing requirements from international markets for certified processing plants seems to be more promising triggers towards further reuse and recycling. Although without support from environmental authorities a treatment system is not very likely to be established, a joined proactive request from processors might make the best chance, either at the Vietnamese authorities or via foreign assistance.

Certification systems are promising instruments to complement the failing state approaches in the environmental management of aquaculture systems. However, most certification networks require that the costs of certification be borne by the enterprise being certified, and involve complex, expert-driven documentation and monitoring processes that are beyond the financial and technical means of small enterprises or community-based institutions (cooperative). Collaboration can indeed assist small farmers to better comply with the requirements of quality certification. A range of difficulties still remain for small farmers wishing to form cooperative groups, and these groups will continue to need technical 'support' from local governments, including technical operation, administration and enforcement of local water discharge agreements.

6.6.2 Recommendations for further study

Based on the results of this study we may identify some needs for further study.

First, not all environmental impacts of shrimp and pangasius production were accounted for. In this study, the focus was mainly on water pollution. Future studies may also consider other environmental impacts and activities, such as air pollution, odor problems, soil pollution, and landscape degradation. In addition, future studies may expand the system boundaries to include a more extended production chain of aquaculture products. This chain would include hatcheries, grow-out farms, processing industries, transportation, supply companies, exporters, retailers and consumers (Loc 2006; Khoi 2007). This approach is typical for life cycle assessments, industrial network studies and value chain analyses (e.g. (Bosma et al. Forth comming).

Second, a similar study like the one presented in this thesis could be performed for other aquaculture products, such as white leg shrimp (*Littopenaeus vannamei*) and Tilapia. In recent years, the Vietnamese government has promoted the production of white leg shrimp (MARD 2008a) as a more environmental friendly alternative than black tiger shrimp. In countries other than Vietnam, white leg shrimp is considered a species with high yields, and with more efficient use of water, low-feed conversion rates, high survival rates, and faster growth cycles (Wyban 2007; Mishra et al. 2008). However, the environmental impacts of white leg shrimp has not been studied for Vietnam, also not in a systems analysis as presented here. Other species may also be interesting to study, such as red-tilapia and black-tilapia, which show also a gradually increasing popularity among farmers.

Third, more experimental and pilot studies of technical reduction options would be worthwhile. These studies would reveal more quantitative potential for emission reduction and their costs and economic implications for Vietnam. Some options, such as the sedimentation ponds, have been extensively tested and applied in experimental studies in Vietnam. However, most other options have found hardly applications in Vietnam. This holds, for instance, for ozone aeration techniques and use of pro-biotic. More research is also needed on feed efficiency improvement. Sediment reuse appears to be a viable option for intensive shrimp farming; however, further research is needed to determine if there is enough economic incentive for farmers to engage in sediment composting. In addition, more information is needed on the practical and long term aspects of treatment and reuse of sludge, including the possibilities for on farm production and trade.

Fourth, it would be interesting to investigate the possibilities for an eco-agro-industrial cluster for pangasius, similar to the study presented here for frozen shrimp production. Such an analysis could also be performed for fish production in general, aiming at a fish-based eco-agro-industrial cluster in the Mekong delta (Figure 6.6)

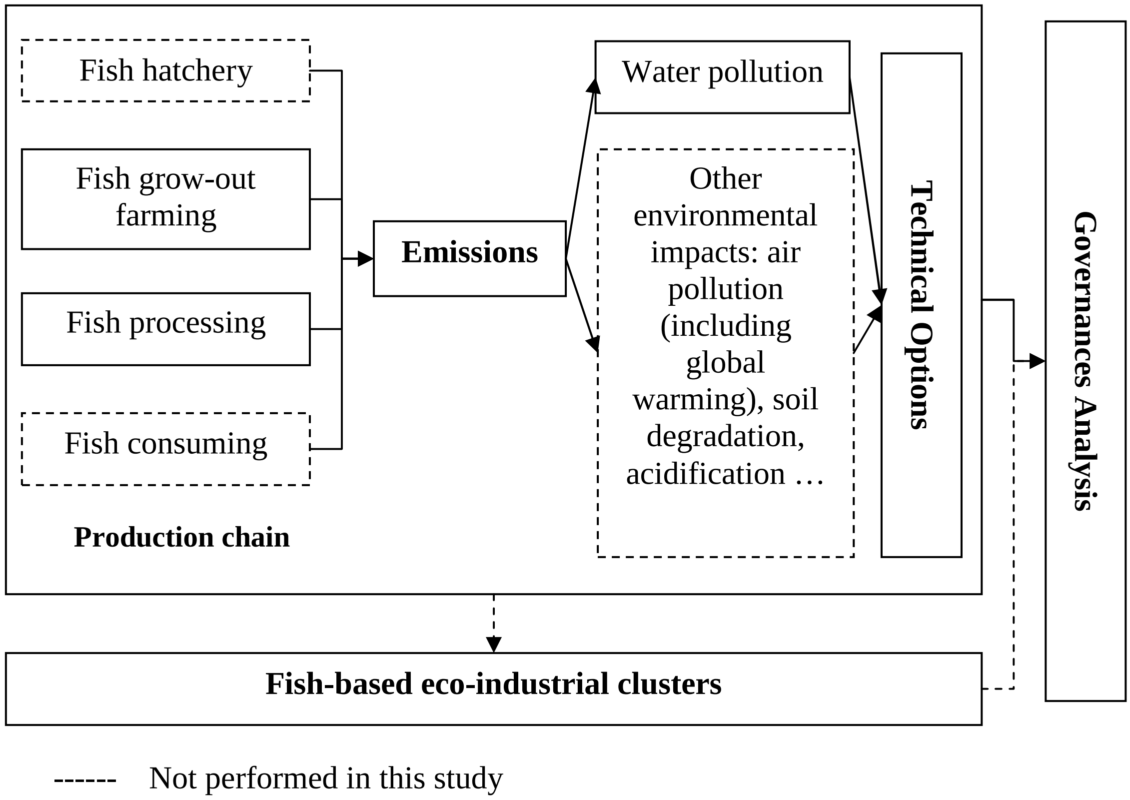

Figure 6.6 Propose a combination of system analysis, technology assessment and governance analysis for increasing sustainability of fish production in the Mekong delta of Vietnam.

Finally, a governance system analysis, as performed here for shrimp and pangasius, can be performed for other exported fish products such as tilapia.

Summarizing, this study may serve as an example for future analyses of the environmental impacts of many other products. The combination of systems analysis, technology assessment and governance analysis as taken in this study has proven to be useful in analyzing complex problems from different angles.

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Summary

From 1986 up to now the Vietnamese fishery sector has developed rapidly in terms of production and export. Aquaculture developed more rapidly than wild-catch fishery. Aquaculture exists in freshwater, brackish water and seawater**.** Among the various fish and shrimp species produced in Vietnam, two dominate both production and export value. These are river catfish (Pangasianodon hypopthalmus - called pangasius) produced in fresh water and black tiger shrimp (Penaeus monodon) produced in brackish water. The farming of pangasius in Vietnam is mainly Tra (Pangasianodon hypophthalmus) and Basa (Pangasius bocourti), and one of the fastest growing types of aquaculture in the world. Ninety percent of the pangasius produced worldwide comesfrom Vietnam. The production of black tiger shrimp (Panaeus Monodon) accounts for 80 – 90% of the total shrimp production in Vietnam. Vietnam is one of few countries producing large sized, high quality, black tiger shrimp and has few direct competitors, except for India and Bangladesh. The increase in fish production in Vietnam has been accompanied by a rapid expansion of the fish processing sector. Over the past decade particularly large modern facilities were developed. Currently, there are about 400 registered fish-processing plants in Vietnam with around 1.2 million tons input capacity for export-oriented production. In addition, there are many local plants, that process other traditional products such as fish sauce, fish paste, and dried fish for domestic markets.

The increased fish production has economic benefits for the country. However, both aquaculture farms and the fish-processing industries may have serious consequences for the environment. The available studies seem to agree that the largest environmental problems caused by aquaculture and processing industries are associated with water use and water pollution. Waste water of fish ponds and processing industries is high in nitrogen (N), phosphorus (P), and organic matter, and therefore has a high chemical oxygen demand (COD) and biological oxygen demand (BOD). In addition, there may be chemical contaminants and pathogens in the waste streams. In response to the environmental impacts of aquaculture in Vietnam, the government and industry alike have invested in environmental management. In addition to the domestic impetus for improved environmental management pressure has also come through international trade relations. Recent events and trends show that significant challenges remain for Vietnam to be competitive in the international market for aquaculture products, which go beyond processing plant quality control and processing technology.

The main objective of this study is to analyze the possibilities for environmental improvement in pangasius and shrimp production in Vietnam and to identify the options for technological and management intervention.

Four sub-objectives were formulated to achieve the overall objective:

Sub-objective 1: To identify causes and impacts of water pollution in the Mekong Delta, associated with pangasius farming and processing industry; and identify possible options to reduce these problems.

Sub-objective 2: To analyse the causes of water pollution, contaminated sediment and spread of disease from intensive black tiger shrimp farming in Vietnam, and identify possible options to reduce these environmental impacts.

Sub-objective 3: To apply the idea of eco-agro-industrial clustering for reducing pollution, protecting natural resources and improving the competitiveness of the shrimp production and processing sector in the Mekong delta, Vietnam.

Sub-objective 4: To analyze current attempts—at multiple levels—to govern water pollution in aquaculture in Vietnam, and illuminate how public-private multilevel governance complexes are starting to address conventional state failures in water pollution problems in Vietnam's aquaculture.

First, we analyzed water pollution caused by the production of frozen filets of *Pangasius hypopthalmus*, including both pangasius farming and the processing industries in the Mekong Delta. The results show that the production of of one ton of frozen fillets releases 740 kg BOD, 1020 kg COD, 2050 kg Total Suspended Solid (TSS), 106 kg N and 27 kg P. Wastewater from fish ponds contributes 60-90% of these emissions. Thus fish ponds contribute more to the pollution than the fish-processing industries. Sludge from fish ponds and wastewater from processing facilities have relatively high concentrations of pollutants, but because of their relatively small volumes, these waste streams comprise only 3 to 27% of the total emissions. Overall, pangasius production accounts for less than 1% of total TSS, N and P loads in the Mekong Delta, making it a minor source of nutrients in the Mekong river. Nevertheless, the discharge of sludge can cause local pollution problems.

The average values of water quality parameters in the effluent of the pangasius ponds were found to generally not exceed the Vietnamese surface water quality standards. However, when we consider the variation among ponds we conclude that there are probably many individual ponds where the standards are exceeded. Reductions in water pollution from pangasius production are possible through more efficient use of inputs and low-cost treatment and reuse of effluent streams. The use of cleaner production technologies; and the development of wastewater treatment plants could be applied to a small number of large farms and processing facilities to reduce water pollution in pangasius processing. Low-cost options for small-scale farms include the reuse of wastewater in crop irrigation.

Second, we investigated water pollution, sediment contamination and the spread of diseases related to shrimp farming in the Can Gio district of Ho Chi Minh City

(Vietnam), an area representative for the impacts of intensive shrimp production in the country. The results indicate that the pollutant loads from waste water to produce one ton of shrimp are 259 kg BOD, 769 kg COD, 1170 k g TSS, 30 kg N, 3.7 kg P and 4.8 kg N-NH_3.

The results indicate that the levels of BOD, COD and TSS concentrations increased within the culture period as well as the age of ponds. While a large number of individual farms may exceed environmental standards; intensive shrimp farming is not always associated with waste streams exceeding water quality standards. This is interesting, because it shows that we can reduce pollution from intensive shrimp farms by using currently available technologies. Finally, technological and economically feasible options are identified for reducing water pollution, mitigating problems associated with contaminated sediment, and the reducing the spread of diseases.

Third, we applied the principles of Industrial Ecology Theory and the Ecological Modernization Theory in the context of Vietnam. A physical-technological conceptual model for minimizing waste in agro-industries was designed, with a case study of frozen shrimp production. The results indicate that it is possible and feasible to develop an eco-agro-industrial cluster which consists of fish= processing companies, by-product plants, and wastewater treatment units. By doing so, industry can cooperate in environmentally sound development. Actors and institutions governing the proposed eco-agro-industrial cluster of aquaculture production are also discussed in this thesis. In addition, there are good opportunities to include aquaculture production in such an eco-agro-industrial cluster.

Fourth, we participated in and investigated a range of activities at all three levels (international, national and community), where institutions and steering mechanisms were designed and created. This study found that water pollution by shrimp and pangasius aquaculture in Vietnam is addressed by new governance arrangements at three distinct governance levels. At the international level the PAD (Pangasius Aquaculture Dialogue) and ShAD (Shrimp Aquaculture Dialogue) Dialogues include a large variety of actors and stakeholders to develop standards of sustainable aquaculture. Although these Dialogues are a lengthy process full of challenges and difficult choices, they do develop a sense of ownership among the participants and stakeholders and develop internationally acknowledged standards for certification.

It should be noted that the focus of these international governance arrangements is on a small percentage of the producers, while a large number of small-scale farmers, who are unable to comply with the developed standards, are left behind. For these significant groups of aquaculture farmers, national and local governance arrangements play an important role. While interesting best practices could be found following these two approaches, overall implementation of these innovative arrangements is still far from successful.

It seems profitable and possible to link these governance networks and to work to harmonized certification approaches for communities and farmers. We have noticed increasing linkage between these nested governance arrangements. However, such harmonization would have to cope with different farmers and farming systems.

A novel aspect of this thesis is that it combines environmental systems analysis with multi-level governance analysis and industrial ecology approaches. Systems analysis was combined with an assessment of eco-agro-industrial clustering for the shrimp industry (chapter 4) to identify ways to minimize pollution and waste production from shrimp production in Soc Trang province. This could serve as an example for other types of fish production and processing in the Mekong delta.

Moreover, this study (chapter 2 and chapter 3) used an environmental system analysis (ESA) approach, defined as a practical strategy for carrying out decision-oriented multidisciplinary research, using a broad range of analytical tools. A key benefit of an ESA approach is that it aids decision makers faced with complex problems to make choices under uncertainty, by defining a system's boundary, identifying environmental indicators and exploring solutions for mitigating impacts. The study included some experiments to test feasible technical options to environmentally improve pangasius and Shrimp farming in the studied areas.

Another strength of the study is the governance analysis at three levels and the direct participation of the researcher at investigating each level: local, national and international. Participant observation and involvement in stakeholder meetings, in-depth (often informal) interviews with all involved actors groups and access to grey literature were all part of our data collection methods. Besides, secondary data was collected from public policy documents, from the websites of international standard-setting organizations and through literature review.

Finally, a strong point of the study is the extensive investigation of the water pollution caused by pangasius and shrimp farming. During the visits to farms, detailed information was collected through sampling and water analysis, observation and interviews with farmers and technicians on the production processes and activities in each subsystem, their associated wastewater problems and the efficiency of current solutions for mitigating pollutants.

The study also allows for a comparison of pangasius and shrimp farming. This comparison indicates that shrimp farming is causing less water pollution than pangasius farming per hectare of farming area. However, per ton of product, the results differ among pollutants: BOD, COD and TSS losses are highest for shrimp aquaculture, while losses of N and P are highest for pangasius.

Shrimp and pangasius governance differ in particular in the degree to which the sectors are confronted with international/and national policies and measures.

The results of the study allow for the following recommendations for environmental management and further studies.

To treat wastewater from the pangasius and shrimp aquaculture, several simple, inexpensive and environment-friendly methods are available. In pangasius and shrimp processing, several low-cost cleaner production opportunities are currently applicable to small, medium and large processing factories, including improved management techniques and simple technologies. Cooperation between processing industries and increasing requirements from international markets for certified processing plants seem to be promising triggers towards further reuse and recycling approaches.

Collaboration can indeed assist small farmers to better comply with the requirements of quality certification. A range of difficulties still remain for small farmers who wishto form cooperative groups, and these groups will continue to need technical 'support' from local governments, including technical operation, administration and enforcement of local water discharge agreements.

Future studies may consider environmental impacts and activities not discussed in this thesis, such as air pollution, odour problems, soil pollution, and landscape degradation. Future studies may expand the system boundaries to include more extended production chains of aquaculture products. Moreover, similar studies including environmental impact, system analysis, and governance analysis could be performed for other aquaculture products, such as white leg shrimp (*Littopenaeus vannamei*) and Tilapia. More experimental and pilot studies of technical options for reduction of wastewater flows and loads would also be worthwhile.

Finally, this study may serve as an example for future analyses of the environmental impacts of many other products. The combination of systems analysis, technology assessment and governance analysis as performed in this study has proven to be useful in analyzing complex problems from different angles.

Samenvatting

De Vietnamese visserij sector heeft zich sinds 1986 snel ontwikkeld gemeten naar produktie en export. Aquacultuur groeide nog sneller van de vangstvisserij.

Deze aquacultuur wordt uitgeoefend in zoet, brak en zeewater. Onder de verscheidene vis- en garnalensoorten die in Vietnam geproduceerd worden zijn twee soorten dominant. Dit zijn pangasius (Pangasianodon hypophthalmus) en zwarte tijger garnaal (Penaeus monodon) welke in zoet respectievelijk brak water gekweekt worden. Het kweken van Pangasius in Vietnam geldt voornamelijk de soorten 'Tra' (Pangasianodon hypophthalmus) en 'Basa' (Pangasius bocourti). Pangasiusteelt is mondiaal gezien een van de snelstgroeiende vormen van aquacultuur. Van de wereldproduktie van pangasius heeft 90% plaats in Vietnam. De produktie van zwarte tijger garnaal neemt 80-90% van de totale garnalenproduktie in Vietnam voor haar rekening. Vietnam is een van de weinige landen die grote, hoogwaardige zwarte tijger garnalen produceert, en het heeft weinig concurrenten, waarbij India en Bangladesh als uitzonderingen genoemd kunnen worden. De toename van de visteelt in Vietnam is gekoppeld aan een snelle expansie van de visverwerkingssector. Gedurende het afgelopen tiental jaren zijn grote moderne fabrieken tot stand gekomen. Momenteel zijn er in Vietnam ongeveer 400 geregistreerde op export gerichte visverwerkingsbedrijven met een totale capaciteit op input basis van 1,2 miljoen ton per jaar. Daarnaast zijn er vele bedrijven die andere, traditionele, producten, zoals vissaus, vispasta en gedroogde vis, voor de eigen markt vervaardigen. De toegenomen visproduktie brengt het land economische voordelen. Maar zowel aquacultuur als visverwerkende industrie hebben ernstige gevolgen voor het milieu. De beschikbare studies schijnen overeen te stemmen in de conclusie, dat de belangrijkste milieuproblemen veroorzaakt door deze bedrijfsvormen samenhangen met watergebruik en watervervuiling. Afvalwater van kweekvijvers en verwerkingsbedrijven bevat veel stikstof (N), fosfor (P) en organische stof, en heeft daardoor een hoog chemisch (COD) en biologisch zuurstofverbruik (BOD). Ook kunnen de afvalwaterstromen chemische microverontreinigingen en ziekteverwekkende organismen bevatten. In reactie op de milieugevolgen van de aquacultuur hebben zowel de regering als de sector geïnvesteerd in milieubeheersmaatregelen.

De drijvende kracht voor verbeterd milieubeheer komt niet alleen voort uit Vietnam zelf, maar ook uit internationale handelsrelaties. Recente gebeurtenenissen en trends laten zien, dat Vietnam geconfronteerd wordt met belangrijke uitdagingen om concurrerend te blijven in de internationale markt van aquacultuurprodukten, en deze gaan verder dan contrôle op de kwaliteit van de fabrieken en een verbeterde verwerkingstechnologie.

Het belangrijkste doel van deze studie is de mogelijkheden tot milieuverbeteringen in de pangasius- en garnalenproduktie in Vietnam te analyseren, en opties te genereren voor technologische en beleidsmatige interventie.

Er zijn vier subdoelstellingen geformuleerd om dit hoofddoel te bereiken:

Subdoelstelling 1: Vaststellen van oorzaken en gevolgen van de waterverontreiniging in de Mekong delta welke samenhangt met pangasiusteelt en -verwerking, en het vaststellen van mogelijke oplossingen om deze problemen te reduceren.

Subdoelstelling 2: Analyseren van de oorzaken van vervuiling van water en sediment, en de verspreiding van ziekten verbonden aan de teelt van zwarte tijger garnaal in Vietnam en het genereren van opties om de milieugevolgen te reduceren.

Subdoelstelling 3: Toepassen van het concept van eco-agro-industriële clustering voor het terugdringen van vervuiling, waarbij natuurlijke hulpbronnen beschermd worden en de concurrentiekracht van de garnalenteelt en -verwerkingssector in de Mekong delta in Vietnam verbeterd wordt.

Subdoelstelling 4: Analyseren van de huidige pogingen – op meerdere niveau's – om de watervervuiling van de aquacultuur in Vietnam bestuurlijk aan te pakken, en te verhelderen hoe publiek-private, bestuurlijke consortia begonnen zijn de conventionele tekortkomingen van de staat bij de aanpak watervervuilingsproblemen aan de orde te stellen.

Ten eerste hebben we de watervervuiling geanalyseerd die optreedt bij de produktie van ingevroren filetten van *Pangasius hypophthalmus* in de Mekong delta, daarbij inbegrepen zowel de teelt als de verwerking. De resultaten laten zien, dat bij de produktie van een ton ingevroren filetten 740 kg BOD, 1020 kg COD, 2050 kg gesuspendeerd materiaal (TSS), 106 kg N en 27 kg P vrijkomen. Afvalwater van de visvijvers draagt 60 tot 90% van deze emissies bij. Aldus is het vervuilingsaandeel van de visvijvers groter dan van de visverwerkende bedrijven. Slib uit de visvijvers en afvalwater van verwerkingsbedrijven hebben een relatief hoog gehalte aan vervuilende stoffen, maar vanwege hun relatief kleine volumes, maken deze afvalstromen slechts 3 tot 27% van de totale emissies uit. In totaal is de pangasiusproduktie verantwoordelijk voor minder dan 1 % van de totaal geloosde TSS, N en P vrachten in de Mekong delta, waarmee het een kleine bron van nutriënten in de Mekong rivier is. Niettemin kan de lozing van slib lokaal vervuilingsproblemen veroorzaken.

De gemiddelde waarden van waterkwaliteitsparameters van effluenten overschreden over het algemeen de Vietnamese kwaliteitseisen van oppervlaktewater niet. Indien we echter de variatie onder de vijvers in beschouwing nemen, concluderen we, dat er waarschijnlijk veel vijvers zijn waar de normen wel overschreden worden. Terugdringen van de watervervuiling vanuit de pangasiusteelt is mogelijk door meer efficiënt gebruik van grondstoffen en goedkope behandeling en hergebruik van effluentstromen. Schone produktietechnieken en afvalwaterzuiveringsinstallaties die tot doel hebben de watervervuiling van de pangasiusproduktie te verminderen zouden kunnen worden toegepast bij een klein aantal grote teeltbedrijven en verwerkingseenheden. Een van de goedkope mogelijkheden voor kleine teeltbedrijfjes is het hergebruik van water uit vijvers voor irrigatie.

De resultaten laten zien dat de BOD, COD en TSS concentraties toenamen met de duur van de teeltperiode en de ouderdom van de vijvers. Ofschoon een groot aantal individuele teeltbedrijven de milieunormen overschrijdt, hoeft intensieve garnalenteelt niet altijd verbonden te zijn met overschrijding van waterkwaliteitsnormen. Dit is interessant, omdat het laat zien, dat wij met momenteel beschikbare technologieën de vervuiling door intensieve garnalenteelt kunnen verminderen. Tenslotte zijn technologisch en economisch haalbare opties geïdentificeerd om watervervuiling terug te dringen, de problemen van verontreinigd slib te verminderen en de spreiding van ziekten tegen te gaan.

Ten tweede onderzochten wij water en sediment vervuiling en de verspreiding van ziekten tengevolge van de garnalenteelt in het Can Gio district in Ho Chi Minh City (Vietnam). Dit gebied is representatief voor de gevolgen van de intensieve garnalenteelt in het land. De resultaten tonen aan dat de vuilvracht in afvalwater dat vrijkomt bij de produktie van een ton garnalen 259 kg BOD, 769 kg COD, 1170 k g TSS, 30 kg N, 3,7 kg P en 4,8 kg N-NH_3 bedraagt .

Ten derde hebben wij de principes van de Industriële Ecologie Theorie en de Ecologische Moderniseringstheorie toegepast in de context van Vietnam. Er werd een fysisch-technologisch conceptueel model ontworpen voor minimalisatie van afval in agroindustrieën met de ingevroren garnalenproduktie als voorbeeld. De resultaten tonen aan, dat het mogelijk en haalbaar is om een ecoagroindustrieel cluster te ontwikkelen dat bestaat uit visverwerkende bedrijven, bedrijven voor bijprodukten en afvalwaterzuiveringseenheden. Op deze wijze kan de industrie meewerken aan een milieuvriendelijke ontwikkeling. Actoren en instituties die het voorgestelde ecoagroindustrieel cluster moeten leiden worden ook in dat gedeelte van het proefschrift besproken. Voorts zijn er goede mogelijkheden om ook de aquacultuur zelf te integreren in zulke ecoagroindustriële clusters.

Ten vierde namen wij deel aan en onderzochten een reeks activiteiten op drie niveau's, het internationale, het nationale en het communale, waarin instituties en sturingsmechanismen worden ontworpen en gestalte gegeven. Deze studie toonde aan, dat op de drie onderscheiden niveau's nieuwe bestuursmechanismen de watervervuiling door garnalen- en pangasiusteelt in Vietnam aan de orde stellen. Op het internationale niveau verenigen de PAD (Pangasius Aquaculture Dialogue) en de ShAD (Shrimp Aquaculture Dialogue) een grote variëteit aan actoren en betrokkenen om normen voor duurzame aquacultuur te ontwikkelen. Hoewel deze dialogen een langdurig proces zijn vol van uitdagingen en lastige beslissingen, versterken zij een gevoel van betrokkenheid onder de deelnemers en leiden zij tot internationaal geaccepteerde certificeringsnormen.

Men moet echter opmerken, dat de aandacht bij deze internationale beheersarrangementen gericht is op een klein percentage van de producenten, terwijl zij een groot aantal kleine telers, dat onmogelijk aan de ontwikkelde normen kan voldoen, buiten beschouwing laten. Voor deze omvangrijke groep garnalen- en vistelers zijn nationale en locale bestuursarrangementen belangrijk. Ofschoon interessante voorbeelden van 'best practices' volgens deze twee vormen van aanpak gevonden werden, is de implementatie van deze innovatieve arrangementen over het algemeen nog verre van succesvol.

Het lijkt winstgevend en mogelijk om deze bestuursnetwerken te koppelen en te werken aan geharmoniseerde certificeringsmethoden voor gemeenschappen en telers. Wij hebben een toenemende verbondenheid geconstateerd tussen deze 'geneste' bestuursarrangementen.

Een nieuw aspect van deze dissertatie is gelegen in de verbinding tussen milieusysteemanalyse, bestuursanalyse op verscheidene niveau's en industriële ecologie. Systeemanalyse werd gecombineerd met een onderzoek naar ecoagroindustriële clustering (hoofdstuk 4), teneinde manieren te vinden om vervuiling en afvalproduktie in de garnalen industrie in de provincie Soc Trang terug te dringen. Dit zou als voorbeeld kunnen dienen voor andere typen van visproduktie en -verwerking in de Mekong delta.

Bovendien heeft deze studie (hoofdstuk 2 en 3) een milieusysteemanalytische aanpak toegepast, welke gedefinieerd is als een praktische strategie bij de uitvoering van besluitvormingsgericht multidisciplinair onderzoek die gebruik maakt van een breed scala aan analytische instrumenten. Een essentieel voordeel van de milieusysteemanalytische benadering is gelegen in de hulp die zij besluitvormers geeft bij het nemen van keuzen in een situatie van onzekerheid. Dit doet zij door systeemgrenzen te definiëren, milieuindicatoren te identificeren en oplossingen te zoeken teneinde milieugevolgen te verzachten. De studie omvatte enige experimenten om haalbare technische opties te testen ter verbetering van de pangasius- en garnalenteelt in de studiegebieden.

Een sterke kant van deze studie is ook de bestuursanalyse op drie niveau's en de directe participatie van de onderzoekster op elk van deze niveau's: lokaal, nationaal en internationaal. Participerende observatie en deelname aan bijeenkomsten van betrokkenen, diepteinterviews (dikwijls informeel) met alle betrokken groepen van actoren en het raadplegen van grijze literatuur maakten deel uit van onze methoden van gegevensverzameling. Daarnaast werden secundaire gegevens verzameld uit openbare beleidsdocumenten, uit websites van internationale organisaties en via literatuuronderzoek.

Tenslotte is een ook sterk punt van de studie de uitgebreide analyse van de watervervuiling door de pangasius- en garnalenteelt. Gedurende de bezoeken aan telers werd breed informatie verzameld door bemonstering en analyse van water, observatie en interviews met telers en technici betrokken bij produktieprocessen en activiteiten in elk subsysteem, de afvalwaterproblemen van deze betrokkenen, en de doelmatigheid van huidige oplossingen om vervuiling tegen te gaan.

De studie maakt ook een vergelijking van pangasius- en garnalenteelt mogelijk. Deze vergelijking toont aan, dat per hectare teeltoppervlakte de garnalenteelt minder watervervuiling dan de pangasiusteelt veroorzaakt. Berekend per ton product echter verschillen de resultaten: de BOD, COD en TSS verliezen zijn het grootste voor de garnalenteelt, terwijl de verliezen van N en P het grootste zijn voor pangasius.

De bestuurlijke aanpak van de garnalen- en pangasiussector verschilt in de mate waarin deze sectoren geconfronteerd worden met internationaal en nationaal beleid en maatregelen.

De resultaten van de studie leiden tot de volgende aanbevelingen met betrekking tot milieubeleid en verdere studies.

Er zijn verscheidene eenvoudige, niet dure en milieuvriendelijke technieken beschikbaar voor de behandeling van afvalwater uit de pangasius- en garnalenaquacultuur. Voor de verwerking van pangasius en garnalen zijn momenteel meerdere goedkope methoden voor schoner produceren toepasbaar voor kleine, middelgrote en grote verwerkingsfabrieken. Deze omvatten verbeterde managementtechnieken en eenvoudige technologische ingrepen. Samenwerking tussen verwerkingsbedrijven en verscherpte eisen aan gecertificeerde verwerkingsfabrieken vanuit internationale markten schijnen de meest kansrijke prikkels tot hergebruik and recycling.

Samenwerking kan kleine telers zeker helpen om beter te voldoen aan de eisen van kwaliteitscertificering. Er blijven voor kleine telers, die een coöperatie willen vormen, echter vele moeilijkheden en deze groepen zullen technische hulp van het locale bestuur nodig blijven hebben, met name op het gebied van technisch beheer, administratie en controle op locale lozingsovereenkomsten.

Toekomstige studies zouden aandacht kunnen schenken aan andere milieugevolgen en activiteiten die niet in deze dissertatie aan de orde gekomen zijn, zoals luchtvervuiling, stankproblemen, bodemvervuiling en landschapsaantasting. Toekomstige studies kunnen de systeemgrenzen uitbreiden naar meer volledige ketens van aquacultuurprodukten. Bovendien zouden vergelijkbare studies op het gebied van milieuaantasting, systeemanalyse en bestuursanalyse uitgevoerd kunnen worden voor andere aquacultuurproducten, zoals de garnaal *Littopenaeus vannamei* and Tilapia.

Meer experimentele en pilotonderzoeken van technische reductieopties zouden ook zinvol zijn.

Deze studie tenslotte kan dienen als voorbeeld voor toekomstige analyses van de milieugevolgen van vele andere produkten. De combinatie van systeemanalyse, technologiebeoordeling en bestuursanalyse zoals toegepast in deze studie heeft bewezen succesvol te zijn in de analyse van een complex probleem vanuit verschillende hoeken.

Tóm tắt

Kể từ năm 1986, ngành thủy sản của Việt Nam đã phát triển nhanh chóng cả về sản lượng và xuất khẩu. Trong đó, nuôi trồng thủy sản đã phát triển nhanh hơn đánh bắt thủy sản. Nuôi trồng thủy sản bao gồm nuôi nước ngọt, nước lợ và nước mặn. Trong số các loại thủy sản nuôi tại Việt Nam, có hai loại thủy sản có tầm quan trọng rất lớn cả về sản xuất và xuất khẩu; đó là cá tra (Pangasianodon hypopthalmus hay pangasius) nuôi ở nước ngọt và tôm sú (Penaeus monodon) nuôi ở nước lợ. Cá tra là một trong những loại thủy sản nuôi trồng tăng trưởng nhanh nhất trên thế giới. 90% cá tra được tiêu thụ trên thế giới là từ Việt Nam. Tôm sú ở Việt Nam chiếm 80-90% tổng sản lượng tôm được nuôi. Việt Nam là một trong số ít các nước sản xuất tôm sú với kích thước lớn, chất lượng cao và có ít đối thủ cạnh tranh, ngoại trừ Ấn Độ và Bangladesh.

Sự tăng trưởng sản xuất thủy sản ở Việt Nam dẫn đến sự mở rộng nhanh chóng ngành chế biến thủy sản. Đặc biệt, trong vòng một thập niên vừa qua, các trang thiết bị hiện đại cho chế biến thủy sản đã được phát triển rộng. Hiện tại, Việt Nam có khoảng 400 nhà máy chế biến thủy sản được đăng ký với khoảng 1,2 triệu tấn sản phẩm xuất khẩu mỗi năm. Thêm vào đó, còn có các nhà máy chế biến các sản phẩm cổ truyền như nước mắm, cá mắm, cá khô cho thị trường trong nước.

Sự tăng trưởng của sản xuất thủy sản đem lại lợi ích kinh tế cho cả nước. Tuy nhiên, cả nuôi trồng và chế biến thủy sản đều gây ra những hậu quả nghiêm trọng đối với môi trường. Các nghiên cứu hiện tại dường như đều đồng ý rằng các vấn đề môi trường nghiêm trọng nhất của ngành nuôi trồng và chế biến thủy sản liên quan đến việc sử dụng nước và gây ô nhiễm nước. Nước thải của nuôi trồng và chế biến thủy sản đều có hàm lượng nitơ (N), phospho (P), hợp chất hưu cơ cao, vì vậy hàm lượng BOD và COD cao; thêm vào đó, trong nước thải còn có thể có các hợp chất hóa học và mầm bệnh. Để đối phó với các tác động môi trường của ngành nuôi trồng thủy sản; chính phủ và ngành công nghiệp thủy sản của Việt Nam đã có những đầu tư trong quản lý môi truờng cho ngành thủy sản. Ngoài ra, việc thúc đẩy nuôi trồng thủy sản nội địa theo hướng cải thiện các áp lực về quản lý môi trường còn thông qua các mối quan hệ thương mại quốc tế. Các sự kiện và xu hướng gần đây đã cho thấy thử thách quan trọng đối với Việt Nam là để cạnh tranh được trong thị trường quốc tế thì việc kiểm soát chất lượng sản phẩm nuôi trồng nên được ưu tiên hàng đầu trước khi đến kiểm soát chất lượng trong các nhà máy chế biến và công nghệ chế biến.

Mục tiêu chính của nghiên cứu này là phân tích các khả năng về cải thiện môi trường trong nuôi trồng và chế biến tôm và cá tra ở Việt Nam và xác định các giải pháp cần can thiệp về công nghệ và quản lý.

Bốn mục tiêu cụ thể đã được xác định bao gồm:

Mục tiêu 1: Xác định nguyên nhân và tác động của ô nhiễm nước ở đồng bằng sông Cửu Long liên quan đến nuôi trồng và công nghiệp chế biến cá tra; xác định các giải pháp để giảm thiểu các tác động này.

Mục tiêu 2: Phân tích nguyên nhân ô nhiễm nước, ô nhiễm bùn thải và lan truyền bệnh do nuôi tôm sú công nghiệp ở Việt Nam và xác định các giải pháp nhằm giảm thiểu các tác động môi trường này.

Mục tiêu 3: Áp dụng ý tưởng về cụm công nghiệp – nông nghiệp sinh thái nhằm giảm thiểu ô nhiễm, bảo vệ nguồn tài nguyên thiên nhiên và nâng cao sự cạnh tranh của sản xuất và chế biến tôm ở đồng bằng sông Cửu Long, Việt Nam.

Mục tiêu 4: Phân tích các nổ lực hiện tại - ở nhiều cấp độ - nhằm quản lý việc ô nhiễm nước trong nuôi trồng thủy sản ở Việt Nam, làm rõ việc quản lý phối hợp đa cấp độ công-tư bắt đầu như thế nào để chỉ ra sự thất bại của cách quản lý truyền thống về vấn đề ô nhiễm nước trong nuôi trồng thủy sản ở Việt Nam.

Đầu tiên, chúng tôi phân tích vấn đề ô nhiễm nước do sản xuất cá tra philê, bao gồm cả nuôi trồng và chế biến cá tra ở đồng bằng sông Cửu Long. Kết quả cho thấy sản xuất một tấn cá tra philê đã thải ra môi trường 740 kg BOD, 1020 kg COD, 2050 kg chất rắn lơ lửng (TSS), 106 kg N and 27 kg P. Trong đó, nước thải từ ao nuôi chiếm 60-90% lượng phát thải này. Vì vậy nuôi cá gây nên lượng ô nhiễm nhiều hơn là công nghiệp chế biến cá. Bùn thải từ ao nuôi và nước thải từ nhà máy chế biến thường liên quan đến nồng độ chất ô nhiễm cao, nhưng do thể tích dòng thải ít hơn nên lượng chất thải chiếm từ khoảng 3 - 27% tổng lượng phát thải. Tổng quan chung, ô nhiễm do sản xuất cá tra được tính là nhỏ hơn 1% tổng tải lượng TSS, N và P ở đồng bằng sông Cửu Long, tạo ra một nguồn ô nhiễm không lớn đối với đồng bằng sông Cửu Long. Tuy nhiên, việc xả thải bùn thải có thể gây nên các vấn đề ô nhiễm khu vực. Các giá trị trung bình về các thông số chất lượng nước được tìm thấy nhìn chung không vượt quá tiêu chuẩn chất lượng nước mặt của Việt Nam. Tuy nhiên, khi xem xét sự biến thiên giữa các ao nuôi, chúng ta có thể kết luận rằng có thể có nhiều ao nuôi xả thải vượt tiêu chuẩn. Việc giảm thiểu ô nhiễm nước do quá trình sản xuất cá tra là hoàn toàn có thể, thông qua việc sử dụng hiệu quả các nguyên liệu đầu vào, xử lý với chi phí thấp và tái sử dụng dòng chất thải. Sử dụng công nghệ sản xuất sạch hơn, xây dựng các nhà máy xử lý nước thải cho các vùng nuôi và nhà máy chế biến qui mô lớn để giảm thiểu ô nhiễm nước trong ngành chế biến cá tra. Các giải pháp với chi phí thấp đối với các ao nuôi qui mô nhỏ bao gồm tái sử dụng nước thải cho tưới tiêu nông nghiệp.

Thứ hai, chúng tôi đã khảo sát ô nhiễm nước thải, bùn thải và lan truyền bệnh liên quan đến nuôi tôm ở Cần Giờ, thành phố Hồ Chí Minh (Việt Nam), một trong những khu vực điển hình về tác động của nuôi tôm công nghiệp ở Việt Nam. Kết quả cho thấy, tải lượng ô nhiễm trong nước thải khi sản xuất một tấn tôm là 259 kg BOD, 769 kg COD, 1170 k g TSS, 30 kg N, 3.7 kg P và 4.8 kg $N\text{-}NH_3$. Kết quả cũng cho thấy nồng độ BOD_5, COD và TSS tăng theo giai đoạn cũng như tuổi của ao nuôi. Trong khi một số các ao nuôi có thể vượt tiêu chuẩn môi trường, nuôi tôm công nghiệp không phải luôn luôn phát thải vượt tiêu chuẩn. Đây là điều rất thú vị vì nó chỉ ra rằng bằng việc sử dụng các công nghệ sẵn có, chúng ta có thể giảm được ô nhiễm từ các ao nuôi tôm công nghiệp. Cuối cùng, các giải pháp khả thi về công nghệ và kinh tế được xác định nhằm giảm thiểu ô nhiễm nước, giảm thiểu các vấn đề liên quan đến ô nhiễm bùn thải, và giảm thiểu sự lan truyền bệnh.

Thứ ba, chúng tôi ứng dụng nguyên lý của thuyết sinh thái công nghiệp và thuyết hiện đại hóa sinh thái vào điều kiện của Việt Nam. Thiết kế một mô hình lý thuyết về công nghệ nhằm giảm thiểu chất thải trong công nghiệp thực phẩm, với trường hợp nghiên cứu về sản xuất tôm đông lạnh. Kết quả chỉ ra rằng điều này là hoàn toàn có thể và trong thực tế để phát triển một cụm công nghiệp thực phẩm sinh thái thì cần bao gồm các nhà máy chế biến thủy sản, các nhà máy chế biến sản phẩm phụ, và các công trình xử lý nước thải. Bằng cách làm như vậy, các nhà máy công nghiệp có thể hợp tác trong sự phát triển thân thiện với môi trường. Các thành phần và cơ quan quản lý cụm công nghiệp sinh thái được đề nghị cũng được thảo luận trong nghiên cứu này. Hơn nữa, mô hình cũng cho thấy một cơ hội thuận lợi để trong tương lai có thể bao gồm cả ngành nuôi trồng thủy sản trong một mô hình sinh thái công nghiệp thực phẩm như vậy.

Thư tư, chúng tôi đã tham gia và khảo sát một loạt các hoạt động thuộc 3 cấp độ (quốc tế, quốc gia, và cộng đồng), những nơi đã thiết lập và tạo ra các cơ chế điều hành trong quản lý chất lượng nuôi trồng thủy sản. Nghiên cứu đã phát hiện ra rằng ô nhiễm nước do nuôi tôm và cá tra ở Việt Nam được xác định bằng các cách quản lý mới ở 3 cấp độ quản lý được phân biệt. Ở cấp độ quốc tế, đối thoại nuôi cá tra (PAD) và đối thoại nuôi tôm (ShAD) bao gồm sự tham gia với số lượng rộng lớn và đa dạng của các thành phần liên quan để phát triển các tiêu chuẩn về nuôi trồng thủy sản bền vững. Mặc dù, các cuộc đối thoại này là một quá trình dài với đầy ắp các thử thách và các sự chọn lựa khó khăn, nhưng nó đã tạo nên ý nghĩa về sự quan tâm giữa các thành phần tham gia, các bên liên quan và đã phát triển được những tiêu chuẩn cấp quốc tế cho việc chứng nhận sản phẩm. Nhưng sự sắp xếp quản lý cấp độ quốc tế chỉ tập trung vào một phần nhỏ những nhà sản xuất lớn, để lại phía sau một lượng lớn các nhà sản xuất nhỏ mà họ không thể tuân thủ được với tiêu chuẩn đã phát triển. Đối với một lượng lớn các nhà sản xuất nhỏ này, việc sắp xếp quản lý ở cấp độ quốc gia và cộng đồng đóng một vai trò quan trọng. Trong khi những thực hành tốt nhất được tìm thấy thông qua 2 khuynh hướng, thì nhìn chung, việc thực hiện các sắp xếp đổi mới này vẫn còn quá xa đối với sự thành công. Nó có vẻ là có thể và khả thi khi liên kết các mạng lưới quản lý này và làm hài hòa khuynh hướng chứng nhận cho cộng đồng và nông dân. Chúng tôi đã nhấn mạnh việc tăng cường liên kết giữa những sắp xếp của các cấp quản lý. Tuy nhiên, một kiểu cân đối như vậy cũng cần phải phù hợp với người nuôi và hệ thống nuôi.

Điểm mới trong nghiên cứu này là kết hợp phân tích hệ thống với phân tích quản lý đa cấp và công nghiệp sinh thái. Phân tích hệ thống được kết hợp với việc đánh giá cụm công nghiệp sinh thái cho công nghiệp chế biến tôm (chương 4) nhằm xác định các cách để giảm thiểu ô nhiễm và chất thải sinh ra từ chế biến tôm ở tỉnh Sóc Trăng. Đây có thể được xem như là một ví dụ điển hình trong nghiên cứu nuôi trồng và chế biến các loại thủy sản khác ở đồng bằng sông Cửu Long.

Thêm vào đó, nghiên cứu này (chương 2 và 3) sử dụng phương pháp phân tích hệ thống, xác định như một chiến lược để thực hiện nghiên cứu đa ngành theo định hướng ra quyết định, sử dụng nhiều loại công cụ phân tích. Điểm lợi ích chính của phương pháp phân tích hệ thống là hỗ trợ người ra quyết định khi đối mặt với các vấn đề môi trường phức tạp để thực hiện các chọn lựa dưới các điều kiện không chắc chắn bằng cách xác định một biên giới hệ thống, xác định các chỉ số môi trường và tìm hiểu các giải pháp nhằm giảm thiểu các tác động. Nghiên cứu bao gồm các thử nghiệm để kiểm tra tính thực tế của các giải pháp công nghệ đối với việc cải thiện môi trường trong nuôi cá tra và tôm tại khu vực nghiên cứu.

Điểm mạnh khác của nghiên cứu này là phân tích quản lý ở ba cấp độ và sự tham gia trực tiếp của người nghiên cứu ở mỗi cấp độ, bao gồm: cấp độ khu vực, quốc gia và quốc tế; khảo sát các thành phần tham gia; tham gia trực tiếp vào các hội thảo và thảo luận; trực tiếp phỏng vấn sâu các thành phần liên quan và các nhóm liên đới là phương pháp thu thập số liệu của nghiên cứu. Bên cạnh đó các số liệu thứ cấp được thu thập từ các tài liệu, trang web của các tiêu chuẩn và thông qua tổng quan tài liệu.

Cuối cùng, một điểm mạnh khác của nghiên cứu này là đã thu thập và phân tích một số lượng mẫu lớn về ô nhiễm nước do nuôi cá tra và tôm. Trong quá trình khảo sát các ao nuôi, các thông tin chi tiết được thu thập thông qua việc thu mẫu và phân tích mẫu, khảo sát và phỏng vấn nông dân và các kỹ thuật viên ao nuôi về quá trình nuôi và các hoạt động cụ thể của từng hệ thống, các vấn đề về nước thải cũng như hiệu quả của các giải pháp giảm thiểu ô nhiễm hiện hữu.

Nghiên cứu cũng cho phép so sánh giữa nuôi cá tra và tôm. So sánh này chỉ ra rằng nuôi tôm gây ô nhiễm môi trường nước ít hơn so với nuôi cá tra trên mỗi hecta diện tích nuôi. Tuy nhiên, tính theo tấn sản phẩm, kết quả lại khác biệt, trong đó tải lượng BOD, COD và TSS trong nuôi tôm thì cao hơn trong nuôi cá tra, ngược lại tải lượng N và P trong nuôi cá tra lại cao hơn so với nuôi tôm.

Việc quản lý trong nuôi tôm và cá tra cũng khác nhau đặc biệt về mức độ mà mỗi loài đang đối mặt với các chính sách và đo lường của quốc tế hoặc quốc gia

Kết quả nghiên cứu cũng cho phép đưa ra các kiến nghị về quản lý môi trường và hướng nghiên cứu tiếp theo như sau:

Các cách xử lý nước thải trong nuôi tôm và cá tra đơn giản, rẻ tiền và thân thiện với môi trường là đang có sẵn. Trong chế biến cá tra và chế biến tôm, một số cơ hội sản xuất sạch hơn đang được áp dụng đối với các nhà máy nhỏ, vừa và lớn bao gồm cải thiện kỹ thuật quản lý và công nghệ. Việc thiết lập sự hợp tác giữa các nhà chế biến và việc tăng cường các yêu cầu từ các thị trường quốc tế để chứng nhận cho các nhà máy chế biến dường như càng ngày càng có khuynh hướng nghiêng về tái sử dụng và tái chế.

Cần có sự cộng tác giữa những người nuôi nhỏ để có thể tuân thủ tốt hơn các yêu cầu về chứng nhận chất lượng sản phẩm. Một số điểm khó khăn vẫn còn tồn tại giữa những người nuôi qui mô nhỏ khi thiết lập nên các nhóm hợp tác, các nhóm hợp tác này cần tiếp tục được hỗ trợ từ phía chính quyền địa phương, bao gồm: kỹ thuật vận hành, quản lý và thực thi các thỏa thuận về xả thải nước trong khu vực.

Các nghiên cứu tiếp sau này cũng có thể xem xét các tác động môi trường và các hoạt động khác của nuôi trồng thủy sản, ví dụ như ô nhiễm không khí, ô nhiễm mùi, ô nhiễm đất và sự suy giảm của cảnh quang thiên nhiên. Các nghiên cứu sau này cũng có thể mở rộng hơn biên giới hệ thống với chuỗi sản xuất mở rộng của các sản phẩm thủy sản. Thêm vào đó, các nghiên cứu tương tự bao gồm nghiên cứu các tác động môi trường, phân tích hệ thống và phân tích hệ thống quản lý có thể được thực hiện đối với các loại sản phẩm thủy sản khác, như là tôm chân trắng, cá Điêu Hồng…. Cần có thêm các nghiên cứu thực nghiệm và thử nghiệm về các giải pháp công nghệ về giảm thiểu các ô nhiễm.

Cuối cùng, nghiên cứu này được xem như là một ví dụ về phân tích các vấn đề môi trường đối với các loại sản phẩm khác nhau. Sự liên kết giữa phân tích hệ thống các vấn đề môi trường, đánh giá công nghệ và phân tích hệ thống quản lý được hình thành trong nghiên cứu này đã chứng minh về sự hữu ích trong phân tích các vấn đề phức tạp từ nhiều khía cạnh khác nhau.

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C E R T I F I C A T E

The Netherlands Research School for the
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Pham Thi Anh

born on 11 October 1971 in Da Nang City, Vietnam
has successfully fulfilled all requirements of the
Educational Programme of SENSE.
Wageningen, 27 October 2010

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The SENSE Research School declares that **Ms. Pham Thi Anh** has successfully fulfilled all requirements of the Educational PhD Programme of SENSE with a work load of 53 ECTS, including the following activities:

SENSE PhD courses

- Environmental Research in Context
- Research Context Activity: "Establishing an Educational and Environmental consultants company: Smartchoice JSC (Vietnam, 2007)"
- Research Methodology: designing and conducting a PhD research project
- Ecological Modernization Theory

Other Phd and MSc courses

- Techniques for Writing and Presenting Scientific Papers
- Social learning in Nature-Society Relations: politics & Creative Methods in Action Research (PNG 0022)
- Environmental Systems Analysis
- Using the economic incentive in Environmental Management
- Advanced philosophy

Oral Presentations

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Pham Thi Anh was born on 11 October 1971 in Da Nang City (Vietnam). She obtained her bachelor degree in Environmental Science in Ho Chi Minh City University of Social Sciences and Humanities – Vietnam in 1995 and her Master degree in Urban Environmental Management in Institute for Housing and Urban Development Studies and Wageningen University – The Netherlands in 1999. From 1995 to 1997 she worked in Vietnam – Russia Tropical Research Center in Ho Chi Minh City. Since 1997, she has worked in Van Lang University - Department of Environmental Technology and Management as the lecturer and she had done trainings, researches and consultants in UCC group on environmental fields. Beginning of 2002 she started her sandwich PhD program in Wageningen University in the Environmental System Analysis group and Environmental Policy group.

The UCC Group was established with the goal of contributing to the solution of environmental problems and to sustainable development. The UCC group has its roots in the Department of Environmental Technology and Management of Van Lang University (DENTEMA), in research centres including CENTEMA and ETM and in the companies involving VLC, VAE, VHC, VAC, SMARTCHOICE and HLC. The latter are all environmental companies, which receive and apply training and research results into practice). UCC operates within a "tripodal" field of initiation, development and improvement of environmental protecting activities, serving to develop a sustainable economy for the southern provinces in Vietnam.

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