Graduate Program in Sustainability Science

Graduate School of Frontier Sciences

The University of Tokyo

2011-2012

Master's Thesis

An ex-post perspective on human-ecological system resilience and dynamics:

a case study of the Philippine brackish-water pond aquaculture

Advisor: Professor Yarime Masaru

Co-advisor: Professor Onuki Motoharu

Submitted in February 2012

(47-106801 Victor Ramil Marius Tronco Tumilba)

ABSTRACT

The "perfect storm" is said to be coming as global population is expected to grow by half from today to the middle of this century and simultaneously contend with soaring global temperatures due to climate change. This is only one of the countless sustainability challenges that humanity faces. It has long been realized that human and nature interrelationships are complex but it is only now that social-ecological dynamics is becoming one of the main foci in sustainability science for dealing with complex sustainability issues existing at multiple scales in multiple domains. This study attempts to contribute to such learning of system complexity by amalgamating forthcoming frameworks, approaches and methodologies to gauge system transformation and evolution. Three main stream sustainability science concepts are employed: system cycle of adaptive change; network analysis and resilience theory. The cycle of adaptive change is honed from observation of empirical studies of ecological cycles and is designed to capture system transformation categorized into four-phase successions. Although simple to comprehend the application has mainly been confined to qualitative narrative of system dynamics for it the intention is to simplify understanding of complex systems and to recognize key elements of system evolution that is common to different systems. The purpose of applying network analysis in terms of the "value chain" is to give a concrete structure to the system which is essentially

ABSTRACT (continued)

the foundation of quantitative description of the system in terms of material flux. Having the structure then caters for the requirements in applying quantification of resilience that is based on network-flow-structure and information theory. The measure of resilience is then reintegrated to the adaptive cycle (albeit qualitatively) to give a sense of quantitative system dynamics. The iterative process is applied to a case study which is a subsector in aquaculture that experience growth, development and disturbances to provide empirical evidence that such approach has merit in studying complex dynamics. One remarkable deduction on the results is that as the aquaculture sector, as a social-ecological system, cycles through growth and development there is a decrease in resilience that leads to an increase vulnerability to disturbances may it be from social, ecological, or economic origins. Prior to perturbations, low levels of system resilience are coupled with rapid increase in growth in terms of production volume. There are also instances that growth may be coupled with increase in resilience although increases in production volume are less progressive and at times stagnating. System efficiency is important in sustainable development of a sector but maintaining system resilience is equally important for system persistence. One could only hope that the result of this study is of value in understanding system complexity and its application is of benefit in navigating human-nature transformations.

ACKNOWLEDGEMENT

Foremost, I would like to give my sincerest gratitude to my principal research adviser Professor Yarime Masaru for his guidance and encouragement in exploring sustainability science research. My appreciation is also given to my research co-advisor Professor Onuki Motoharu for his dedication in enhancing the research by adding insight to the proposed methodology and overall research structure. The same is extended to all the professors in the Graduate Program in Sustainability Science of the Graduate Program of Frontier Sciences for their feedback during the seminar sessions that directed the research.

Furthermore, recognition is given to Tina Hautea, Aileen Jamandre, David Villaluz, Rose Mueda, Roed Shane Hablo, Mary Jade Gonzalez, Leah Gonzales, Crispino Saclauso, Valeriano Corre Jr. , Dan Baliao, Roman Sanarez, Janice Tronco Ragus and Jessica Esmao. They have all been valuable resource persons in the conduct of the field interviews.

I am also grateful to all my fellow students in GPSS, especially to Yoko Takishita, Mamiko Kuwaki, Yuta Hirose, Shogo Kudo and Juan Haruichi Watanabe Osorio for the inspiring discussions in sustainability and sustainability science. Last but not the least; I thank my wife, Michelle Buen Tumilba, for the unceasing support despite the distance.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

INTRODUCTION

The world is becoming less and less disjointed and the problems humanity is facing are becoming more integrated and complex. Global population is expected to grow by half from today to the middle of this century and simultaneously contend with soaring global temperatures due to climate change. This scenario will be coupled with increasing demand for food and water whilst international efforts such as the UN Millennium Development Goals continue to struggle in reducing the hunger-afflicted shares (Morse, 2010). In this respect, aquaculture plays an important role in meeting food security and amidst declining wild stocks in capture fisheries and agricultural land loss due to urbanization. The remarkable growth and development of aquaculture surpassed direct-food-consumption production of capture fisheries in 2007 and is still expanding to meet growing demands (OECD, 2010). The expectation on aquaculture is high but nonetheless, it has its own set of social, ecological and economic challenges. These problems that require coherent solutions can no longer be dealt with by employing traditional disciplines. The ever increasing obstacles that involve social-ecological system relationships call for broader approaches to provide integrated and systemic solutions and warrants an approach encompassing complex causalities occurring in a myriad of systems existing in different domains at different scales and under the presence of uncertainty (Spangenberg, 2011). Over twenty year ago the

World Commission on Environment and Development (WCED, 1987) initiated the institutionalization of sustainability as a principle and yet there is no single definition that could reconcile the different implications behind the concept. It is applied to ecological, economic and social dimensions; divided into categories of weak and strong or even external or internal; defined as either local, regional or global (Voinov, 2007); and in some cases becomes ambiguous represented by a few simple figures.

Sustainability science

The need to solve the ever increasing complex problems is calling for a new science that deals with the challenges set forth by sustainability that is not merely defined by the tools and methodologies, but a science that is distinctive and defined by the problem it faces rather than the disciplines it employs. Under the ideals of sustainability there is an increasing effort to consolidate ideas and approaches that addresses a myriad of complex problems and yet have its own set of problems to deal with as it continuously reinvents itself. The research field of sustainability science combines areas of environmental science, social science and economics to better comprehend dynamic interactions between human and environmental systems. Sustainability science is on the inquest of environment and human relationships often times expressed in epitomes of conceptual frameworks. Sustainability and its science are no longer focused towards environmental realm but have wider interpretations. (Spangenberg, 2011).

Research description and objectives

Given such conditions, this study is oriented towards understanding system complexity dynamics which is one of the potential tools in dealing with multifaceted problems and focuses on answering questions such as how do systems interact and transform and would it be possible to apply a common unit of measure that would reflect at least a component of such dynamics. The objective of this research is to provide a better understanding of system alteration by taking an ex-post perspective on the growth, development and transformation of social-ecological systems.

The current undertaking seeks to incorporate several sustainability science approaches that are trending in dealing with system evolution and interaction. As much as this study relies on empirical studies it still remains exploratory in structuring a potential approach that could integrate qualitative and quantitative measures for system to system interactions. An integration attempt is also made by employing sustainability science directives such as transdisciplinarity, human-ecological system complexity and the concept of resilience. The research process is an iteration of assessing applicability of frameworks, methods and tools on a selected case study which is the brackish-water pond aquaculture system and the process of verification of applicability is as valuable as the results obtained in this experiment. The aim is to understand the logic of the puzzle of system complexity and not merely to offer a solution but to open a discourse on the possibility of the found approach in dealing with issues of sustainability. The intention of the research is also to open the approach to a wider audience and simplification of emerging trends in sustainability science studies is thus necessary and yet adhering to the basic academic principles and standards in conducting research study. Thus this paper is an empirical investigation in sustainability science involving complex system dynamics represented by an aquaculture system and offers a possible approach in conducting sustainability science research; assessment tool in managing large scale systems; and contributing to the knowledge of system dynamics.

This exploratory analysis of system dynamics is open to the reader to reject the approach; learn from it; or test it by doing further work on other systems and the purpose is to contribute to a much bigger question of how different systems at different scales interact based on the statement of Voinov (2007):

"…. analysis could be improved if there were a measure of sustainability that could be used to track the state of the system and compare its various stages"

Before embarking into research it is essential to frame the problem according to the standards of sustainability science research. Kates et al. (2001) proposed core questions to give research focus on the basic nature-society interactions and human capability in mapping a course towards sustainability. Five guide questions are lifted there from:

1. "How can the dynamic interactions between nature and society—including lags and inertia—be better incorporated into emerging models and conceptualizations that integrate the Earth system, human development, and sustainability?"
2. "What determines the vulnerability or resilience of the nature-society system in particular kinds of places and for particular types of ecosystems and human livelihoods?"
3. "Can scientifically meaningful "limits" or "boundaries" be defined that would provide effective warning of conditions beyond which nature-society systems incur a significant increased risk of serious degradation?"
4. "How can today's operational systems for monitoring and reporting on environmental and social conditions be integrated or extended to provide more useful guidance for efforts to navigate a transition towards sustainability?"
5. "How can today's relatively independent activities of research planning, monitoring, assessment and decision support be better integrated into systems for adaptive management and societal learning?"

Checked against the given core questions as a criteria then the approach may be of value for sustainability science research for learning. It is by aligning the research objectives of this study to the proposed questions that guides the results towards contribution to the field of sustainability science. Before continuing, some clarifications are in order to cover the under pinning key points in conducting this research project.

Social-ecological systems

Humanity is an overpowering force that shapes the ecological system from local, regional and global scales. Humanity manages well to grow and develop systems to provide for their own social needs but less can be said when the system is on the path towards catastrophe.

A system being referred to this study may be social, economic and ecological or any combination thereof. Social systems may be in the form of governance which experiences social revolutions. Economic systems such as those of Latin America, Asia and the United States which experienced financial crises in 1994, 1997 and 2008 respectively (Bussiere & Fratzscher, 2006; Samarakoon, 2011); and these are often time described as akin to a disease that spread from one financial system to the next. Ecological systems such as the wild stock in capture fisheries which have been deemed suffering from decline and “fishing down the food web” (Bhathal & Pauly, 2008). Of course the described systems have overlaps: economic systems are dependent on natural resources and governance through policy formulation which regulates economic and resource use. These systems are interlinked and become a system of systems having interactions within and in-between systems.

In the past, the solution to manage to avoid disturbances was to create systems that are impregnable to disturbances, systems that are "fail-safe" (Ahern, 2011). This is under the assumption that nature and man hangs on a balance and by striking this equilibrium one may hope to achieve sustainability. This is a common world view that society has the capacity to control a system by managing the components leading to the idea that the planet is a human dominated system. In marine fisheries, the concept of maximum sustainable yield was developed to determine the allowable catch that could be harvested from the wild that would not lead to the decline of stock. These management attempts have failed for harvest and population replacement rate of the stock are not the only variables in social-ecological system, there are also political, economic and other ecological variables that needs to be considered (Cash et al., 2003). Such is the case of the Peruvian anchovies that began to see the importance of adaptive social-ecological system concepts (Arias Schreiber, 2012). In consideration of all variables acting in the system it is necessary to identify an indicator that manifests their interactions.

There is another emerging view that considers disturbances, unknowns and opportunities for system recreation (Ulanowicz, 2002). Systems theory is the interdisciplinary area of science that examines complex systems and these behaviors and many principles is applicable to both ecological and human systems. Systems thinking facilitate both qualitative and quantitative aspects of understanding system dynamics. Social-ecological dynamics and science of complexity is used here as a response to the previously stated guide question.

Resilience

An inherent property emerging in social-ecological system studies is resilience. It was previously defined as "the capacity of a system to respond to change or disturbance without changing its basic state" (Walker and Salt, 2006). This so called response has two emerging properties which are the state to resist change and the state to adapt to change. The state of resilience that resists change has been described by Holling (1996) as a form of engineering resilience. This is the "fail-safe" state that can only be achieved if all variables within and external to the system are known and addressed to prevent system change. If there is an entity that can know all the variables and their causalities and effects, one may suspect that engineering resilience may be possible to achieve but in the world of imperfect information and unfamiliar dynamics this would be improbable. The other property of resilience which is the ability of a system to adapt to change has been defined by Walker et al (2004) as the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks.

Given the statements above there is a third definition of resilience arising from a multidisciplinary perspective of network analysis and information theory. Before giving the definition of resilience it is important to understand that the broader context of sustainability is normative in form. The emerging definition by Ulanowicz (2009) proposes that sustainability is the function of efficiency and resilience and is said to be:

“The capacity for a system to undergo evolutionary change or self-organization consists of two aspects: It must be capable of exercising sufficient directed power (efficiency) to maintain its integrity over time. Simultaneously, it must possess a reserve of flexible actions that can be used to meet the exigencies of novel disturbances”.

Sustainability in this context is merely to define a system in existence in terms of a network and is non-normative. In other words, system sustainability deals with system persistence. A system in persistence has two emergent properties which are efficiency and resilience and having inadequate allocation for both would render a system’s existence towards a state that is unsustainable in the presence of novel disturbances. The theoretic is consistent with the first two definitions of resilience. In network theoretic, resilience is the ability of a system to maintain structure and flows (feedbacks) which is parallel to engineering resilience. Efficiency on the other hand is the ability of a system to grow and develop which is parallel to the ability to adapt.

The various research being conducted in sustainability science have been broadly distinguished into two categories by Spangenberg (2011): science “for” sustainability and science “of” sustainability. Science for sustainability is described as a science that tackles sustainability issues and employs fundamental sciences which are disciplinary-based but interdisciplinary-framed. Science of sustainability on the other hand is geared towards searching for understanding of human and environmental interactions which is the core in capturing the ideals of sustainability represented by conceptual models. The science of sustainability also bridge gaps between concepts of different disciplines. This research project very much belongs to the latter which is the science of sustainability. Under the following section we shall advance to the peripherals of this research which are the recommended underlying concepts of sustainability science investigations. These concepts operationalized in the conduct of this research and are considered to be essential components in any study within the science “of” and “for” sustainability.

Transdisciplinarity

There are also imperatives in sustainability science as much as other disciplines and it is no longer a matter of just obtaining results but also the manner of how to arrive at the results, in a sense: the process is as much as important as the result and the drivers for the process should also have value. One of the peripherals in this research is the concept of transdiscipinarity, a suggested component in sustainability science that the research should employ because traditional disciplines, either as stand alone or in coordination are simply not enough to meet the current challenges of required analysis of human-environment relationships (Rapport, 1997). Transdisciplinarity is no longer bounded by academic disciplines such as science and humanities but also societal disciplines. The term societal discipline used in this circumstance is the occupation in which an individual or institution represents and the local knowledge that they possess. They may not be directly involved in the academic field but have a role in shaping future directions for sustainability or development being part of social processes. They are a source of local experience and knowledge, and holds valuable information and a degree of influence in decision making or simply by being part of the societal development. In a sense, in the conduct of a sustainability science research, people and institutions in these societal disciplines are treated as collaborators shaping the outcome of the research process and not merely as test subject for gathering data and information. There are numerous studies of transdisciplinarity and various perspectives and definitions and are referred to Lawrence (2004) and Maxneef (2005). In this study there are two important aspects. One is building an argument and seeking of evidence founded on academic empirical studies may it be mono or multi disciplinary. The second is the inclusion of actors both from the academic and non-academic fields for a consultative transdisciplinarity (Mobjörk, 2010) process. The origins of transdisciplinarity can be traced back to the early 1970s during the first “international conference on interdisciplinarity research and education” and was then believed would revolutionize general theories of systems and constructs (Thompson Klein, 2004).

Qualitative and quantitative modeling

Both qualitative and quantitative approaches have their own advantages and disadvantages, from being too complex and time consuming to being too ambiguous. Trying to key in the advantages both can give a better understanding to the dynamics of a social-ecological system. The research tries to balance both to meet academic standards and possible application outside the academic disciplines. Qualitative analysis gives a rational understanding of systems phenomena which may not be captured quantitatively due to emergent behavior in a system. Quantitative analysis on the other hand can provide better understanding of system behavior according to its components (Bondavalli, Favilla, & Bodini, 2009).

Review of sustainability assessment tools

Frameworks, methodologies and tools have also been developed to address the multifaceted definition and issues of sustainability. It is acknowledged here that there already exists a wide variety or assortment of sustainability assessment tools ranging from indicators to product-related to integrated assessment approaches. The increasing number of assessment procedures is called for in response to the need to evaluate goals or objectives of transition towards sustainability from any existing state and resulted in the expansion within this field. A study (Ness et al., 2006) broke down sustainability tools into three broad categories: indicators/indices, product related assessment and integrated assessment tools. In the review of sustainability assessment tools, they have concluded that there is a contradiction in future developments: one is the need for case and site specific tools and the other is that for broader tools that can be accessible to extensive users and applicable under varying conditions. A further recommendation is that an appropriate tool can be developed only if all parameters are concurrently taken into account. This would only suggest that all parameters would include both known and unknown variable and thus the inclusion of perturbations in tool development. Since sustainability could be defined in different domains and at different scales, these contradictions may in actuality be complimentary. One emerging approach that may contribute to integration is the social-ecological system dynamics that is still in its infancy (Folke, 2006).

Case study selection

Given the minimum requirements for conducting sustainability science and social-ecological system research, the Philippine brackish-water pond aquaculture system is selected as a case study. In terms of problem framing, the selected system has both human and ecological components. The system also features interactions among elements in social, economic and environmental domains. Increase in volume production are motivated by natural resource use; policy implementation for growth and development; financial assistance from government and funding agencies; and technology and innovation to increase production. Aside from growth and development the brackish-water pond system also features experienced perturbation coming from all three domains from consumer demand shift to proliferation of diseases in the prawn industry.

In studying large scale system behavior ex-post, empirical studies should be available as evidence for establishing arguments. These peer reviewed papers determines the importance of a variable or a set of variables and their implication to system dynamics being analyzed. Qualitative and quantitative peer reviewed papers on aquaculture are available owing to the establishment fisheries research and academic institutions like the South East Asia Fisheries Development Center (SEAFDEC) and the College of Fisheries and Ocean Sciences of the University of the Philippines in the Visayas (CFOS-UPV).

Since the investigation is an empirical study of system transformation it is therefore necessary to ascertain data availability over the period of observation even at least partially. Aquaculture production volume and value have been monitored by both local and international institutions to assess growth and development of the aquaculture sector particularly to measure and monitor projected targets and intervention impacts.

Even though this is an academic research there still reason to be practical. The author already has qualification on the fisheries field of study and has been fortunate enough to have been part of an international technical assistance program for aquaculture development under the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Trade Policy and Trade Promotion Project. The author likewise has an established network of institutions and individuals necessary for field verification and a consultation.

Lastly, Aquaculture plays an important role in domestic food security. The knowledge produced in this research is hopefully applicable in managing system transformation of the aquaculture sector as well as offer a systemic analysis by bringing together different empirical studies in aquaculture development. It is also a personal motivation for the conduct of this research to promote the sustainable development of the aquaculture sector in the Philippines.

Case study background

The background introduces the Brackish-water pond aquaculture and its components according to the type of species being grown. A brief history of development is covered and the different elements, variable and conditions which are key drivers for it stages of evolution and transformation are emphasized. The drivers or conditions are broadly categorized into social, ecological and economic domains. Not everything is included but select variables are noted. To understand the development of brackish-water pond aquaculture it will be presented after defining several basic and key elements.

Historically, the growth and development of the brackish pond system, as represented by milkfish and tiger prawn, could be explained through technological, institutional and cost-return perspectives and involves the social, ecological and economic dimensions. The milkfish and prawn industry are very well studied in various these aspects and under different fields of research although mainly remaining disjointed. This is by no means a complete description of the brackish-water pond aquaculture.

Brackish-water pond aquaculture

Aquaculture can be defined as a form of agriculture, a practice of culturing select species in a controlled or semi-controlled area with the intention of increasing crops by exerting control over certain parameters in the production process and production environment.

Brackish-water pond aquaculture is a practice of culturing aquatic species utilizing mixed fresh and sea water in earthen ponds. There are several species being cultured in Philippine Brackish-water pond aquaculture but none as important as milkfish and giant tiger prawn. Tiger prawn can be viewed as a “cash crop” while milkfish has always been regarded as an answer towards local food security (Bagarinao, 1998).

Milkfish, *Chanos chanos* (Forskal)

Milkfish (Figure 1), *Chanos chanos*, (forskal), of the family Chanidae, are phytophagus non-cannibalistic benthic filter feeders. Being euryhaline, *C. chanos*, can tolerate extreme but gradual changes in salinity gradients from 0 to 100 parts per thousand (ppt) but exhibits

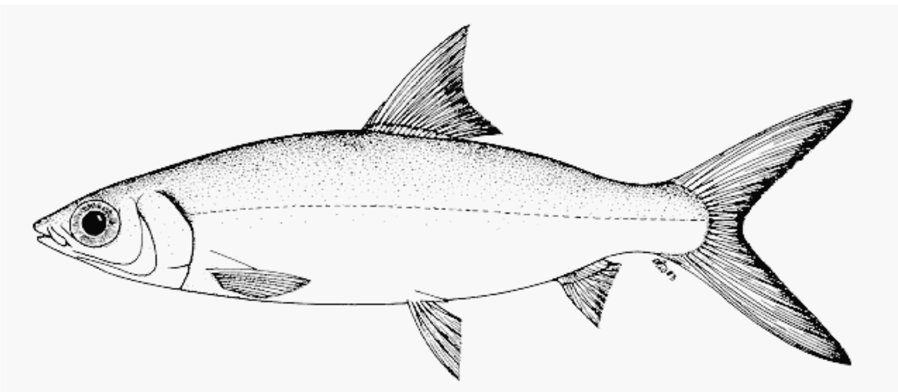

Figure 1. Milkfish (*Chanos chanos*, Forskal)
Source: FAO, Fisheries and Aquaculture Department

faster growth rates below 40 ppt. They also exhibit compensatory growth behavior in which they can be stunted by crowding in a small confined area but experiences growth spurts when conditions become more favorable. Milkfish can be grown to broodstock-stage from 5 to 10 years in captivity and is also highly resistant to infectious disease which allows them to be grown in higher densities (Baliao et al, 1999). Milkfish is thus a robust selection of species for aquaculture. Further biological (taxonomic and morphological features); oceanographic distribution in the Indo-pacific and South East Asia; and reproductive cycle of milkfish have been summarized by Bagarinao (1991) from empirical studies and experiments conducted by the author herself as well as others. Interested readers are directed towards her earlier literature on more detailed characteristics of milkfish.

Giant tiger prawn (*Penaeus monodon)*

The giant tiger prawn (Figure 2), *Penaeus monodon*, is an aquatic crustacean and is known to be one of the biggest among prawns. In contrast to milkfish, tiger prawn is less robust for aquaculture production. Recommended intensive pond production conditions are strict: dissolved oxygen at not less than 5 parts per million (ppm); pH from 7.5 to 8.5 and 0.5 abrupt change must be avoided; salinity within 15 to 25 ppt with only a narrow permissible range of fluctuations in salinity (Drairaj et al, 1984.); temperatures greater than 28° centigrade but below 32° centigrade; and very low concentrations of ammonia (0.1 ppm)

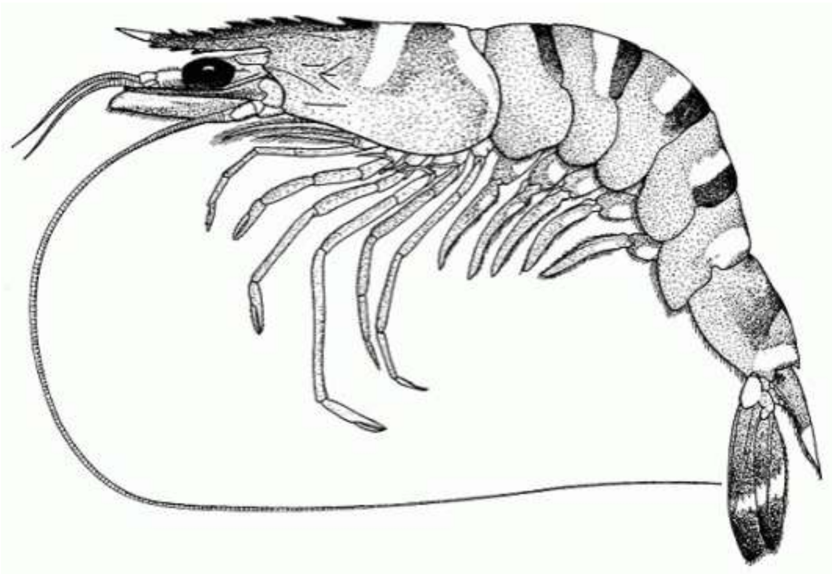

Figure 2. Giant tiger prawn (*Penaeus monodon*)
Source: FAO, Fisheries and Aquaculture Department

and hydrogen sulfide (0.02 ppm) (Baliao, 2000). Such narrow range of production parameters is not only to optimize growth but to deter the onset of disease such as luminous bacteria (*Vibrio harveii)* and white spot syndrome virus (WSSV) during production.

Socio-economic conditions

The growth and development of the brackish-pond sector is a human concerted endeavor to increase production may it be achieving food security or economic gain. Certainly there were also efforts towards conservation of the environment and addressing social inequality. Primavera (1993) recorded pertinent governing laws for aquaculture development which also includes mangrove conservation efforts and marine pollution from 1932 to 1991. The establishment of government, academic, research and private sector institutions, private and public donor agencies to promote aquaculture development also played a role in the growth of the aquaculture sector (Schmittou et al., 1983). The brackish-water pond production is also driven by the market demand of society. In the 1980s tiger prawn has become one of the most important traded species for global consumption. While tiger prawn is more export oriented, milkfish has remained for domestic consumption and export is mainly targeted at Filipino community abroad (Tan et al., 1984). During the stages of development there are social factors contributing to the increase in production of the brackish-pond aquaculture system but the most critical is the private sector initiative especially in the tiger prawn industry which is driven by the high price of the product in the international market. These social conditions determined the mobilization of both human and natural resources in brackish-water pond aquaculture

Natural resources

The chronicles of Philippine aquaculture extends over half a century and the first pond officially recorded in the Philippine census was in 1863 (Primavera, 1993). In the early stages of Philippine aquaculture development, production was primarily practiced in earthen brackish-water ponds most of which have once been prime areas of mangrove forests. From

1920 to 1990 there is a documented decrease of mangrove areas from 450,000 to 132,500 ha coupled with growth in brackish-water pond culture areas to 223,000 ha: 141,000 ha of which comes from mangrove areas from 1951 to 1988 (Primavera, 1995). In the early to late 1950's the growth in aquaculture inland production, which has been synonymous to brackish-pond production, was due to area expansion. Average yield remained relatively constant at 0.35 tons per hectare per year and increase in production and average yields post 1950s can be attributed to increase in production area, institutional empowerment and capacity building through training and lectures; increase in availability and application of technology and innovation, and access to credit (Chong et al., 1984). Tiger prawn has always been a byproduct of brackish-water pond milkfish production. The earliest documentation of tiger prawn production was back in the 1950s by Villadolid and Villaluz (1951) but it was not until the late 1960's that the industry took off (Villaluz et al, 1969) and started to change the features of the brackish-water pond aquaculture. The global production of prawn is dominated by the tiger prawn primarily cultured in Asia. The increase in prawn production was driven by the international market demand, particularly Japan, for this high value species and earned valuable foreign exchange for the country. The high demand of the black tiger prawn motivated the producers to shift from milkfish to tiger prawn production and intensify operation systems. The increase in production was also partly responsible for pollution in mangrove and coastal areas.

Fry sources

An essential component in brackish-water pond production is the source of fry for stocking the ponds. In the past, fish farmers would simply allow milkfish and prawn fry to enter the production area with the incoming tide during the water exchange production cycle. For milkfish, it was later discovered that production volume could be increased beyond what could be previously attained by gathering wild fry from coastal areas for stocking in the ponds: hence a sub industry of fry gathering emerged to meet the increasing demands of pond production. The continued growth in production volume of the brackish-water pond aquaculture required more fry than can be harvested from the wild thus spurring the proliferation of fry hatcheries. It can be said that one of the reasons that paved the way to the rapid expansion of tiger prawn production in the 1980s can be attributed to the introduction of technologies by research institutions for tiger prawn brood-stock and hatchery operations (Primavera, 1993). A discourse also evolved around the concern of dwindling wild milkfish fry supply and inefficiencies in the sub-industry (Smith et al, 1978) which also lead to the promotion of and introduction of milkfish hatcheries in the mid 1990s. Economic feasibility studies have been conducted and this is the role of research diffusing the technologies to the economic sector (Agbayar et al, 1991) and further policy studies was conducted with an orientation towards “sustainable growth” of the milkfish fry hatchery industry (Israel, 2000).

Other Technologies

Aside from brood-stock and hatchery management and technology there are also other innovations applied in brackish-pond management. Fertilization is a form of technology and innovation in brackish pond production which contributes to higher production levels. It is used to grow the natural food in a pond system which is composed of micro organisms like algae and planktons. Natural food growth of planktons in the water column for milkfish and tiger prawn involves organic or inorganic fertilization. For milkfish alone there is the “lab-lab”, which is a collection of benthic microorganisms forming algal mats, on the pond bottom surface which can be enhanced by increased fertilization. There is also the application of feeds and feed management techniques based on research and development efforts of research institutions which optimizes growth rates and thus increases production volume (Kühlmann et al, 2008; Tarawa et al, 2002; Sumagaysay et al, 1991). Application of commercial feeds also require advanced water management systems (use of pumps and frequent water change) to maintain the quality of the culture environment. Chemotherapeutants and biological products are also widely used in both hatchery and grow out productions. The uses are mainly for prophylaxis, parasitic control, and physiochemical conditioning of soil and water parameters conducive for production. Primavera (1993) categorized these in prawn production: therapeutants and disinfectants; soil and water treatment; organic decomposers; pesticides and algicides; plankton growth parameters and feed additives. So far, technological application is in terms of production inputs to maintain, reduce losses or enhance production by increasing the use of these technologies. The prawn sector is vulnerable to pathogenic outbreaks of luminous bacteria and WSSV which causes high mortalities in both hatchery and pond production systems and thus requires more intensive application of chemotherapeutants. Another example of technology innovation is on pond design such as the modular production system. The modular production system is an innovation that optimize yield per unit area for a given culture area. Modular production method in milkfish production, to close the yield gap closer to the projected 2,000 kg/ha, optimizes space utilization in growing milkfish by breaking in into compartments and stocking fish in series and revolving the cropping cycle (Agbayani & Ticar, 1989). There are also varying culture management techniques such as milkfish and tiger prawn mono-culture, poly-culture and crop rotation employing these technological inputs. Production types are at times categorized into extensive, semi-intensive and intensive management systems depending on the level of technology employed and the amount of inputs versus the production output. In the review of the combination of various management system types there are four critical steps in the production cycle: pond preparation, fry stocking, culturing, and harvesting. In increasing production volume per year, inputs can be increased or production cycles shortened by the use of the different technologies previously described.

Some believe that milkfish continues to fail to meet projected productions due to sluggish adoption of technology and recommendations are geared towards increasing production through production efficiency and value adding of milkfish products and access to credit (Learned, 2005). It has always been viewed that the industry suffers from too many inefficiencies and dealing with these inefficiencies would render the milkfish development more sustainable with minimal consideration for systemic analysis of the industry.

Aquaculture as a social-ecological system

The brackish-water pond aquaculture industry is a complex social-ecological system. Rather than dichotomizing into two rigid structures of social and ecological systems, it is taken as a whole system. It is shaped by the social interaction of different actors which determines the use and allocation of both man-made and natural resources. The area in which culture production operates came from a natural ecological system and it is even declared by law that mangrove buffer zones should be integrated with the production area (Republic Act 8550) which inherently combines a natural ecological system into the man-constructed production system. The activities in culturing rely heavily on ecological resources and their conditions such as water and soil quality. Within the pond exists a semi-controlled ecological system with biotic and abiotic factors that supports the growth of the cultured milkfish and tiger prawn.

The ecological and social factors, both known and unknown, determines the behavior of the brackish-water pond aquaculture system and thus its structure and production output. The cultivation is governed by human processes according to the social and economic conditions. The harvest goes through the supply chain influenced by the economics of supply and demand. The social and ecological systems are thus intertwined and the result is a complex dynamic system that has been studied in parts in the past. Short and long term effects of recommendations from various empirical studies are not very well evaluated considering that disturbances could occur at anytime within or outside the system. As an example, the Philippine tiger prawn industry experienced collapse due to disease outbreaks, negative environmental impacts, increased food quality and safety regulations, market demand shifts, mal-policy formations, and use, misuse and abuse of technology and innovation, among others. The brackish-water aquaculture industry also features stages of growth, development and collapse in a relatively short time frame which is a prerequisite in observing system resilience in this type of empirical study for sustainability science since large scale ecological systems undergoes transformations for a longer period of time. These are just some of the elements, variables and condition that describes that the brackish-water pond aquaculture network system is indeed a social-ecological system. As a final note in this section, the noble intention of developing the aquaculture sector through these efforts created anticipated side effects leading to runaway growth and development.

METHODOLOGY

Overview of the methodology

The methodology in this research is an iterative process of evaluating the fitness of frameworks and concepts to the case study with the intention of using resilience as a measure for system transition. The first step is to assess the conceptual framework for system dynamics known as “Panarchy” or the adaptive renewal cycle (Gunderson and Holling, 2002). Panarchy is a heuristic model spawned from observing various ecosystems and their respective transformation processes. The framework describes how a dynamic system undergoes four phases in its cycle and through these cycles there are varying degrees of resources accumulation, resource utilization and system resilience. Although Panarchy gives a clear narrative of how a system undergoes change it still requires a unit of measure. The second step is making explicit the system structure using the value chain approach. This value chain represents the system as a network structure composed of nodes and flow. This is the qualitative description of the components of the brackish-water pond system. The products flowing from production to market constitutes the quantitative description of the network. The qualitative description is then the foundation for the quantitative analysis for resilience by mapping the values for the cultured products flowing through the system. The third step is the application of the mathematical model introduced by Ulanowicz et al. (2009) expressing sustainability as a function of efficiency and resilience. The mathematical model is then tested using the structure and flow values of the defined value chain of the brackish-water pond aquaculture system. The fourth step is to fit the values of resilience to Panarchy and asses if the transformation of the system follows the proposed cycle of change and determine the measure of resilience.

Panarchy gives the qualitative narrative of system transformation; the value chain represents the qualitative structure and quantitative flow of the system, and the window of viability gives the quantitative assessment for the value of resilience as the system undergoes transformation.

Adaptive change cycle (Panarchy)

The following framework is based on the work of Gunderson and Holling (2002) on the Adaptive change cycle also known as “Panarchy”. Panarchy is a general framework that makes explicit the transformations in coupled human and natural systems which transcend boundaries of time, space and scale and is based on empirical observations of ecological system successions (Figure **3**). There are four defined phases: growth, conservation, release and reorganization. There are two components in the framework which are the system proceeds through the cycle and these are the degree of capital in the system and

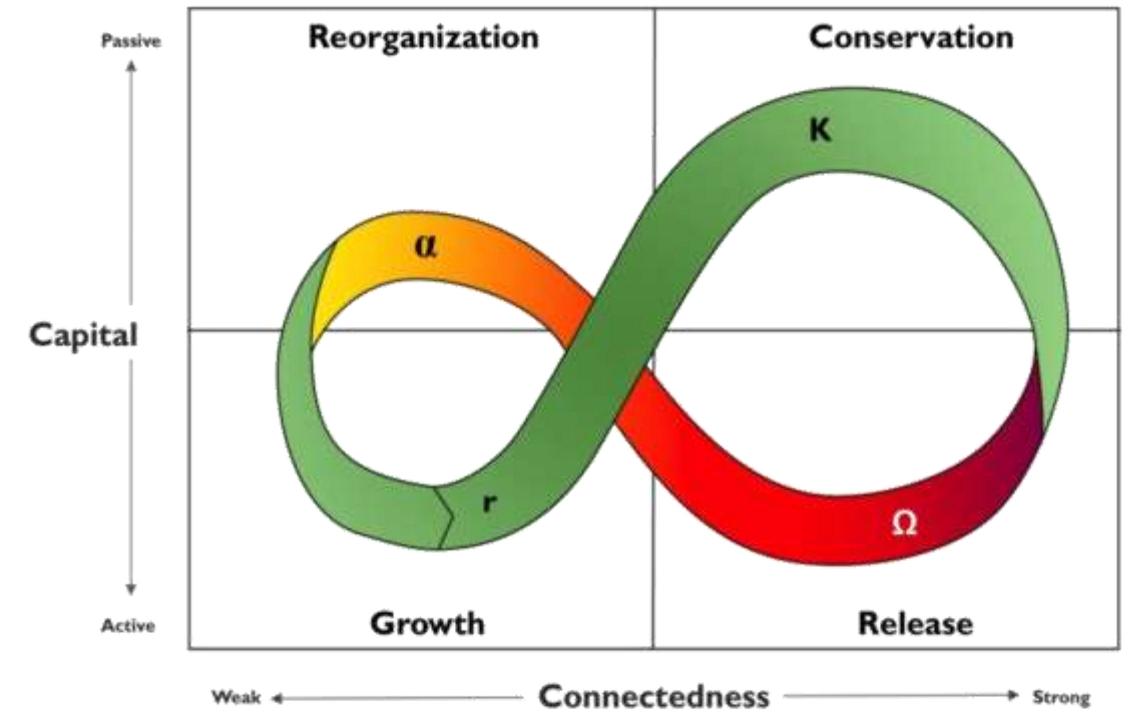

Figure 3. Cycle of adaptive change (Panarchy)
Source: stylized by Noah Raford from Gunderson and Holling,2002;
http://news.noahraford.com/?p=648

degree of capital accumulated in the system and the degree of connectedness of capital within the system. As the system passes through each phase, the degree of capital and connectedness also changes. Capital in a general sense can be referred to as resources that support the function of a system. In a natural environment it would be the biomass and nutrients circulating within it. Connectedness on the other hand is the level of integration of these resources within the system. It may either be tightly bounded within the system or easily lost making it available for utilization within or outside of the defined system.

Growth and conservation phases

In an ecological system, the growth phase is characterized by colonization and exploitation of a given area that has experienced disturbance. This phase is designated as r which is essentially the same designation for r-strategist species that have higher growth rates at the exploitation stage in an ecological succession. As opposed to the growth phase, the conservation phase is designated as K after what has been coined in classical ecology as K-strategist species. K-species have slower growth rates but thrive in the phase of conservation. K-phase is also known as the phase of stability. During the phase of growth, there is low accumulation of capital that is loosely bounded and increases and becomes tightly bounded as the system moves towards the conservation phase. The growth and conservation stage constitutes the forward loop of the cycle is the very foundation of the framework based on evolving ecological systems that exhibits growth and development.

Release and reorganization

The third stage in the cycle of adaptive change is the release phase which is designated as omega (Ω) as it denotes the ultimate limit or the end in a theological sense. As the system reaches the K-phase the capital becomes tightly connected until a disturbance exerts itself unto the system. In a natural environment this could be in a form of forest fires; pest outbreaks; or even human intrusion. The disturbance causes the release of capital within the system and leads to the fourth stage which is the function of reorganization and is designated as alpha (α) symbolizing the beginning. This α-phase is the restructuring of the system that again leads to the exploitation stage and into a new type of system which may have similar or completely different characteristics from its original structure or form. At the α-phase there is also the possibility that capital leaks out of the system into other systems. The Ω-α-phase constitutes the backward loop of the framework.

r-K and Ω-α momentum, scales and surprisals

The cycle of adaptive change also has the component of time that progress unevenly through-out the phase sequence. The predictable r-K transition or forward loop is a slow process of capital acquisition, increasing connectedness, stability and vulnerability. The Ω-α transition occurs after a chaotic collapse at the K-Phase and proceeds very rapidly, releasing sequestered materials making available for system renewal. The capital can also leak out to other systems and be part of capital sequestration of that system as it proceeds on its own forward loop. This backward loop is highly unpredictable but also opens new opportunities and innovation for the system. The term Panachy also implies that systems exist in hierarchy of scales as it does exhibit both order (forward loop) and disorder (backward loop). The conceptual framework also includes the unknown surprisals on the system that moves forward loop to the backward loop.

Narrative of Philippine Brackish pond production Vis-à-vis Panarchy

As Panarchy is patterned after ecological transformations it is only appropriate to start the frame of the problem on a natural habitat related to the brackish pond production. Brackish ponds essentially came from mangrove systems. The first estimates of mangrove forest areas in the Philippines were made in 1918 and historical records show there has been a decline from 500, 000 to 120, 000 ha in 1994 and that 95% of brackish pond were obtained from these areas (J H Primavera, 2000). It is acknowledged that the decline can be attributed to many factors such as conversion to agricultural land, settlements and over exploitation of coastal communities but none as prevalent as conversion to aquaculture ponds.

Taking the Panarchy perspective, (Figure 4) illustrates the development of mangrove forest as it continuously grows and experienced an external disturbance. The mangrove forest went slowly through the forward loop and at the point at K-phase experienced disturbance in the form of deforestation for aquaculture production which lead the mangrove system to undergo the backward loop. There is release of capital at the α-phase making vast areas available for re-organization which becomes part of the brackish-water pond system. Even though the conversion of mangrove forest to fish ponds took over 80 years it still considered as a very fast process relative to the time the mangrove to develop reaching the K-phase.

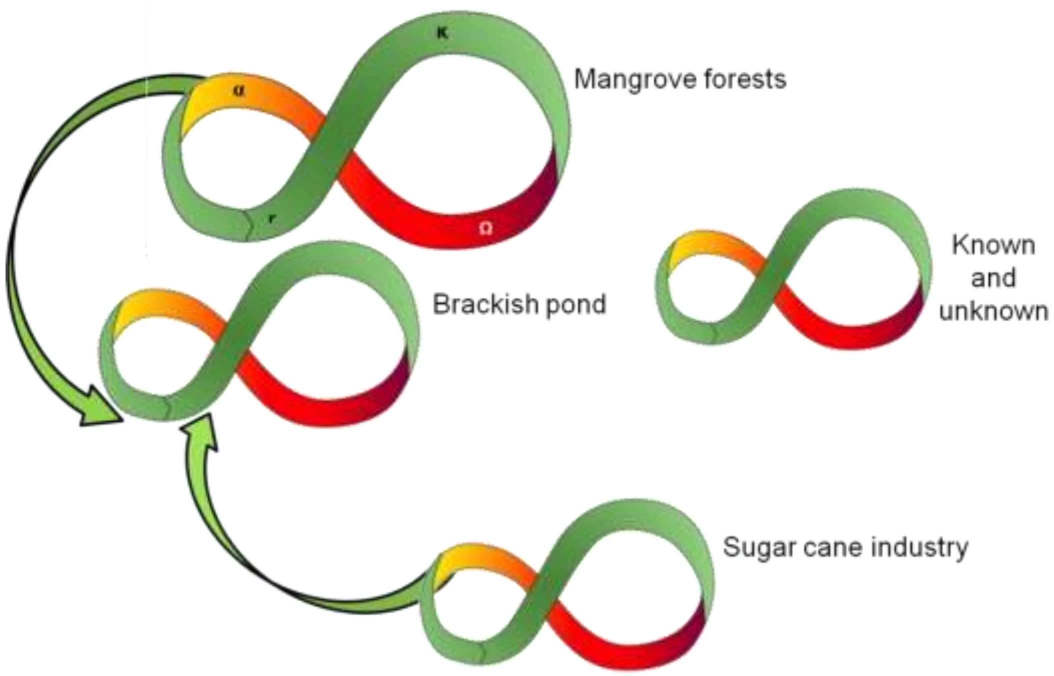

Figure 4. Panarchy of systems

The transformation of mangrove forest to pond is evident but there are other systems as well that contributed to the growth phase of the brackish-water pond system. In the latter part of the brackish-water pond aquaculture growth and development, another system also experienced a disturbance which released capital to be utilized by the brackish pond system. In the 1980s the “sugar bowl” industry in the Philippines collapsed as it lost competitiveness in the global sugar trade and areas were partially converted into shrimp ponds (Hall, 2004). The brackish pond in this case becomes partially nested in both the mangrove and agricultural system as it has undergone transformation. The sugar production system as opposed to the mangrove forest system constitutes a social-ecological system and the capital that became available for the brackish pond is much more diverse and includes human and financial resources. To say that capital transfer between systems occurs only during times of crises in other systems is erroneous. There are other systems that diffuse capital without undergoing collapse or a system that could even facilitate transfer of capital. Establishment of the Bureau of Fisheries and Aquatic Resources, a government institution, early in the development stage created policies that facilitated availability of resources for growth. Research and academic institutions were also established and provided technology and innovation for growth. There are studies that give account how government institutions were formed and policies implemented for the purpose of aquaculture development; financial assistance from development organization to increase aquaculture production to alleviate poverty; technological and innovation transfusions as well as market demand and shifts.. There are also other systems that are unknown that may contribute to either growth or decline of the central system which is the brackish-water pond. There are also other systems which contribute to growth, decline or disturbance of the brackish pond and these systems may either apparent or non-apparent.

Although the cycle of adaptive change gives a clear narrative on system succession it remains very qualitative. Measuring all the possible capital within a system is a daunting task if not impossible. It is thus necessary to select a quantitative indicator of transitions as the human-ecological system goes through the cycle of growth, development and decline. In classical models, ecological systems (forestry and fisheries) are often times assessed using the biomass representing capital. The biomass in a system is the result of the interaction of variables, elements and prevailing conditions and is a manifestation of these conditions.

Aquaculture activities also produce biomass in terms of farm production output in terms of production volume. The production volume here therefore is the manifestation of the interaction of all variables known or unknown; in the social, economic and ecological domains of the case study system; and in the presence of stochastic disturbances.

Figure 5 shows quantitatively how the brackish pond, with its subcomponents of milkfish and shrimp follows the pattern of adaptive cycle. It can be seen that production oscillates very much like the cycle of adaptive change. From the 1950s to the late 1970s the brackish pond production was mainly milkfish and the two systems follows the fashion of the forward loop reaching the K-phase at early 1980s after which there is a split where the brackish pond production proceed towards the K-phase while the milkfish under goes one cycle and reaching K-phase again in early 1990s after which it again undergoes another cycle. The Tiger prawn system went through the forward loop from ate 1970s to mid 1990s and the backward loop from mid 1990s to late 1990s

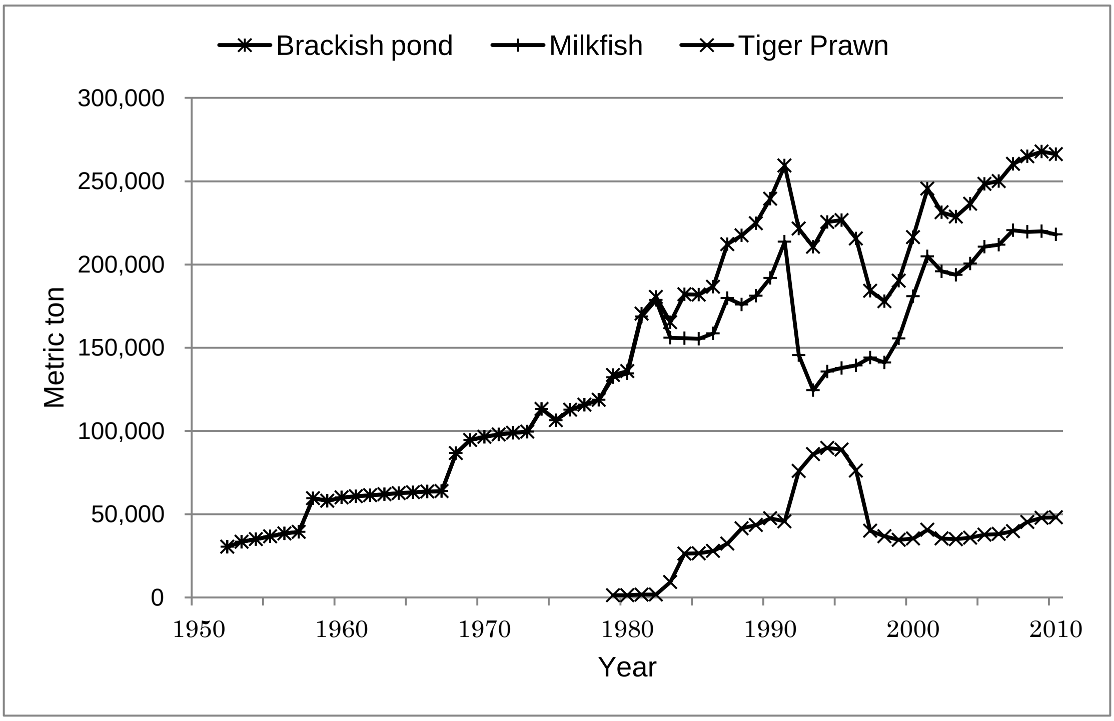

Figure 5. Milkfish, giant tiger prawn and total brackish-pond production volume
Various sources: Chong et al., 1984; BFAR Fisheries Profile from 1978-2010

where it rested at the r-phase and slowly proceeded on the forward loop. The peeks are considered K-phases at its maximum state and in between peaks are the Ω-α-r-phases after occurrence of perturbations. The cycle of the three systems become apparent only after the fact that it has occurred as indicated by the production cycle. At the peak of the K-phase and without knowing the value of the succeeding year, production could either increase or decrease. This concern is not apparent in the framework for it is not designed to capture the description of structural change within the system and in this case network analysis may be complementary in defining system dynamics (Janssen et al., 2006).

Value chain network

Basic network components

A complex system can be represented by using a network perspective in terms of a collection of elements and their relationships. A network is a collection of inter-connected nodes which has a definite structure according to the inter-linkages. The connections are known as arcs which represents material, energy or information flow. The nodes are the compartments where the fluxes either originate or received. These elements of nodes and arcs form a system structure which resembles the value chain popularized by Michael Porter (Al-Mudimigh, 2004).

Network flux

Quantitatively the selected indicator for capital which is production volume matches the narrative of Panarchy and is also the basis for the selection to represent the fluxes in the network. Even thought the interest of measure is material flow there is a need for a common measure for milkfish and prawn products. Obviously the unit of measure for milkfish and prawn are both in metric tons but still the fluxes are heterogeneous in nature. It is akin to comparing tons of apples and oranges, or in this case, comparing tons of milkfish and prawn on the same network. To homogenize flow, there is a need to convert material units from production volume to production value. The conversion allows the unit of measure for milkfish and prawn to be comparable because it captures the economic capital used to produce one unit of material within the system. Thusly, material flow is expressed in monetary value by using a conversion factor that is the cost of inputs for one unit of production. In this case farm gate production value divided by the total production volume is conversion factor used to quantify the flow in the network.

Overall network

Based on the defined unit of flux the essential compartments are then identified. In tracing the flow of material (milkfish and prawn) it is shown that production has forward and backward linkages. Figure 6 is the basic depiction of the integrated systems structure for milkfish and prawn representing the over-all brackish-water pond system. Milkfish and prawn production nodes represent the production area where each species is farmed. To produce one unit of milkfish and prawn each production node requires fry inputs which could be sourced either from hatcheries or fry gatherers that harvest from wild stocks in coastal areas. Milkfish hatcheries, prawn hatcheries and fry gatherers are the nodes that receive the monetary flux from the milkfish and prawn production nodes. This comprises the backward linkages of the network. The forward linkages are composed of the fluxes coming from the markets as brackish-water pond products are sold. The forward nodes are composed of the market types of domestic and export. Prawn and milkfish export markets are separate

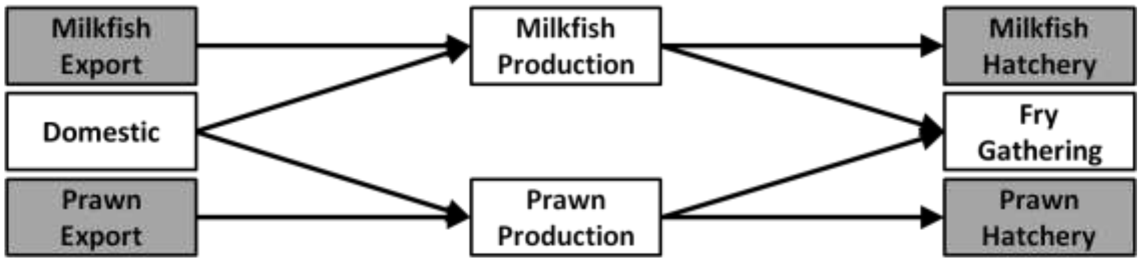

Figure 6. Brackish-pond value chain network (simplified)

nodes due to the consumer preference towards the products. Milkfish exports differ from that of prawn because the demand is driven by Filipino expatriates. The complete network is a representation of three supply or value chain networks which are the milkfish, prawn and integrated milkfish-prawn system which is the brackish-water pond aquaculture system.

Referring to the same figure above, the un-shaded nodes is the original composition of the network during the early stages of growth (r-phase). It is during the latter stages of the brackish-water pond aquaculture development that export markets have been opened and hatchery production facilities (shaded nodes) have been in operation. It is also noted in this research that the fry gatherer node for the prawn system network has “died out” as the fry supply had been over taken by the prawn fry hatcheries This has been previously described in other research on system studies described that at times there would be decreasing or increasing fluxes or completely lost (Janssen et al., 2006). Describing the case study system in terms of a value chain network captures the dynamic changes in structure as nodes and fluxes changes over time.

Network nodes disaggregation

Milkfish and prawn production nodes are decomposed into production by regional area. The Philippines is composed of 17 regions which are geo-politically defined. The Cordillera Administrative Region is the only landlocked area and does not produce either species. There are 16 production nodes for milkfish and also for prawn totaling 32 production nodes for the Brackish-water pond system. The disaggregated milkfish export nodes comprises of 41 countries and territories although export flows are intermittent. Prawn has 43 export market and 1 aggregated export node for minor quantity exports. The difficulty in the network disaggregation is tracing the financial flow from the specific export market to the specific region of production and finally to the specific source of fry. There is no data available to trace such specific flows to make an empirical analysis throughout the time frame of interest. To address the drawback, pseudo-nodes (Figure 7) are introduced to aggregate flows coming from the market before redistribution to each regional area of production. This is also done on the backward linkage of flow from production areas to the pseudo-nodes for milkfish and prawn before redistribution to each fry source. Use of such

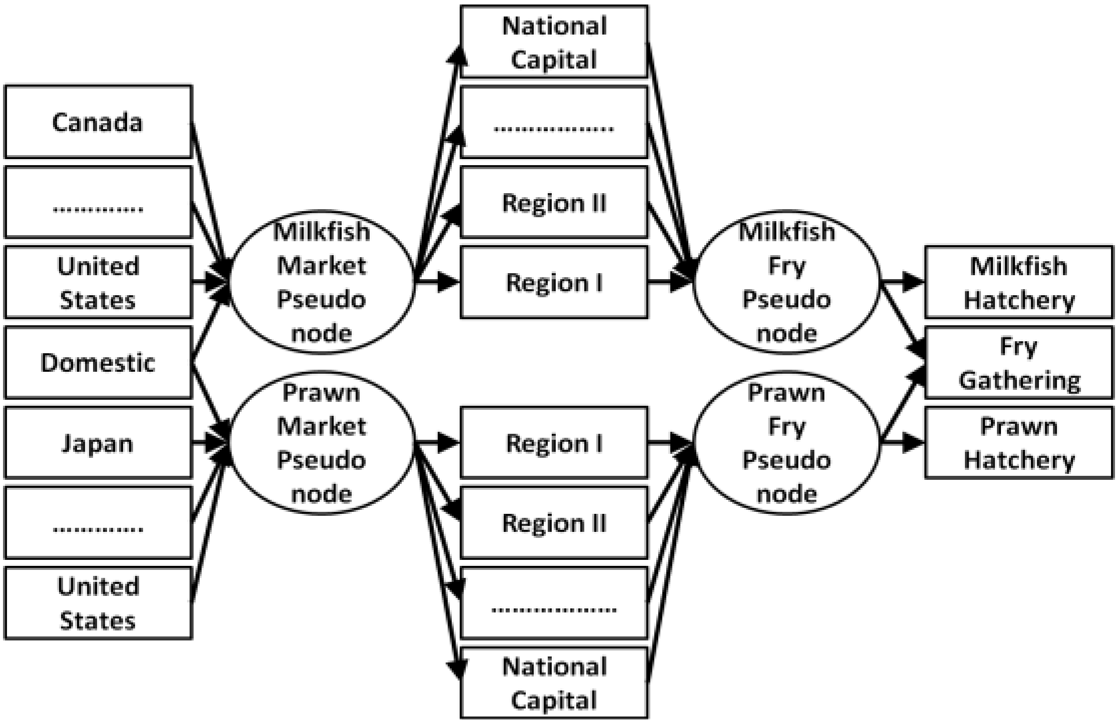

Figure 7. Brackish-pond disaggregated value chain network

nodes have been used in Supply Chain Networks Analysis modeling and functions as a hub to improve network flow (Battini and Persona, 2007).

The said pseudo-nodes also are representation of market supply channel sub-systems in the defined network. Milkfish and prawn have market channels as well as the fry sources. Historical changes in these systems are much harder to determine due to lack of both data and information within the time frame of interest. It is assumed that the effect of these nodes remains constant by having inputs and output flows being equal. In other words, the total incoming and outgoing fluxes through these pseudo nodes remain equal.

Measure of resilience

It is argued that the sustainability of a network flow can be described as a balance of system efficiency and resilience (Ulanowicz et al.,2009). Figure 8 shows that moving towards greater resilience can lead to un-sustainability as well as moving towards greater efficiency. In network-flows, efficiency is defined as the ability of a system to grow (increase flow) and develop (reorganize to increase flow). This is also known as the effective performance of a system. Resilience in the same context is the ability of a system to withhold flow and retain its structure. This is the reserved capacity of a system. Efficiency and resilience are complementary rather than opposing traits and inadequate allocation to either can lead a

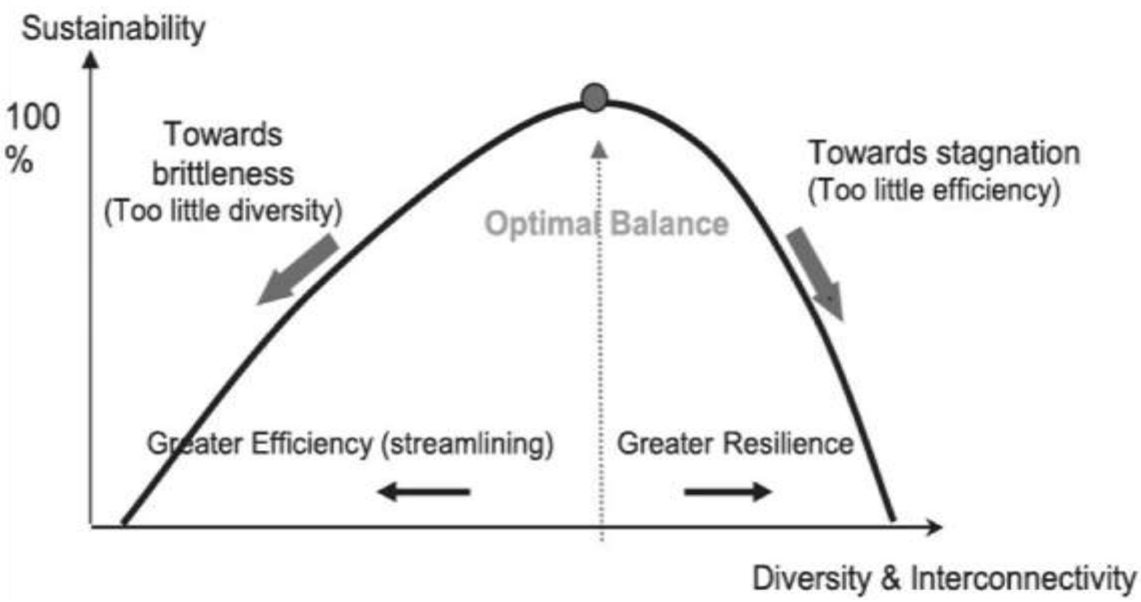

Figure 8. Sustainability as a function of efficiency and resilience
Source: Ulanowicz et al, 2009

system towards transition, transformation or collapse. In taking this account in parallel to the definition of resilience described by other authors: efficiency is the ability of a system to recover or adapt to shocks which is parallel to the component of resilience as defined by other authors to be the same. The opposing view is noted here as a matter of semantics as the definition remains consistent.

The following equation is said to be the function of sustainability (S) where the first part corresponds to system efficiency and the second part to resilience capacity: $S = \Sigma_{i,j}T_{ij}\log(T_{ij}T_{..}/T_{i.}T_{.j}) - \Sigma_{i,j}T_{ij}\log(T_{ij}^2/T_{i.}T_{.j})$. The authors of the sustainability as a function of efficiency and resilience provides a full account of the derivation process using computational information theory following the laws of probabilities, readers are referred to their previous publication.

The fluxes are represented by “T”, which are the flow in-between nodes, and indicated by the prefix i and j. To understand the equation, the network structure of figure 6 is transformed into matrix form (figure 9). The prefix i denote the first column in the matrix and j denotes the first row. The shaded areas are the i and j combination of fluxes for the defined system structure. For resilience, fluxes are divided by the total sum of fluxes; this joint probability for each i and j flux. The joint probability flux of i and j are then divided by the sum of each column. This is the conditional probability that j will conditional probabilities of the

flow. The “T” outside the log function is a scalar unit to give a physical dimension of value to

i,j	Milkfish Export	Domestic	Prawn Export	Milkfish production	Prawn production	Milkfish hatchery	Fry Gathering	Prawn Hatchery
Milkfish Export								
Domestic								
Prawn Export								
Milkfish production								
Prawn production								
Milkfish hatchery								
Fry Gathering								
Prawn Hatchery								

Figure 9. Matrix form of “Brackish-pond value chain network (simplified) (fig 6)”

the measure and is the total sum of all fluxes or also called as the total throughput of the system. Before discussing the quantitative analysis of system change it is essential to revisit a third component of the framework of the adaptive cycle. Presented before as a two dimensional figure, Panarchy has two essential components: the axis of capital and connectedness. Panarchy also has a third dimension which is resilience and represented as a third axis. As the system progresses through the cycle the resilience also shifts. Overlaying Panarchy and the window of viability model (Figure 10), it could be inferred that as the system moves for r-phase to K-phase there is a possible tendency that the path may veer towards a system that is too efficient or a system that is too resilient. When the system reaches the K-phase and experience perturbation at the moment of having either too little

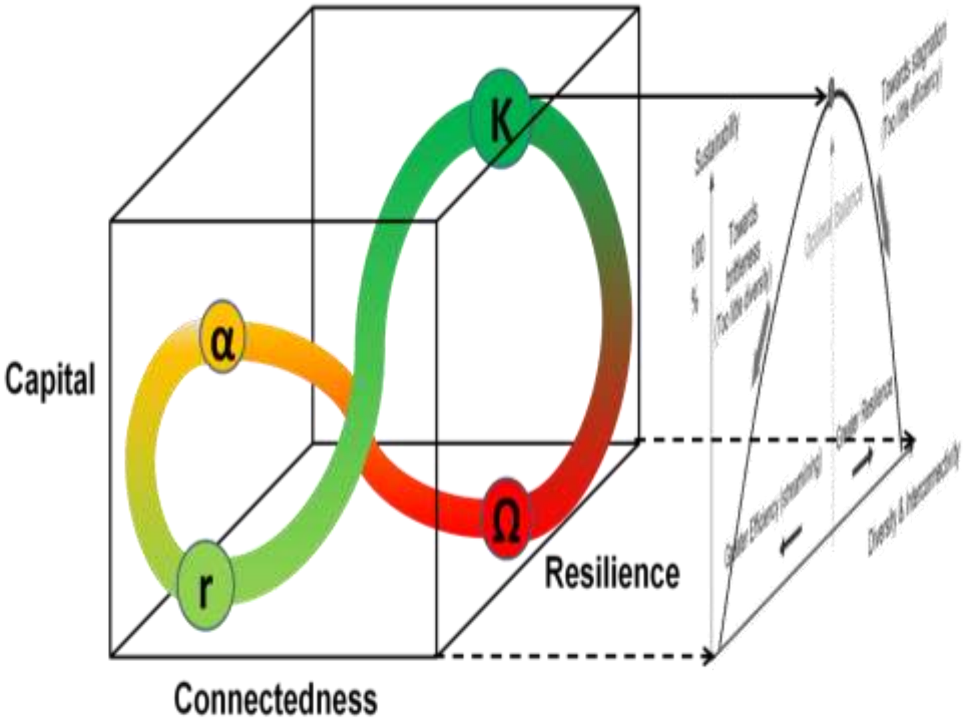

Figure 10. Panarchy visa vis window of vitality

or too much of resilience then it would proceed towards the Ω-phase starting a new cycle of renewal or complete destruction of the system if all the capital leaks out. Efficiency and resilience thus determines the behavior of a system to perturbation at any given phase.

Data sources and handling

The main source of production volume and value data for milkfish and prawn is the Bureau of Agricultural Statistics (BAS) of the Philippines as published in the Philippine Fisheries Profile by the Bureau of Fisheries and Aquatic Resources (BFAR) and as aggregated by Philippine Council for Aquatic and Marine Research and Development (PCAMRD) (appendix A). Production volume and value are also lifted from Chong et al. (1984) due to the reason that earlier publications of the Philippines Fisheries Profile prior 1977 are inaccessible. Milkfish and prawn export were aggregated by country (appendix B) based on the disaggregated milkfish and prawn market exports volumes by country and product type from PCMARD. Assumptions on changes in fry source production are based on the field survey interview (appendix C). The average cost per ton of production is taken by dividing the farm gate value by the volume of production for each year. This then becomes the conversion factor for the volume of products coming from the production area to the markets. Milkfish fry data and, consequently prawn fry data, are acknowledged to be difficult to obtain and that monitoring systems are not in place (I R Smith et al., 1978) thus it is necessary to make certain assumptions on the milkfish fry as a sub-industry system particularly in its volume and value of production. Values of flow from production area to fry sources are allocated as 10% and 20% for milkfish and prawn respectively, It was studied by (Shang, 1976) that the cost of milkfish seed is 9% of the total production cost or at $23/Ha between

1972 and 1975. The cost of overwintered fingerling and newly caught fry costs 1.4c and 0.34c (U.S.) in the Philippines between 1972 and 1975. The average stocking rate between 1972 and 1975 is 6,424 fry and fingerling/Ha. This is based on the average cost of production (Shang, 1976 and Kongkeo, 1997) rounded-off to the nearest ten. The rationale for maximizing the allocation value is to capture possible changes in input prices of fry. Based on the interviews, a 10% increment was also used to capture the shift of fry supply from wild fry gathering to hatchery sources. In prawn, the shift is from 1975 to 1984 where the wild fry gathering no longer supply production or at least it is taken to be insignificant in quantity. Shift from milkfish fry gathering to milkfish hatchery started from 1997 until there is a 90% and 10% value allocation for milkfish hatchery and milkfish fry gathering respectively. Production by region prior 1977 is also reconstructed by maintaining the same proportion of production based on 1988 production data; this is to test the effect on the change in resilience if production changes by the same proportion. The data set used for the computation of sustainability, efficiency and resilience is attached in Appendix D. The absolute and index values of sustainability, efficiency and resilience can be found on appendix E. During the course of research it was known that other cultured species have been introduced to brackish-water pond aquaculture post 2000 which may obscure the results and thus limits the analysis to year 2000. In-depth analysis could also only be done post 1970 due to the availability of disaggregated data per regional production.

RESULTS and DISCUSSION

Overview of the results and structure

This provides the overview of the results and discussions. There are three sections under the portion of results and discussions. The first section deals with verifying the applicability and limitations of the measure of resilience. The use of a simple brackish-water pond network configuration is used for the quantitative application of the mathematical formula of resilience. The second section is the application of the measure of resilience to the disaggregated network (composed of disaggregated export markets and regional production areas for milkfish and tiger prawn). The third section integrates the measured values of resilience vis a vis the cycle of adaptive change.

To better comprehend the nature of resilience, the mathematical model is applied and the changes in value is observed as the structure and flows is defined for appropriateness since there is no prescribed procedure in identifying node and flows structure for network analysis (Janssen et al., 2006). This is conducted in parallel to the actual network structure change as the case study goes through its different stages of development. Disturbances as an important component of the cycle of adaptive change are also discussed in terms of network resilience. The application and limitations are reviewed as well.

The first section is dealing with a process of testing the validity of the network structure employed in relation to the measure of resilience. It is a step by step procedure of understanding how the measure of resilience changes in terms node disaggregation of the network, starting with export market nodes disaggregation followed by production area node disaggregation and the use of pseudo-nodes. This is done for both milkfish and prawn systems and the milkfish-prawn integrated network that represents the brackish-water pond system. It is supposed that a system with very high or very low measure of resilience may continue to persist in the absence of perturbations thus historical evidence is then presented based on empirical studies of other authors that give meaning to the change in resilience as the three described systems undergo the development cycle. Comparison between milkfish and prawn systems is done and critical differences that effect resilience is highlighted. The meaning of sustainability in this research is the ability of a system to persist and is defined by the property of resilience. The following segment attempts to add meaning to the measure of resilience by featuring select external disturbances imposing on the systems. Perturbations coming from social, ecological and economic domains occurring on varying scales are underscored and reaction of the systems is described by the component of resilience. The third portion emphasizes the integration of the Panarchy framework and the measure of resilience which is the overall objective of the research: a possible approach to measure dynamics within and in-between systems on different domains at different scales.

Milkfish aggregated network

The following are the results of the step by step process of determining the appropriate network structure for the study and how each configuration affects the value of resilience. The purpose is to understand how the measure of resilience changes as the network is being defined. This is a validation process of the consistency and the rationale behind the mathematical expression of resilience as the structure is redefined and actual changes occur in the systems. Figure 11 reflects the absolute values of sustainability, efficiency and resilience of the milkfish network, as it go through transformation, having four nodes: Domestic market, export market, production area, fry gathering and hatchery.

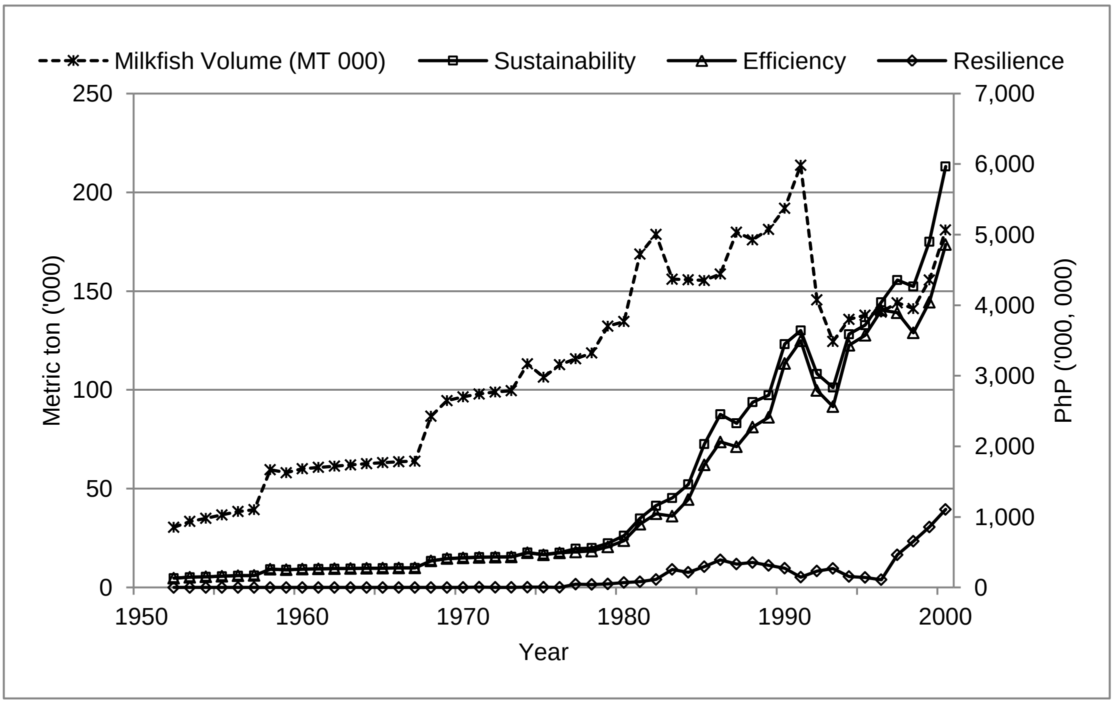

Figure 11. Milkfish system sustainability, efficiency and resilience

The limitation of the equation is that it requires at least three active flows in the system (as indicated in Figure 6 in the methodology section). Before 1970 the only active flows are domestic market-to-production and production-to-fry gathering and this structure of flow is described as having maximum efficiency and resilience being zero. From 1970 to 200, there is a trend of increasing efficiency although drops are also observed. The increase in resilience from 1980 is due to the increasing flow coming from the export market as connections are established with other countries. Post 1997, the increase in resilience is due to the increasing flow from the export market to production and from production to milkfish fry hatcheries shifting from fry gathering. By increasing the nodes and with corresponding increase in flows, resilience of an efficient oriented system also increases. This also reflects the increase in connectedness of the system.

Resilience as an index

It is also the intention of this research to have a unit of measure that could be applied on other systems with its own defined structure and flows. Having a physical unit for the measure of resilience may hinder such possible investigation on other systems, and also encumber comparison of dynamics in between human, ecological or human-ecological systems. So far, sustainability, efficiency and resilience are expressed in terms of monetary value based on the nature of the flow. The sustainability mathematical model can also be expressed as an index by dividing the value of efficiency and resilience by sustainability. This is a simple normalization process. The step removes the physical unit and states the existence of sustainability in terms of direct proportion of efficiency and resilience. The index value of efficiency can be directly inferred from the value of resilience. Figure 12 is the resulting measure of resilience in terms of an index from 0-1.

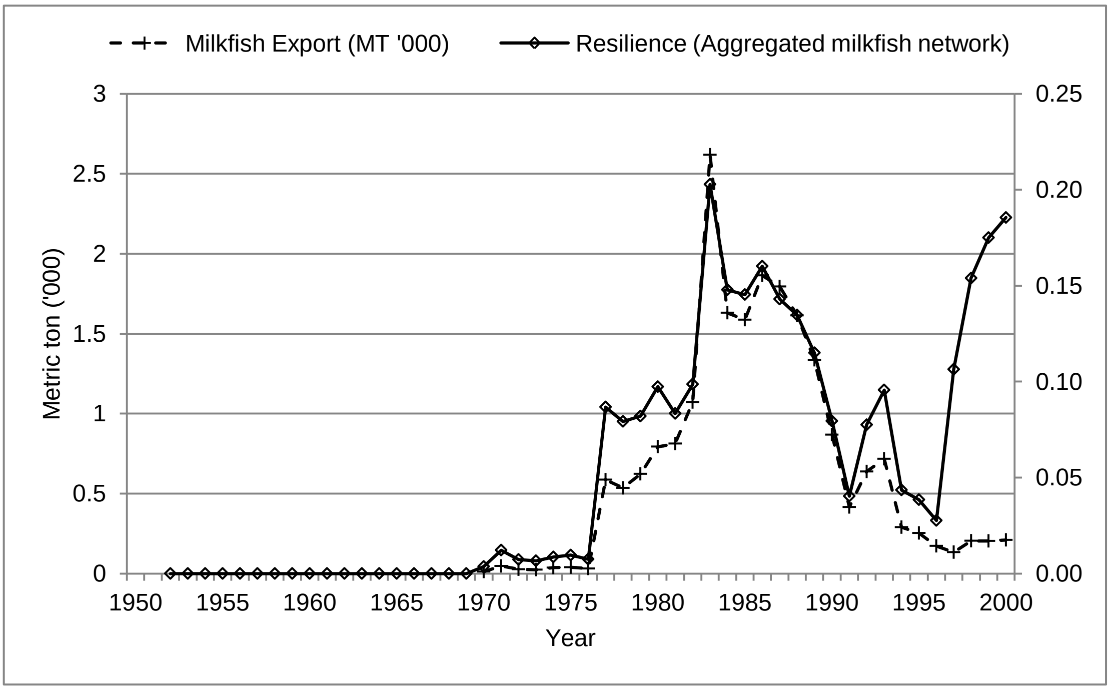

Figure 12. Milkfish export versus resilience

Above shows the influence of export flow on resilience. Increase in export flow from 1970 to 1997 increased resilience. The increase in resilience post 1997 is due to the shifting of flow from fry gathering to milkfish hatchery in supplying production. It could be inferred that the system becomes more resilient because it has now two possible sources of fry and the system could still persist if it loses either one of the fry sources. Milkfish being domestic market oriented can also afford to increase its resilience by shifting the flow of market products towards the international market. Expressing resilience as an index thus far follows the logic of the milkfish development in terms changes occurring in the market and fry source nodes with corresponding changes in flows.

Pseudo-nodes: effects on network properties

Adding pseudo nodes in-between the market-to-production and production-fry source nodes to re-aggregate and redistribute flows does not affect the absolute value of resilience. It does however increase the absolute value of efficiency and thus the absolute value of sustainability as it is the sum of the two other properties. The addition of aggregation and disaggregation hubs thus increases the system efficiency as it has been observed in another empirical research by Nicola (Nicola et al., 2007).

The reason behind this can be observed in the mathematical formula of resilience (Resilience = $\Sigma_{i,j}T_{ij}\log(T_{ij}^2/T_{i}.T_{.j})$). Figure 13 is the matrix representation of the milkfish network with the additional nodes. The fluxes are from 1997 production volume and value figures. In the network configuration represented above, the additional flows being created

i,j	Milkfish export	Domestic market	Market pseudo-node	Milkfish production	Milkfish fry pseudo-node	Milkfish hatchery	Fry Gathering
Milkfish export			7,449				
Domestic market			8,046,054				
Market pseudo-node				8,053,503			
Milkfish production					805,350		
Milkfish fry pseudo-node						80,535	724,815
Milkfish hatchery							
Fry Gathering							

i = Milkfish export; j = Market pseudo-node
7, 449 log ((7, 449)^2 / (7, 449*(7, 449 + 8, 046, 054))

i = Domestic market; j = Market pseudo-node
8, 046, 054 log (8, 046, 054)^2 / (8, 046, 054 * 7, 449 + 8, 046, 054)

i = Market pseudo-node; j = Milkfish production
8, 053, 503 log (8, 053, 503)^2 / (8, 053, 503 * 8, 053, 503) = 0

i = milkfish production; j = milkfish fry pseudo-node
805,350 log (805,350)^2 / (805,350 * 805,350)) = 0

i = milkfish fry pseudo-node; j = milkfish fry hatchery, milkfish fry gathering
805,350 log (((805,350)^2 / (805,350 + 724, 815) * 805,350))
724, 815 log (((724, 815)^2 / (805,350 + 724, 815) * 724, 815))

Figure 13. Matrix form of simplified milkfish network with pseudo-nodes

are the market pseudo-node to the Milkfish production node; and the Milkfish production node to the milkfish fry pseudo-node. When applied to the mathematical formula, these flows impart no resilience whatsoever to the summation because the value within the log function is zero and the value of the log function, as a condition, is also considered as zero.

At this point it is necessary to acknowledge that the index value of resilience will decrease because of the increase of the value of sustainability with which it is being normalized with. Although the index value of resilience will decrease the trend does remains consistent such that whether resilience increases or decrease can be observed in the milkfish network with and without the pseudo-nodes (Figure 14). In this case study it is more important to have an indication of the change in resilience than to have an absolute measure.

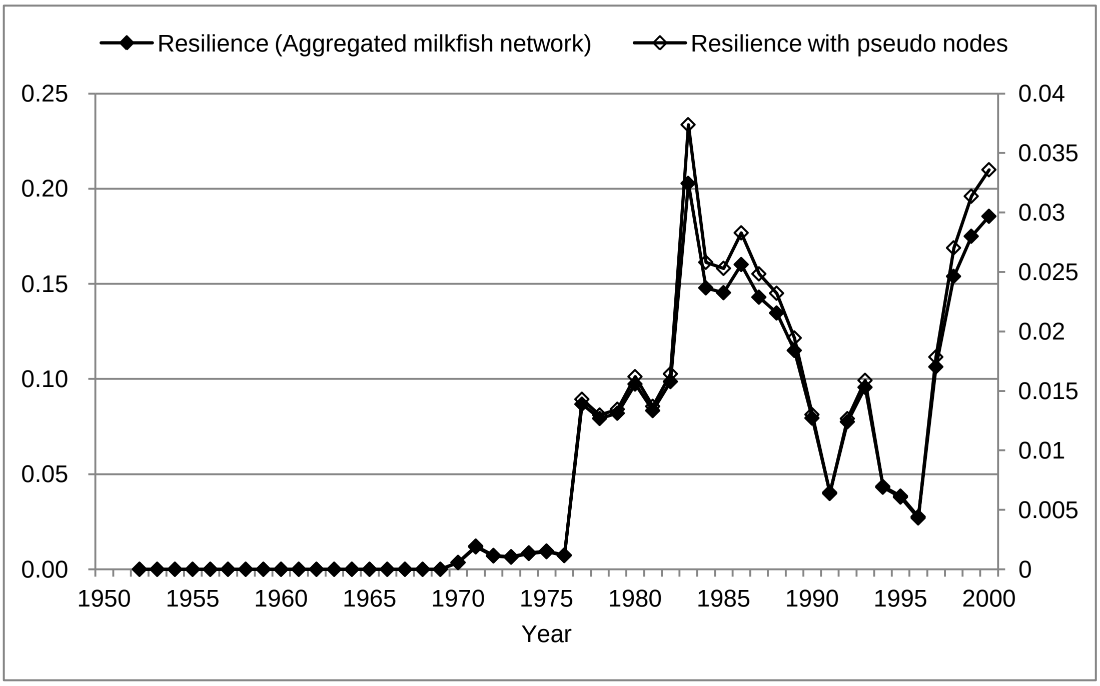

Figure 14. Milkfish system resilience with and without pseudo-nodes

Having established a possible unit of measure and a feasible technique to completely disaggregate fluxes of the networks, the following section will deal with the changes in resilience for Brackish-water pond system firstly by looking into the resilience of its components which are the milkfish, prawn and brackish-water pond systems vis a vis the cycle of adaptive change.

Milkfish system resilience

Figure 15 shows the production volume and resilience index from 1970 to 2000 of the milkfish system with disaggregated markets and regional production nodes. Observing the steepness of the slope of production volume against resilience indicates that increase in production is coupled with decrease in resilience.

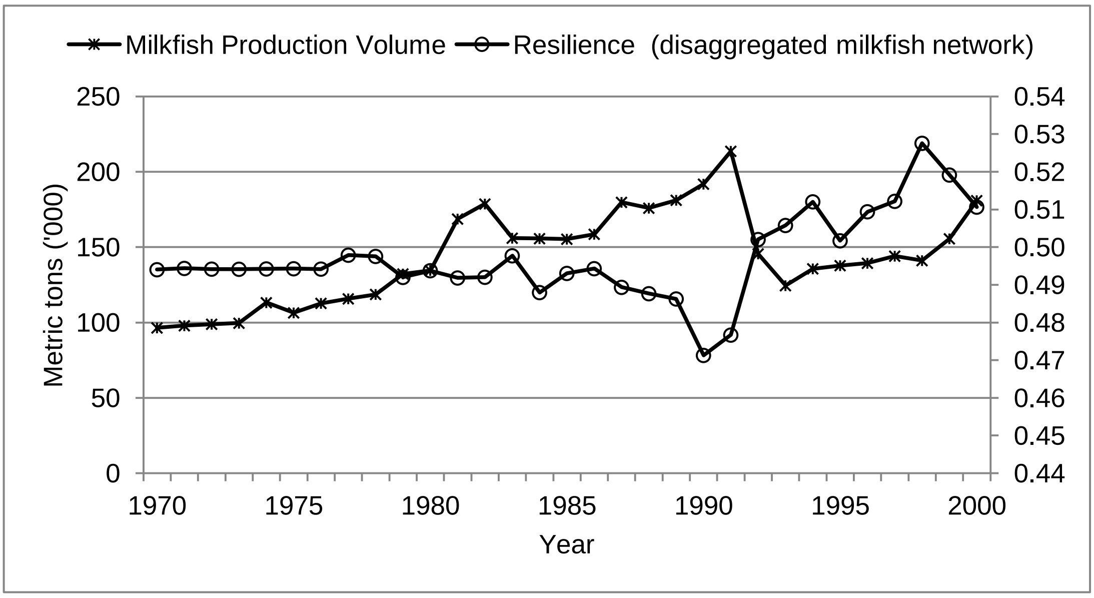

Figure 15. Milkfish production volume and resilience

As resilience decrease this instinctively indicates increase in system efficiency which is indicative of growth. From 1970 to 1976 the resilience remains relatively flat at 0.49 and is coupled with a slow increase in production. A drop in resilience from 1978 to 1982 (0.50 to 0.49) indicates an increase in efficiency and thus in the steep increase of production output. The 1982-1983 drop in production is the first illustration of perturbation coming from outside the system and affecting the economic (market) domain of the milkfish-system. It was pointed out by Baliao during the interview that fish pen production may be one of the reasons for decline in production from brackish-water ponds. Milkfish fish pen production area in Laguna de Bay increased from 40 to 30, 000 Ha during 1971 to 1983 (Delmendo, 1987). Due to the lower production cost in fishpen culture there is price competition between fishpen and brackish-water pond produced milkfish. From 1982 to 1984 is also the period where there is an increase in prawn production from 2,000 to 26,000 metric tons. The increase in production from 1986 to 1991 is paired with decrease in resilience from 0.49 to 0.47 and 0.48 on 1990 and 1991 respectively. During this period there is already the introduction of commercial feeds for milkfish production that is an offshoot of the commercial feed industry for prawn (Villaluz, personal communication). Looking at the farm level, application of feed contributes to the efficiency of production and is reflected in the overall milkfish system efficiency. In 1991 onwards, there are a number of perturbations occurring simultaneously. From the environmental domain there is the eruption of Mount Pinatubo in 1991 which deeply affected pond areas with its volcanic ash fall and “lahar” (muddle of earth and ash).   An excerpt from Stevenson (Stevenson and Irz, 2005) says: “The resilience of the fishponds in the lahar-affected areas matches the resilience of the people living there. While river dredging of the lahar is a year-round activity to ease the flow of floodwaters out to the sea, polyculture production in ponds neighbouring the affected waterways somehow survives.” Post 1991 was also the shift from milkfish production to prawn due to the increasing market demand for the high value species as technological breakthroughs in production process as well as hatchery production that has became a private sector initiative (Delmendo and Delmendo, 1987). This is a perturbation in the form of production intrusion as it is taken that the prawn production system is external to that of milkfish. Generally it can be said based on the graph that it is possible to determine resilience of a system using production structure and flow and that decrease in proportion of resilience can lead a system to faster growth rates but render it more vulnerable to perturbations. Increase in production volume with matching increase in resilience is also possible as for 1995 to 1997 but with slower production growth.

Tiger prawn system resilience

Figure 16 represents the production volume and resilience relationship for tiger prawn. From 1970 to 1980 there is a discrepancy between production and export volume. Brackish-water pond production of tiger prawn is lower than the export volume on this period. Export volume may have been compensated by capture of prawn being sourced from marine fisheries. After 1981 there is a drop in resilience from 0.51 to 0.43 in 1991. Between 1982 and 1984 there is a rapid rise in production from 2,000 to 26, 000 metric tons after which there is only a gradual increase until 1991 as there is also an increasing trend for resilience meaning the

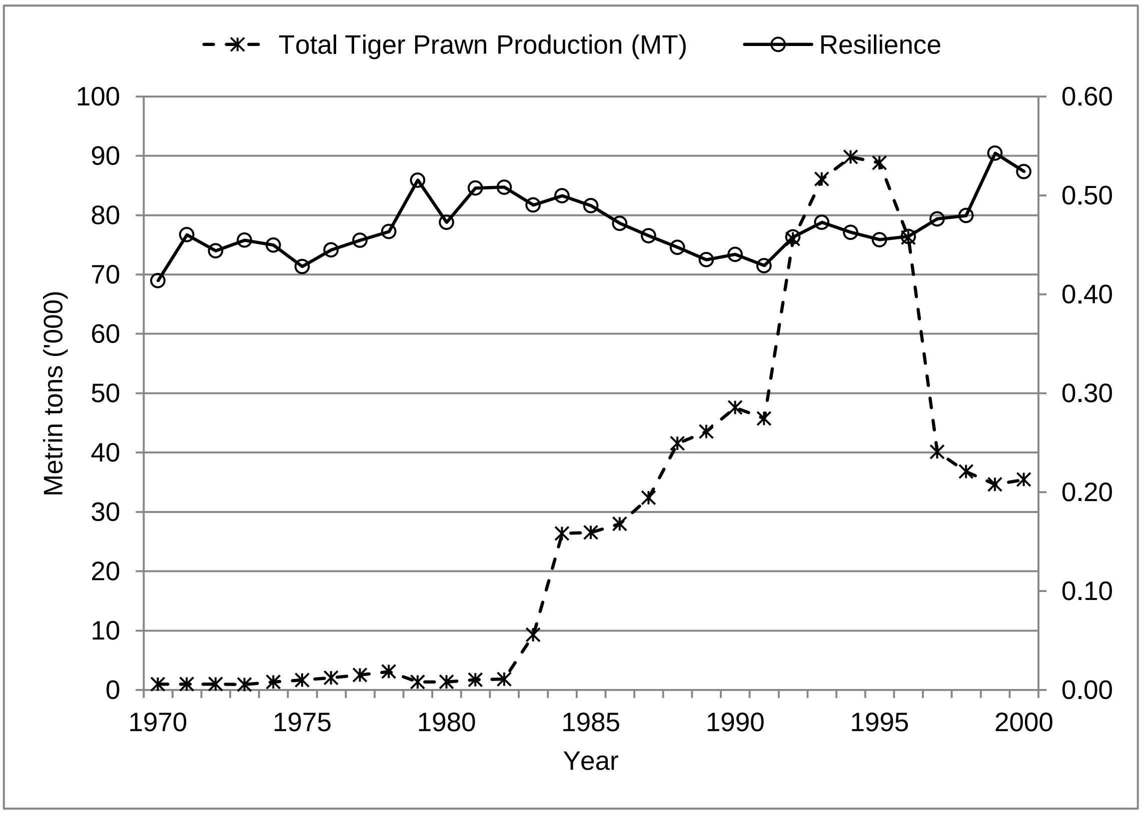

Figure 16. Giant tiger prawn production volume and resilience

system is becoming less efficient. The increase in production can be contributed to introduction of technology for tiger prawn culture (prawn hatchery, feeds, aeration and chemotherapeutants to name a few); support of institutions and as well as the drive of the private sector to promote the industry.

The first underscored shock for the tiger prawn system comes from the social domain external to the system. In 1989, Japan suffered the loss of Emperor Hirohito. His prolonged illness and passing resonated to the prawn market with resulting decrease in farm gate prices. Another reason for the change in price may also be due to the increasing global supply of prawn. The manifestation of these forces is a drop of farm gate prices from US$8.50 to US$4.50 and thus a stagnation in production volume (Briggs et al, 2005). The drop in resilience observed from 1980 to 1990 is followed by an abrupt increase in production volume from 46, 000 to 90, 000 tons in 1994. According to Baliao (personal communications) this is the second wave in the tiger prawn frenzy where large corporations enter the industry to take advantage of the high price of prawn but came in too late into production to do so as prices already was decreasing during the time. Simultaneously, there is perturbation coming from the ecological domain in the form of disease outbreaks. In the early 1990s the occurrence of diseases such as the Yellow Head Virus (YHV) and the WSSV have been occurring in Indonesia, Thailand and the Philippines (Briggs et al, 2005). At the peak of 1994, production rapidly declines to 40, 000 metric tons with a corresponding increase in resilience of 0.46 in 1995 to 0.48 in 1998 where the drop of production also tappers off due to the increase in system resilience. It is notable in the graph that during the growth in production, when resilience is relatively low there is a steep increase in production volume (1982-1984 and 1991-1993).

Brackish-water pond resilience

Figure 17 represents the resilience and total production of the over-lapping value chain network structure of the brackish-water milkfish and tiger prawn systems which the result is the Brackish-water pond system.

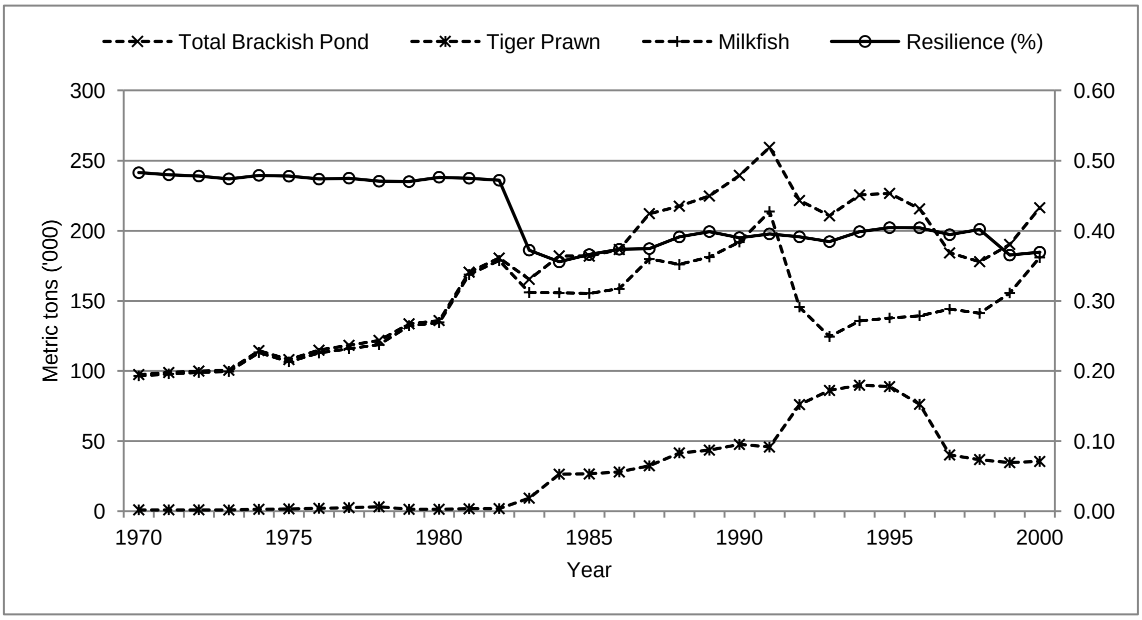

Figure 17. Brackish-water pond production volume and resilience

From 1970 to early 1980s there is a consistent drop in resilience; it should also be taken into account that the brackish-water pond system at this point is represented by the milkfish system and prawn production is slowly increasing. By 1982 the resilience of the brackish-water pond system drops to 0.37 and lowest point at 0.36 in 1984. It can be said that there is a system transformation as the milkfish system became vulnerable to the introduction of tiger prawn production. Past 1983 there is already an increase in resilience for the system as the tiger prawn system becomes integrated with the milkfish system. Even thought post 1984 there are disturbances occurring for both milkfish and prawn systems, the brackish-water pond system resilience generally remains stable. This is an emergent feature of the overall system where both the milkfish and prawn systems impart resilience and functions as reserves for the overall system. If the milkfish for whatever reason, collapses, the brackish-pond system would still persist as a purely prawn production system and vice versa. It is important to recall that having diverse nodes in the system increases its resilience if the flow is also substantial enough to have influence in the overall flow structure. At this point (1983) it may also be said that there is a separation of the milkfish systems from the overall brackish-water pond system and that the prawn industry as a system has become integrated with the milkfish industry. The decrease in resilience from 1982 is also coupled with a steep increase in production of brackish pond peaking at 1991 at 222, 000 metric tons. The drop in production post 1991 is matched with slight decrease in resilience (1989: 0.4 – 1993: 0.38). From 1993 to 1998 there is an increase in resilience from 0.38 to 0.40 respectively. During this period the production of milkfish is stagnating between 125,000 to 144,000 metric tons while tiger prawn collapses and tapers off towards stagnation at 35, 000 metric tons.

CONCLUSION

System resilience

Resilience is the apophasis of a system that experiences growth, development and disturbances. It is articulated by the system in terms of its structure and flow and yet remains apparently unobserved. The novel approach in integrating conceptual framework; system structure and flow; and the mathematical model of sustainability as a function of efficiency and resilience is offers a possible process in qualifying and quantifying the dynamics of a complex system that encompasses the environmental factors, biological interactions, market forces, human activities and perturbations. According to Gunderson and Holling (2002), the resilience of a system shrinks as it proceeds towards the K-phase. These are also readily observable in the three cases (milkfish, tiger prawn and brackish-water pond systems) as the peak productions are considered to be approaching the K-phase after which disruptions occur. Each moment that a shock occurs at the peak production the resilience of a system increases and prevents further deterioration. In human ecological-system such as the brackish-water pond aquaculture growth in production is mostly coupled with decrease in resilience. Looking into the pond production level of the system there is always an effort to increase production by use of more technology and inputs that also needs favorable conditions for mobilization such as access to credit and market demand and prices.

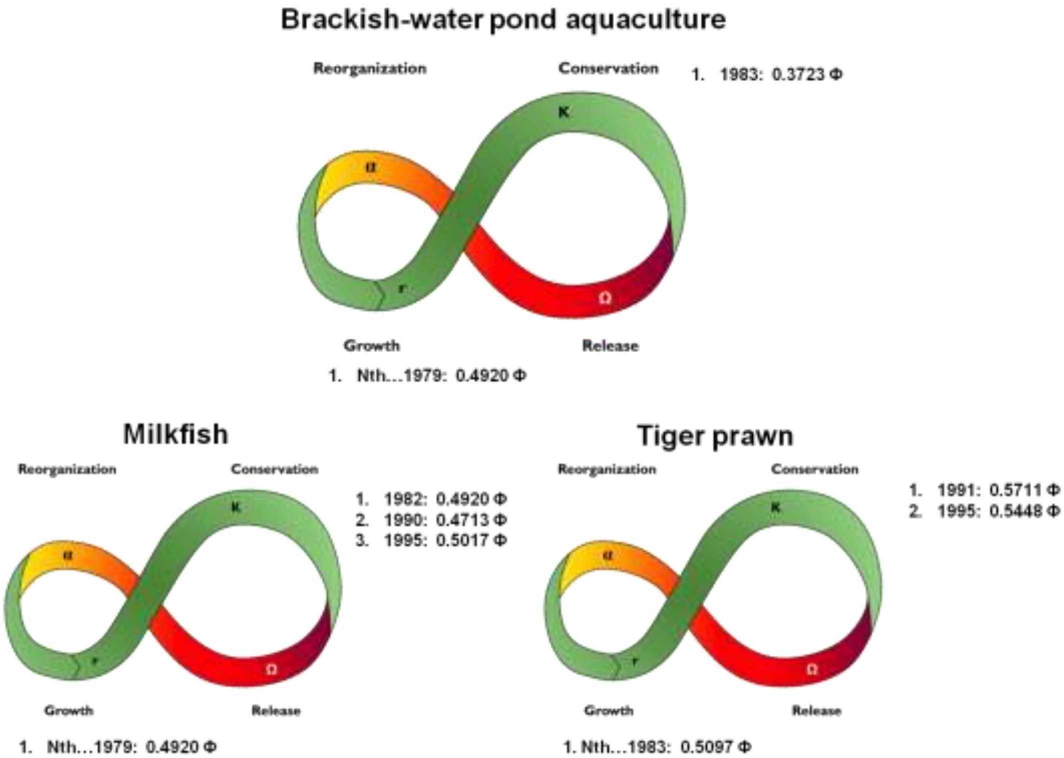

Figure 18. Panarchaic momentums

As far as the objective of this research is concerned, measuring dynamics as a system proceeds through transformations have been attained. Figure 18 is a simple illustration of how to use the measure of resilience vis a vis the cycle of adaptive change. The selected years in the diagram are the troughs in resilience for all three systems. The beginnings of the brackish-water system are one and the same as the milkfish system. Both cycling through the adaptive cycle from the very beginning represented by “Nth” and its first recorded growth begins from the early 1950s. A system that is to grow needs to be efficient thus the r-phase of milkfish and brackish-pond is speculated to have low resilience which is starting at 1979 and approached the K-phase in 1980s. This does not necessarily mean that the two systems have reached the peak of K-phase as the two begun to become two different and separate systems in the period 1982-1983. This period coincides with low resilience and high efficiency of the tiger prawn system in 1983 which is the r-phase of the tiger prawn system. This is the time where tiger prawn is impinging itself into the milkfish system and resulting to the integration and creation of the brackish-pond system. From 1983, the fall and rise in the value of resilience of the brackish-pond is nearly indistinguishable and is thus conjectured as being in the moment of the front loop or growth phase. Post 1982, the milkfish system undergone a full cycle reaching the K-phase in 1990 and once again in 1995. 1990 is the point of low resilience to disturbances and shifting of milkfish production to prawn. The shift is a qualitative indication that the function of the system is changing from milkfish to prawn production.

The tiger prawn system at r-phase at “Nth” proceeded towards the K-phase and having relatively low resilience and high efficiency leading to fast production growth. The prawn system reaches the lowest value of resilience in 1991 prior to an abrupt increase in prawn production. Again, low resilience, in this case, is equivalent to high efficiency and faster growth rates. This also period may also refer to the "second wave" of prawn fever Baliao have mention during the interview saying that big corporation tried to take the opportunity into prawn production but came in too late. A qualitative description of system change even prior to 1995 is that it was indicated that intensive production of tiger prawn closing during the price collapse in the export market (Primavera, 1993).

Prior to the drastic decrease in prawn production in 1997 due to disease outbreaks, economic and social reasons, resilience have already dropped in 1995. At this point the prawn system have already made two full cycles of adaptive change and is now on the third cycle. If production per region in the network is further disaggregated it can be said that the system has lost a critical function of intensive prawn production. The result is that the capital resources are now being absorbed by milkfish production. Villaluz during the interview stated that intensive prawn farms have been converted into intensive milkfish production units. Thus, the milkfish industry is again on its growth phase but at this growth phase the system is no longer the same as intensive production areas abandoned by prawn farmers have converted to milkfish production. Again, further disaggregation of production units would have revealed that the system has undergone structural change and not merely a change in amount of flow or production. "Renewal in components helps a system to persist" (Voinov, 2007) where the milkfish and tiger prawn systems are components of the brackish pond system, the collapse of tiger prawn extend the “life” of the milkfish and brackish-pond system by providing material, area and other resources for reorganization and adaptation. One could always argue that a system could continue towards growth and the results presented herewith are merely fluctuations if observed over a longer period. Even though structural changes have already been described to substantiate that the system has indeed gone through transformations further evidence is offered in the following. Since the 1980s the projection of milkfish production is at 2 tons per hectare (Chong et al., 1982). Given estimates on existing brackish-water ponds at 239, 323 ha (Fisheries statistics of the Philippines 2007-2009, 2010) the maximum attainable volume from for milkfish production is only at 478, 646. Thus the changes in volume representing the K-phases are not merely a small fluctuation set against an ever increasing production in the future. It is also recognized in this study that even thought the system went through the cycle it does not necessarily mean that the systems reached the end of the omega phase. There has been transformation and release of resources in between systems but essentially the system continues to persist through transformations.

Implications

This is an amalgamation of sustainability science concepts being applied on a defined system with social, economic and ecological components and their interactions and whose main gauge is resilience. In increasing brackish-water pond production, there are options to increase resilience as well by considering the distribution of flows within the network. An even redistribution in market, production and fry source flows can increase resilience of the system but these components also have their limits: market has a limit in absorbing production; production is limited by the natural resources available and the market demand; and the fry source is also limited by the demand from production as well as their own resources. These factors should be considered and once verified, the resilience can be determined together with the expected growth and development of the system. There is also a trade-off between efficiency and resilience where greater resilience in a system results to retarded growth and greater efficiency results to vulnerability to perturbations.

The approach thus gives an indication whether a system is moving towards resiliency or efficiency and growth can be weighed against the risk of disruptions that may impinged on the system. The approach hence has the potential to be used as an assessment tool among the other sustainability assessment tools already developed. This can serve as an assessment of system resilience when there is a proposed intervention for system growth and development. Intervention is needed to be done but to be able to understand what is to be done there is a need to understand the problem. Interventions have been applied before with mixed results in aquaculture. Benefits do occur but with consequences as presented in the case study. By understanding how a system behaves then perhaps we can understand how to reduce factors that contribute to the degradation of system resilience. Then, interventions can be modified to mitigate unintended effects on the target system as well as other systems around it or that nests it. It is hoped that this would contribute to the analysis of larger issue looking at even bigger systems and complexity and involving stakeholders that manage system growth and development.

Having an idea how resilience change as interventions are conducted may help navigate the system towards a more sustainable state that may have more consideration to social and ecological concerns. This is in support on the view of Walker et al (2004) who argues that managing resilience can improve possibilities of maintaining sustainable pathways toward development where there is the presence of surprisals.

Perhaps with a common unit of measure for system resilience, the way forward is to dichotomize the system according to the three domains of sustainability which are the social, economic and ecological domains. The components of this research have been simplified yet adhering to academic standards for the reason that it is also the interest of this research to extend the approach beyond the boundaries of the academe to the actual field where growth and development is taking place being determined by actors of the system.

During the field survey and collaborative interviews several key points were raised that may adversely affect the brackish-pond system. One is the prolonged spawning of milkfish broodstock. This may be seen as a positive light in terms of hatchery operations as well as grow out production. But the question is how does this affect the growth of the system? Would such change in spawning behavior lead to increase production with corresponding resilience?

Research is also currently being conducted for increasing milkfish production in marine areas. But would such increase in production be a surprisal to the brackish pond production just as the fishpen production reached the system through the market channel? Baliao mentioned that the aquaculture industry is suffering from an aging population. Could this mean that loss in human capital lead to another system transformation? There are more questions raised as problems and knowledge were being co-produced on field, but the real challenge is: whatever the proposed solutions are, would there be a way to ensure resilience of the system?

The work thus far has a potential for both sustainability science as a field of study and the aquaculture sector as a social-ecological system that needs navigating through transformations.

Limitations

There is still a need to verify transition of the systems by considering the level of connectedness as per the cycle of adaptive change. Given the structure and flows this would be possible to conduct and perhaps require another methodology to measure connectedness by using the number of arcs of the systems (the number of flows in the system in between connections) and the number of nodes. Admittedly this has not been part of the scope of the study. Ultimately, the objective is to have a unit of measure for transition towards sustainability as it is defined by the actors in the system. Further quantitative analysis of the values of resilience is still necessary to determine the turning points of the systems. This study has relied heavily on past empirical studies conducted on the different dimension of the brackish-water pond aquaculture using mono, multi, and inters disciplinary approaches. It is hereby acknowledged the importance of these fields in conducting sustainability science research and that it is also the reason why collaboration is needed to manage large scale system dynamics especially for ex-ante research. In network analysis there is no prescribed standard in describing nodes and flows. This perhaps is the greatest limitation in the conduct of this type of study.

The approach remains exploratory and caution is advised in its application although it has the potential in application to other systems.

REFERENCES

Agbayani, R. F., & Ticar, R. B. 1989. An Economic Analysis of the Modular Pond System of Milkfish Production in The Philippines. Economic Analysis, 83, 249-259.

Agbayar, R. F., Lopeza, N. A., Tumaliuan, R. E., & Berjamin, D. 1991. Economic analysis of an integrated milkfish broodstock and hatchery operation as a public enterprise. Development, 99, 235-248.

Ahern, J. 2011. From fail-safe to safe-to-fail: Sustainability and resilience in the new urban world. Landscape and Urban Planning, 100(4), 341-343. Elsevier B.V. doi:10.1016/j.landurbplan.2011.02.021

Al-Mudimigh, a. 2004. Extending the concept of supply chain: The effective management of value chains. International Journal of Production Economics, 87(3), 309-320. doi:10.1016/j.ijpe.2003.08.004

Arias Schreiber, M. 2012. The evolution of legal instruments and the sustainability of the Peruvian anchovy fishery. Marine Policy, 36(1), 78-89. Elsevier. doi:10.1016/j.marpol.2011.03.010

Baliao, D., De Los Santos, M., Franco, N. 1999. The modular method: milkfish pond culture Issue 25 of Aquaculture extension manual. Southeast Asian Fisheries Development Center. Aquaculture Dept. 18p.

Baliao, D. D. 2000, State of Art Environment-Friendly Schemes in Intensive Shrimp Farming, extension manual 31 Aquaculture Department , SEAFDEC,

Bagarinao, T.U. 1991. Biology of milkfish (Chanos chanos Forsskal). Iloilo: Southeast Asian Fisheries Development Center. (http://hdl.handle.net/10862/650; This document is downloaded at: 2012-01-19 15:39:45 CST)

Bagarinao, T. U. 1998. Ecological Considerations in Milkfish Farming in Marine Pens and Cages in the Philippines. Sciences-New York, 43001452.

Battini, D. and Persona, A. 2007. Towards a use of network analysis : quantifying the complexity of Supply Chain Networks. International Journal of Electronic Customer Relationship Management, Volume 1, 75-90. ISSN 1750-0664

Bhathal, B., & Pauly, D. 2008. Fishing down marine food webs and spatial expansion of coastal fisheries in India, 1950–2000. Fisheries Research, 91(1), 26-34. doi:10.1016/j.fishres.2007.10.022

Bondavalli, C., Favilla, S., & Bodini, A.2009. Quantitative versus qualitative modeling: a complementary approach in ecosystem study. Computational biology and chemistry, 33(1), 22-8. doi:10.1016/j.compbiolchem.2008.07.012

Briggs, M., Funge-Smith, S., Subasinghe, R.P., Phillips, M. 2005. Introductions and movement of two penaeid shrimp species in Asia and the Pacific. Organization (No. 476. R., p. 78). FAO Fisheries Technical Paper, FAO.

Bussiere, M., & Fratzscher, M. 2006. Towards a new early warning system of financial crises. Journal of International Money and Finance, 25(6), 953-973. doi:10.1016/j.jimonfin.2006.07.007

Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., Jäger, J., et al. 2003. Knowledge systems for sustainable development. Proceedings of the National Academy of Sciences of the United States of America, 100(14), 8086-91. doi:10.1073/pnas.1231332100

Chong, K-C., M.S. Lizarondo, V.F. Holazo and I.R. Smith. 1982. Inputs as related to output in milkfish production in the Philippines. ICLARM Technical Reports 3. 82 p. Bureau of Agricultural Economics, Quezon City;Fishery Industry Development Council, Quezon City and International Center for Living Aquatic Resources Management, Manila, Philippines.

Chong, K.-chai, & Smith, I. R. 1984. Milkfish Production Dualism in the Philippines: A Multidisciplinary Perspective on Continuous Low Yields and Constraints to Aquaculture Development. Fisheries (Bethesda).

Delmendo, M.N., 1987. Milkfish culture in pen: an assessment to its contribution to overall fish production of Laguna de Bay. ASEAN:UNDP:FAO Regional Small Scale Coastal Fisheries Development Project-ASEAN:SF:87:Tech. 5. Manila, Philippines

Delmendo, Medina N. and Delmendo, B. H., 1987. Small-Scale Aquaculture Operations in the ASEAN Countries. ASEAN:UNDP: FAO Regional Small Scale Coastal Fisheries Development Project-ASEAN:SF:87:Tech. 6. Manila, Philippines

Drairaj, K., Mohanraj, G., Gandhi, V., Raju, A., Rengaswamy, V. S., and Rodrigo, J.X. 1984. On a potentially rich milkfish seed collection ground near Mandapam along with the methods of collection and transportation. Indian J. Fish,, 31 (2): 257-271.

Fisheries Statistics of the Philippines 2007-2009 .2010. Fisheries Statistics Division, Bureau of Agricultural Statistics, Philippines

Folke, C. 2006. Resilience: The emergence of a perspective for social–ecological systems analyses. Global Environmental Change, 16(3), 253-267. doi:10.1016/j.gloenvcha.2006.04.002

Hall, D. 2004. Explaining the diversity of south-east Asian shrimp aquaculture. Journal of Agrarian Change 4: 315-335.

Holling, C.S., Sanderson, S., 1996. Dynamics of (dis)harmony in ecological and social systems. In: Hanna, S.S., Folke, C., Ma¨ ler, K.-G. (Eds.), Rights to Nature: Ecological, Economic, Cultural, and Political Principles of Institutions for the Environment. Island Press, Washington DC, pp. 57–85.

Holling, C. S., L. H. Gunderson, and G. D. Peterson. 2002. Sustainability and panarchies. Pages 63-102 in L. H. Gunderson and C. S. Holling, editors. Panarchy: understanding transformations in human and natural systems. Island Press, Washington D.C., USA.

Israel, D. C. 2000. The Milkfish Broodstock-Hatchery Research and Development Program and Industry : A Policy Study. Development, (January 2000).

Janssen, M. A., Bodin, Ö., Anderies, J. M., Elmqvist, T., Ernstson, H., Mcallister, R. R. J., Olsson, P., et al. 2006. Toward a Network Perspective of the Study of Resilience in Social-Ecological Systems. Ecology And Society, 11(1).

Kates, R. W., Clark, W. C., Corell, R., Hall, J. M., Jaeger, C. C., Lowe, I., McCarthy, J. J., et al. 2001. Sustainability science. Science, 292(5517), 641. American Association for the Advancement of Science. doi:10.1007/s11625-006-0007-4

Kongkeo, Hassanai. 1997. Comparison of intensive shrimp farming systems in Indonesia, Philippines, Taiwan and Thailand. Aquaculture Research 28, pp. 789–796.

Kühlmann, K.-J., Focken, U., Coloso, R. M., & Becker, K. 2008. Diurnal feeding pattern and gut content of milkfish Chanos chanos (Forsskål, 1775) cultured semi-intensively during the wet and dry season in brackish ponds in the Philippines. Aquaculture Research, 40(1), 2-12. doi:10.1111/j.1365-2109.2008.02096.

Lawrence, R. 2004. Futures of Transdisciplinarity. Futures, 36(4), 397-405. doi:10.1016/j.futures.2003.10.005

Learned, K. L. 2005. Dissemination and adoption of Milkfish aquaculture Technology in the Philippines. Production.

Maxneef, M. 2005. Foundations of transdisciplinarity. Ecological Economics, 53(1), 5-16. doi:10.1016/j.ecolecon.2005.01.014

Mobjörk, M. 2010. Consulting versus participatory transdisciplinarity: A refined classification of transdisciplinary research. Futures, 42(8), 866-873. doi:10.1016/j.futures.2010.03.003

Morse, Stephen. 2010. Sustainability: a biological perspective. Cambridge University Press, New York. xi t 261 p.

Ness, B., Urbel-Piirsalu, E., Anderberg, S., Olsson, L., 2007. Categorising tools for sustainability assessment, Ecological Economics, Volume 60, Issue 3, 15 January 2007, Pages 498-508, ISSN 0921-8009, 10.1016/j.ecolecon.2006.07.023. (http://www.sciencedirect.com/science/article/pii/S0921800906003636)

OECD. 2010. *Advancing the Aquaculture Agenda: Workshop Proceedings*, OECD Publishing. doi: 10.1787/9789264088726-en

Primavera, J. Honculada. 1993. A critical review of shrimp pond culture in the Philippines. Reviews in Fisheries Science, 1(2), 151-201. doi:10.1080/10641269309388539

Primavera, J. H. 1995. Magrove and brackishwater production.pdf. Hydrobiologia, 303-309.

Primavera, J H. 2000. The Values of Wetlands: Landscape and Institutional Development and conservation of Philippine mangroves : institutional issues. Ecological Economics, 35, 91-106.

Rapport, David J. 1997. Transdisciplinarity: transcending the disciplines, Trends in Ecology & Evolution, Volume 12, Issue 7, July 1997, Page 289, ISSN 0169-5347, 10.1016/S0169-5347(97)81031-2. (http://www.sciencedirect.com/science/article/pii/S0169534797810312)

Republic Act 8550 The Philippine Fisheries Code of 1998

Samarakoon, L. P. 2011. Stock market interdependence, contagion, and the U.S. financial crisis: The case of emerging and frontier markets. Journal of International Financial Markets, Institutions and Money, 21(5), 724-742. Elsevier B.V. doi:10.1016/j.intfin.2011.05.001

Schmittou, H. R., Grover, J. H., Peterson, S., Librero, A. R., Rabanal, H. R., Adriano, M., & Hole, W. 1983. Developmmke of aquacult re. Aquaculture.

Shang, Y. C. 1976. Economic comparative of milkfish in taiwan and Philippines, 9, 229-236.

Smith, I R, Cas, F. C., Gibe, B. P., & Romillo, L. M. 1978. Prelimenary analysis of the performance of the fry industry of the milkfish (*Chanos chanos* forskal) in the Philippines. Aquaculture Research, 14, 199-219.

Spangenberg, J. H. 2011. Sustainability science: a review, an analysis and some empirical lessons. Environmental Conservation, 38(03), 275-287. doi:10.1017/S0376892911000270

Sumagaysay, N. S., Marquez, F. E., & Chiu-chern, Y. N. 1991. Evaluation of different supplemental feeds for milkfish (Chartos charm) reared in brackishwater ponds. Survival, 93, 177-189.

Stevenson, J. R. and Irz, X. T. 2005. Sustainability as Compromise: An Analysis of the Farm-Level Trade-Offs Between Development Objectives in Philippine Aquaculture. In Proceedings of the 95th Seminar European Association of Agricultural Economists, December 9-10, 2005, Civitavecchia, Italy. Pp 192-217.

Tan, E. O., de Guzman, D. L., Darvin, L. C., & Balgos, M.C . 1984. Milkfish research in the Philippines. In: J.V. Juario, R.P. Ferraris, & L.V. Benitez (Eds.) Advances in milkfish biology and culture: Proceedings of the Second International Milkfish Aquaculture Conference, 4-8 October 1983, Iloilo City, Philippines. (pp. 171-181). Metro Manila, Philippines

Tarawa, S., Lückstädt, C., & Reiti, T. 2002. Investigations on the feeding behavior of juvenile milkfish (*Chanos chanos* Forsskål) in brackishwater lagoons on South Tarawa , Kiribati Nahrungswahlverhalten juveniler Milchfische (*Chanos chanos* Forsskål) in, (August 1998), 5-9.

Thompson Klein, J. 2004. Prospects for transdisciplinarity. Futures, 36(4), 515-526. doi:10.1016/j.futures.2003.10.007

Ulanowicz, R. E. 2002. The balance between adaptability and adaptation. Bio Systems, 64(1-3), 13-22. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11755484

Ulanowicz, R.E., Goerner, S.J., Lieater, B., Gomez, R. 2009. Quantifying sustainability: resilience, efficiency and return of information theory. Ecology Complexity 6 (1), 27-36 March.

Villadolid, V. and D.K. Villaluz. 1951. The cultivation of sugpo (Penaeus monodon Fab.) in the Philippines. Phil. Fish. J. 1:66–65

Villaluz, D.K., Villaluz, A., Ladrera, B., Sheik, M. and Gonzaga, A. 1969. Production, larval development, and cultivation of sugpo (Penaeus monodon Fabricius). Philippine Journal of Science, 98, 205–233.

Voinov, A. 2007. Understanding and communicating sustainability: global versus regional perspectives. Environment, Development and Sustainability, 10(4), 487-501. doi:10.1007/s10668-006-9076-x

Walker, B., C. S. Holling, S. R. Carpenter, and A. Kinzig. 2004. Resilience, adaptability and transformability in social-ecological systems. Ecology and Society 9(2): 5. [online] URL: http://www.ecologyandsociety.org/vol9/iss2/art5/

Walker, B.H. and D. Salt. 2006. Resilience Thinking: Sustaining Ecosystems and People in a Changing World. 174p. Island Press, Washington, D.C., USA. http://www.islandpress.org/books/detail.html/SKU/1-59726-093-2

World Commission on Environment, Development (WCED). 1987. Our common future. Oxford University Press, Oxford

APPENDIX A: Production and value data (see separately attached EXCEL file)

APPENDIX A (continued)

Milkfish Production by region

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
NCR	1,333	1,389	670	670	674	620	620	629	621	666	603	604
CAR												
I	8,433	8,724	15,522	16,131	16,211	14,678	15,197	15,900	17,032	16,744	16,995	17,804
II	174	174	527	548	116	304	492	659	703	691	680	754
III	33,988	34,672	50,754	56,048	49,452	43,222	46,420	44,051	51,633	48,118	49,477	52,759
IV	15,150	15,494	18,367	18,357	16,594	8,567	11,177	10,159	10,167	9,312	9,062	9,509
(IV-A)												
(IV-B)												
V	4,628	4,816	5,079	6,097	5,527	5,500	5,522	6,352	6,357	3,971	3,961	4,167
VI	45,986	46,283	50,612	52,375	43,853	56,302	50,132	54,028	62,723	63,296	64,959	68,022
VII	3,356	3,471	4,085	4,362	3,649	3,441	4,438	6,565	6,565	6,389	6,771	6,897
VIII	3,623	3,715	3,818	4,666	2,512	2,218	2,428	2,124	2,135	2,263	2,349	2,512
IX	7,723	7,911	8,351	8,351	7,013	9,683	7,867	7,923	10,300	12,747	14,254	16,040
X	2,299	2,369	2,383	2,383	1,568	2,946	2,274	2,104	2,659	2,784	2,910	3,103
XI	2,313	2,366	4,262	4,262	5,343	4,851	5,376	4,922	5,726	5,835	6,012	6,412
XII	3,256	3,307	4,297	4,429	3,483	3,377	3,401	3,206	3,170	3,230	3,264	3,395
CARAGA												
ARMM												
Total Production (tons)	132,262	134,591	168,727	178,679	155,995	155,709	155,344	158,621	179,791	175,935	181,197	191,878
Total Value (PHP 000)	1,190,358	1,372,828	1,855,997	2,162,016	2,091,893	2,578,541	3,594,660	4,265,319	4,126,203	4,702,741	4,988,353	6,566,424

Giant tiger prawn production by region

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
NCR	13	14	7	7						64	66	68
CAR												
I	85	88	157	163	380	1,545	2,060	2,175	2,330	3,685	3,765	4,189
II	2	2	5	5			3	4	8	12	19	21
III	343	349	513	566	574	12,420	12,459	12,770	8,202	10,673	12,058	12,857
IV	153	156	186	186	417	6,425	6,613	5,880	5,880	7,652	8,035	8,431
IV-A												
IV-B												
V	47	49	51	62	66	193	216	343	336	800	1,276	1,347
VI	465	468	511	529	7,216	4,952	4,319	5,842	14,358	16,669	15,699	16,435
VII	34	35	41	44	5	22	33	156	156	263	371	458
VIII	37	38	39	47	234	340	374	327	324	384	450	479
IX	78	80	84	84	5	26	45	50	65	202	368	1,763
X	23	24	24	24	51	108	79	70	76	110	156	200
XI	23	24	43	43		6	21	20	309	544	603	642
XII	33	33	43	45	339	320	315	343	336	590	683	711
CARAGA												
ARMM												
Total Production (tons)	1,336	1,360	1,704	1,805	9,287	26,357	26,537	27,980	32,380	41,548	43,539	47,591
Total Value (PHP 000)	12,024	13,872	18,744	22,376	835,830	2,244,035	2,493,947	3,777,300	4,460,994	7,437,508	6,966,240	9,278,889

APPENDIX A (continued)

Milkfish Production by region

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
NCR	509	2,407	3,644	4,216	6,266	4,626	3,830	4,666	606	447	626	409
CAR												
I	23,561	17,017	11,195	11,875	18,440	17,099	13,536	11,143	14,679	16,278	17,652	17,621
II	904	14	77	70	174	176	192	170	211	243	302	299
III	47,393	32,915	31,953	29,247	37,571	34,076	37,476	32,103	34,147	45,950	70,349	65,586
IV	11,945	19,718	13,822	13,162	9,354							
(IV-A)						9,362	9,087	14,627	11,121	11,123	12,720	13,726
(IV-B)						2,712	2,586	2,341	2,298	2,417	2,580	3,052
V	4,383	3,079	2,845	1,752	1,649	1,401	1,323	1,180	1,370	1,303	1,525	1,553
VI	82,104	39,704	35,184	39,648	40,755	43,460	47,007	44,488	49,962	59,560	55,442	52,362
VII	8,123	9,709	7,906	10,774	5,705	7,597	7,479	6,378	6,623	6,255	6,576	6,707
VIII	2,679	1,061	1,488	1,883	1,608	1,574	1,299	1,377	1,463	1,580	1,713	2,077
IX	17,104	4,530	5,737	10,304	5,907	5,705	6,131	5,042	14,098	15,498	12,284	9,327
X	3,445	1,679	156	215	2,312	2,936	3,294	4,305	4,582	5,074	5,570	5,568
XI	7,792	11,502	7,311	7,866	4,208	4,475	4,954	4,678	5,073	5,623	7,022	7,125
XII	3,732	2,219	872	2,091	1,777	1,791	3,289	6,229	6,662	6,673	7,142	6,755
CARAGA			2,247	2,007	1,663	1,485	1,223	1,143	1,085	1,367	1,461	1,566
ARMM			73	572	517	898	1,370	1,272	1,713	1,640	1,899	2,144
Total Production (tons)	213,674	145,554	124,510	135,682	137,796	139,372	144,076	141,131	155,593	180,931	204,862	195,877
Total Value (PHP 000)	7,230,887	5,775,514	5,302,603	7,099,507	7,392,332	8,128,932	8,053,503	7,465,377	8,360,892	10,052,227	11,736,839	10,656,251

Giant tiger prawn production by region

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
NCR	57	428	541	67	89	73	63	12	10	4		37
CAR												
I	4,556	875	1,619	413	686	573	336	209	170	164	221	217
II	35	16	14	30	110	123	151	130	160	181	70	66
III	11,045	15,474	10,496	27,749	25,591	24,693	18,421	19,467	18,458	19,061	19,686	15,164
IV	8,658	992	2,326	4,161	2,095	1,590	1,828	1,739	1,853	1,639	1,593	
IV-A												432
IV-B												910
V	1,433	1,724	1,271	925	817	567	412	326	334	346	512	507
VI	14,876	40,748	55,153	38,375	33,958	21,715	3,381	1,579	935	1,139	1,796	767
VII	783	4,589	4,305	2,520	4,994	5,857	3,436	2,769	2,055	2,063	1,668	1,609
VIII	499	503	444	204	375	316	218	207	215	202	228	247
IX	1,935	3,174	3,248	6,053	6,764	5,614	4,244	3,368	3,403	3,472	6,628	7,083
X	237	2,208	2,710	891	1,683	1,872	1,382	666	761	433	5,811	5,674
XI	782	4,382	1,550	5,568	7,600	7,772	870	642	415	453	65	91
XII	844	883	2,419	1,507	3,767	4,030	4,107	4,414	4,775	4,942	489	634
CARAGA				67	34	1,354	1,062	1,086	893	1,177	1,663	1,741
ARMM				1,276	1,252	71	199	184	189	178	278	314
Total Production (tons)	45,740	75,996	86,096	89,806	88,815	76,220	40,110	36,798	34,626	35,454	40,698	35,493
Total Value (PHP 000)	8,246,568	12,472,439	15,619,849	19,341,207	19,330,911	18,040,573	11,431,588	11,006,867	10,860,177	11,791,303	13,599,984	12,355,723

APPENDIX A (continued)

Milkfish Production by region

	2003	2004	2005	2006	2007	2008	2009	2010
NCR	411	320	416	421	429	438.69	411	464.27
CAR								
I	18,014	19,427	20,379	23,574	26,123	23,823.63	16,252	16,487.90
II	296	217	311	533	671	821.01	724	487.14
III	58,200	56,894	58,805	57,706	56,530	59,965.69	59,200	56,704.10
IV								
(IV-A)	13,882	13,938	14,930	13,698	13,908	11,893.35	9,820	11,492.95
(IV-B)	3,392	3,554	3,866	3,986	4,291	4,373.49	3,829	3,708.90
V	1,674	1,638	1,756	1,862	2,288	2,543.59	3,744	4,194.60
VI	55,554	62,714	66,249	67,329	71,067	67,906.61	75,998	73,745.76
VII	6,993	6,784	6,528	5,878	6,444	6,383.41	6,698	6,333.76
VIII	2,178	2,456	3,072	3,205	4,187	4,822.87	6,290	6,268.94
IX	9,722	9,776	11,141	10,073	10,695	9,832.39	11,446	11,966.49
X	6,164	5,888	7,984	8,025	9,137	10,090.51	10,422	10,885.99
XI	7,083	6,545	4,979	5,054	4,806	4,461.95	4,793	4,060.94
XII	6,654	6,503	6,892	6,841	7,081	7,713.37	7,442	7,059.95
CARAGA	1,607	1,900	1,407	1,597	1,956	2,146.51	1,233	1,183.69
ARMM	1,914	1,977	1,937	1,980	2,056	2,393.26	2,596	3,021.14
Total Production (tons)	193,738	200,531	210,652	211,841	220,567	219,610	219,977	218,067
Total Value (PHP 000)	10,374,298	11,766,666	12,679,276	13,359,982	13,756,279	16,324,098	17,478,069	16,492,422

Giant tiger prawn production by region

	2003	2004	2005	2006	2007	2008	2009	2010
NCR		15	3	4	6	6.69	3	2.8
CAR								
I	202	186	175	418	435	497.05	801	834.88
II	62	42	123	136	144	87.49	70	54.81
III	14,807	15,281	16,647	17,568	18,997	23,424.45	24,232	24,763.55
IV								
IV-A	338	1,137	1,173	1,176	1,105	198.51	209	237.59
IV-B	864	854	664	707	697	693.31	700	603.86
V	569	468	454	479	532	774.50	1,010	1,156.23
VI	737	720	716	791	771	1,960.88	2,030	2,006.66
VII	1,662	1,749	1,718	1,763	1,810	2,167.24	1,790	1,351.14
VIII	272	285	362	360	452	470.81	481	392.27
IX	7,291	7,129	7,103	6,403	6,660	5,372.15	6,671	7,280.89
X	5,182	5,137	6,159	6,162	7,406	7,883.02	8,736	8,530.33
XI	123	66	140	130	30	43.91	36	35.00
XII	694	614	546	541	302	319.93	57	12.76
CARAGA	1,977	2,028	1,534	1,349	1,270	1,231.38	767	647.40
ARMM	229	217	204	222	208	222.11	238	251.79
Total Production (tons)	34,999	35,917	37,720	38,209	39,825	45,342	47,830	48,162
Total Value (PHP 000)	12,136,635	12,854,974	13,623,396	14,292,149	14,934,951	17,914,616	18,507,501	18,224,182

APPENDIX B: Export market volume data (see separately attached EXCEL file)

APPENDIX B (continued)

Milkfish Export (MT)

Country Destination	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Arabian Peninsula States											
Australia									2		
Austria											
Bahrain											
Belgium											
Bosnia											
BPI								0			
Brunei											
Canada		1		0	3	6	4	86	46	82	67
China											
Cyprus											
Czechoslovakia											
Denmark								0	0		
Egypt											
France											
French Indian Ocean Areas											
Germany											
Greece											
Guam											
Hawaii											
Hongkong				0					3	2	0
Indonesia											
Iraq											
Israel											
Italy											
Japan			0					0	0	1	1
Jordan											
Korea											
Kuwait											
Lebanon											
Macau											
Malaysia											
Marshal Islands											
Micronesia											
Nauru								12	7	3	
Netherlands			2						6	9	9
New Guinea											
New Zealand											
Norway											
Oman											
Palau											
Papua New Guinea											
Portugal											
Puerto Rico											
Qatar											
Sabah											
Saudi Arabia									4	16	33
Singapore									1	0	0
Spain											
St. Helen											
Sweden											
Switzerland											
Taiwan											
Thailand											
TTPI						0	0	0			
UAE											
UK									16	4	10
US	12	46	24	23	34	33	27	487	464	606	684
USSR											
Wake Island											
x Other Countries											
Total Export Milkfish (MT)	12	47	26	24	37	39	31	687	636	623	793

APPENDIX B (continued)

Milkfish Export (MT)

Country Destination	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Arabian Peninsula States					2		0	0			
Australia	1		1	0	1	1	34	2	13	17	10
Austria				0			0			0	0
Bahrain	0	0			0	6	0	2	8	8	1
Belgium											
Bosnia											
BPI											
Brunei				0						0	0
Canada	61	67	90	116	127	133	98	128	46	37	26
China	3	0									
Cyprus											
Czechoslovakia											
Denmark								3	1	0	0
Egypt											
France											0
French Indian Ocean Areas											
Germany		11	3			0		4	7	7	0
Greece											
Guam											
Hawaii											
Hongkong	0	2	1	0	0					0	0
Indonesia				0							
Iraq	1	2									
Israel											
Italy											
Japan			827	4		49	3			2	21
Jordan											
Korea											
Kuwait	26	6	19	2	4	13	24	20	31	2	1
Lebanon											
Macau											
Malaysia											
Marshal Islands											
Micronesia											
Nauru			0	0	1	3	1	16	8	4	
Netherlands	2	6				7	6	14	6	16	9
New Guinea		0	0		2						
New Zealand							0		0	0	
Norway						0	0	0			0
Oman							0				
Palau											0
Papua New Guinea	1										
Portugal											
Puerto Rico											
Qatar	1										
Sabah											
Saudi Arabia	84	147	330	207	91	40	348	76	4	2	
Singapore	0	0		16	146	0	3				
Spain								0			
St. Helen											
Sweden								0		1	0
Switzerland	0				0	0	13	1		1	3
Taiwan											
Thailand											
TTPI		0	3	8	4	9	67	11	4	18	47
UAE											
UK	10	2	13	2	1	3	9	10	11	12	2
US	623	838	1,332	1,276	1,208	1,699	1,188	1,328	1,198	743	296
USSR										0	
Wake Island											
x Other Countries											
Total Export Milkfish (MT)	812	1,072	2,618	1,630	1,687	1,864	1,794	1,613	1,336	868	416

APPENDIX B (continued)

Milkfish Export (MT)

Country Destination	1992	1993	1994	1995	1996	1997	1998	1999	2000
Arabian Peninsula States									
Australia	10	3	9	4	6	2	2	4	21
Austria			0				0		
Bahrain	2	3	3					9	
Belgium		1	9		1				
Bosnia									0
BPI									
Brunei		0	1		0			0	
Canada	38	31	7	6	3	1	2	6	3
China									0
Cyprus									
Czechoslovakia	3								
Denmark						0			
Egypt									
France									
French Indian Ocean Areas									
Germany	1			0			0		
Greece	2	0	0	1				0	
Guam									
Hawaii									
Hongkong	1	0	6	1	2	2	6	6	17
Indonesia									
Iraq									
Israel									
Italy			1					0	
Japan	21	27	24	6	16	1	2	6	1
Jordan									
Korea								1	
Kuwait	19	12	18	16				0	
Lebanon						0			
Macau							0	0	0
Malaysia							0		
Marshal Islands									
Micronesia									
Nauru									
Netherlands	13	0	8	1	7				
New Guinea									
New Zealand	0		0				0		2
Norway	0	0	0			0			
Oman									
Palau	0	0	4		0	2	0	0	0
Papua New Guinea	0								
Portugal									
Puerto Rico									
Qatar									
Sabah					0				
Saudi Arabia		8	1	0	2				
Singapore	3	0	4	6	6	7	6	6	6
Spain									
St. Helen									0
Sweden									
Switzerland	2	1	1	1	0	1	1	0	
Taiwan						0	12		0
Thailand									
TTPI	67	68	36	11	9	4	2	1	0
UAE	0	2							
UK	0	0	1	1					9
US	466	669	161	201	123	114	173	168	161
USSR									
Wake Island									
x Other Countries									
Total Export Milkfish (MT)	637	717	289	263	172	133	206	204	210

APPENDIX B (continued)

Giant tiger prawn Export (MT)

Country Destination	1969	1970	1971	1972	1973	1974	1976	1976	1977	1978	1979	1980
Arabian Peninsula States												
Australia								31	3	46	12	69
Austria												
Bahrain												
Belgium												
Bosnia												
BPI												
Brunei												
Canada		120	77	141	87	66	16	39	27	3	4	1
China											0	
Cyprus												
Czechoslovakia												
Denmark						0		0	0			
Egypt												
France		7	3	4			2					
French Indian Ocean Areas												
Germany					2							
Greece												
Guam		6	23	34	68	24	67	60	64	47	49	67
Hawaii			1	12	0	2	6	26	32	20	13	9
Hongkong			26	28	36	17	1	17		1	1	2
Indonesia												
Iraq												
Israel												
Italy			2									
Japan		396	1,260	1,609	2,446	1,336	1,109	2,021	2,286	2,992	3,603	2,307
Jordan												
Korea												
Kuwait												
Lebanon												
Macau												
Malaysia												
Marshal Islands												
Micronesia												
Nauru												
Netherlands					1							
New Guinea												
New Zealand										2		
Norway										2		
Oman												
Palau												
Papua New Guinea												
Portugal												
Puerto Rico												
Qatar												
Sabah												
Saudi Arabia												29
Singapore									0	0	4	1
Spain							1					18
St. Helen												
Sweden												
Switzerland				2								
Taiwan												
Thailand												
TTPI								0	0			
UAE												
UK		1		0			62	6				12
US		62	133	283	438	334	431	269	148	86	143	64
USSR												
Wake Island									0			
x Other Countries												
Total Export Prawn (MT)		681	1,624	2,012	3,067	1,778	1,672	2,469	2,649	3,200	3,829	2,669

APPENDIX B (continued)

Giant tiger prawn Export (MT)

Country Destination	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Arabian Peninsula States				0	12	13		0			
Australia	3	76	37	123	109	81	169	191	219	206	213
Austria									1	0	
Bahrain			0							1	
Belgium								91	63		
Bosnia											
BPI											
Brunei											
Canada	1	2	3	6	40	28	70	77	210	284	214
China		6	26	3	2	21	0		6	2	
Cyprus							6			0	
Czechoslovakia											
Denmark								1	0		
Egypt											
France						10	26	66	80	182	292
French Indian Ocean Areas											3
Germany		1	3			37	19	30		10	29
Greece										13	0
Guam	64		76	72	160	101	122	193	286	434	310
Hawaii	0	0	1	2	26	236	234	186	296	241	261
Hongkong	2	12	26	60	66	36	68	34	117	60	184
Indonesia											
Iraq											
Israel										0	
Italy						7	19	8	4	41	19
Japan	2,632	3,683	3,870	4,626	6,917	8,686	12,124	19,068	18,832	18,702	21,910
Jordan											
Korea										41	119
Kuwait											
Lebanon											
Macau											
Malaysia		0			14						
Marshal Islands										2	
Micronesia											
Nauru					0			0			
Netherlands			10		9	23		8	6		
New Guinea											
New Zealand	1						0				
Norway								0			
Oman											
Palau											0
Papua New Guinea											
Portugal											24
Puerto Rico									7		31
Qatar											
Sabah											
Saudi Arabia	4		22	0					14		
Singapore	3	2	10	12	4	16	12	9		12	2
Spain									12	26	177
St.Helen											
Sweden			0	0				7	26	18	17
Switzerland								1			
Taiwan								4			4
Thailand						8				13	
TTPI	0	1	3	1	1	1	4	10	46	40	128
UAE											
UK			0	0	6	64	9	10	70	30	11
US	17	167	666	1,631	1,769	1,864	2,074	3,644	6,770	3,797	6,660
USSR										1	
Wake Island											
x Other Countries				12							
Total Export Prawn (MT)	2,716	3,938	4,743	6,438	8,106	11,211	14,936	23,636	26,062	24,146	29,607

APPENDIX B (continued)

Giant tiger prawn Export (MT)

Country Destination	1992	1993	1994	1995	1996	1997	1998	1999	2000
Arabian Peninsula States									
Australia	146	96	46	23	0	6			
Austria		2	3	0		2			
Bahrain		0	0						
Belgium	9						36		
Bosnia									
BPI									
Brunei									
Canada	207	182	106	166	132	114	104		
China		0	137			9	21		
Cyprus									
Czechoslovakia									
Denmark									
Egypt									
France	91		3	3			49		
French Indian Ocean Areas									
Germany	20	7	0		24	0	60		
Greece	3	6							
Guam	202	188	239	194	168	194	138		
Hawaii	206		48	96	49	12	16		
Hongkong	318	138	363	229	179	314	429		
Indonesia									
Iraq									
Israel			10			1			
Italy	12			8					
Japan	17,342	18,469	16,920	13,486	9,611	7,206	7,671		
Jordan									
Korea	270	301	1,082	1,466	1,693	1,069	126	324	686
Kuwait									
Lebanon									
Macau									
Malaysia									
Marshal Islands									
Micronesia									
Nauru			0						
Netherlands					18	4	16		
New Guinea									
New Zealand									
Norway									
Oman									
Palau	2	0	6			6	2		
Papua New Guinea									
Portugal	82								
Puerto Rico	21	16	22	26		4			
Qatar	0								
Sabah									
Saudi Arabia									
Singapore	60	30	66	6	18	2	0		
Spain	40						74		
St.Helen									
Sweden	26	26	37	72	21		0		
Switzerland	0	10	3	0	1	6	9		
Taiwan	46	160	148	100	68	136	17		
Thailand						0	20		
TTPI	110	134	119	127	128	221	183		
UAE									
UK		0	0	16		28	76		
US	3,800	2,463	2,319	1,817	1,062	962	1,681	1,374	1,993
USSR									
Wake Island									
x Other Countries							10	1,006	1,211
Total Export Prawn (MT)	23,003	22,206	21,676	17,824	13,062	10,273	10,626	2,704	3,890

APPENDIX C: Field interview

Summary of interview

Fry hatchery operations

Tina Hautea is a milkfish fry hatchery manager and practices grow out production.

Tina Hautea expressed the company direction for expansion is under the planning process and premature to make any final statement. The company maintains competitiveness against imported milkfish fry from Indonesia by having an order replacement system based on the survival of milkfish fry during the production process. It is customary to add 10% of the ordered number of fry to cover expected mortalities from production. Milkfish hatchery production cycle is also changing due to the extended in spawning season of milkfish broodstock. The dry season, the time where production ceases and repair and servicing of facilities are conducted, is being delayed to meet the milkfish fry demands of producers. The company also receives technical support from institutions. Critical success factors for production are hard to determine but weather temperature and water quality are prime considerations. The skill of the technician is also noted and that it is based on having a “green thumb” in raising milkfish fry.

Aileen Jamandre, over a phone conservation, said her operation have shifted from tiger prawn fry hatchery production to peneaus vannamaie.

Milkfish and tiger prawn brackish-water pond production

Mr. David Villaluz of the Iloilo Fish Producer's Association was previously a milkfish brackish-water pond producer who has currently shifter production to Tilapia fresh water culture due to shifts in production and market costs. Mr. Villaluz clarified that brackish-water pond production of milkfish moved towards intensification upon the introduction of feed in the 1980's benefiting from the technology transfer that was brought in for the prawn industry. Mr. David Villaluz mentioned the importation of fry from Indonesia to the Philippines which confers Miss Hautea's claim. Villaluz that milkfish production will still increase due to increasing population. In discussing the distribution channels of milkfish he says that the milkfish goes through several stages of middle men before reaching the market and for producers to be able to maintain returns in production is to integrate production, consignment, processing and marketing. Villaluz stated that wild fry supply is less than 10%.

Representative of fish processing actor

The milkfish processing plant the author had previous contact in his previous work was not longer in operation. I lieu thereof is from the academe who has extensive knowledge and experience involving fish processing not only within the institution but as well as with the processing industry. Rose Mueda is a university research associate II of the CFOS-UPV, discussed the value chain of the milkfish industry as the product moves from production to the market. There is a loss of quality and value of the product from handling. The value of milkfish also decreases over time as it is being sold in the local markets.

Government Institutions

Roed Shane Hablo from the Bureau of Fisheries and Aquatic Resources (BFAR), with DTI, confirmed that there are efforts towards value adding, diversification and mainstreaming of milkfish products. He was also part of technical assistance from donor agencies that help develop the industry. Mary jade Gonzales and Leah Gonzalesof the Department of Trade and Industry (DTI) Region VI expressed that the milkfish industry no longer the main focus of development of the institution as it has shifted its focus on other areas although support can still be provided at the provincial level. This is to the response of demand according to the sector. Several companies are also interested in operating milkfish processing facilities in the area but were currently at the preliminary stages of observing the possibilities of operations.

They have also confirmed that there are movements to other culture species in the aquaculture sector such as catfish. Their office provided a copy of a report on the "Strengthening and direction-setting of the Select sub-sector of the Processed Food in Negros Occidental"which was conducted on September 26, 2011. As almost always, project implantation has set targets, the following increase and exercise are to be met by end of the 2011:

1. number micro, small and medium enterprise to at least 5
2. $ 1 Million export sales
3. Php 2 million investment
4. Php 50 million domestic sales
5. Monitoring of project

Those who were present though signified interest in increasing production for export. One strategy for improving the milkfish industry as a whole is mainstreaming the product and product diversification as well as positioning against sardines. They have acknowledge limitations in technical advice for production but have the capacity to address market linkages as it is the main role of their institution with regards to the milkfish industry. Their office also provided services to small and medium enterprise development.

Academic and research institutions

Doctor Crispino Saclauso is currently the director of the institute of aquaculture, College of Fisheries and Ocean Sciences (CFOS), University of the Philippines in the Visayas (UPV). In relation to climate change, Dr. Saclauso pointed to shifting in natural production techniques for milkfish alternating between algal mats production and green filamentous algae production depending on the change in season. Algal mats grows best in summer and filamentous algae in during the prolonging rainy seasons.

During a discussion with Valeriano Corre junior from CFOS-UPV, he affirmed that there are government efforts to revive the tiger prawn industry and the current measure for the sustainable growth and development are technologies such as the use of biofloc and immunostimulants to improve water quality and to combat against disease outbreaks specifically for white spot syndrome virus (WSSV). WSSV is said to be the major obstacle in recovery of the tiger prawn industry. Combination of products and practices will also be sought. It was also suggested that by the 1980s, supply of prawn fry is from hatcheries.

Mr. Dan Baliao of the South East Asia Fisheries Development Center (SEAFDEC) produced various manuals for milkfish and prawn production techniques. This is aside from his various scientific publications. Baliao stated that there are five critical factors for successful milkfish production:

1. Availability of pond area: Area should be available for production and reversion of ponds to mangrove areas will affect the ability of the industry to meet the needs of local food security.
2. Access to fund: There is a need to cater to the financial requirements of producers for production
3. Knowledge in production: Producers tend to copy practices that increases production lacking proper knowledge on the underlying requirements of technology, innovation or management technique

4. Technical support: Technical support from institution is needed for transition to intensive production of milkfish to increase production and meet food demand.
5. Supervision: Supervision is a form of monitoring that recommended management practices are followed to prevent miss-use and abuse of the natural state of pond areas.

During the interview it was also stated that the Aquaculture sector is facing an aging population crises. Younger generation is no longer interested in brackish-water pond production as a source of income due to the nature of activities involved being out in the field or production site. This is conferred by Hautea based on her experience and it is the reason she is taking responsibility in the hatchery management of their company. Baliao also confirms the existence of small scale prawn hatcheries in operation during his appointment as a technician in 1975). Roman Sanarez of CFOS of UPV was consulted for data handling and verification. Janice Tronco Raguz and Jessica Esmao, both from the Bureau of Aquatic and Fisheries Resources (BFAR) were consulted for other possible sources of data and confirmed that disaggregated production data according to management system types are not available.

APPENDIX C (continued)

DTI Region 6
Office of the Regional Director
COMMUNICATIONS INSTRUCTIONS

Ref. #. 2011- 2749-1
Date:
To: Lea

✓ For your info/reference
For your comments
Please follow up
Please reply
✓ For your appropriate action
For dissemination to POs

DOMINIC P. ABAD
Regional Director

Elen
For info

2749-1

We are submitting a Post-activity Report on the Planning/workshop of Strengthening and Direction-setting of Select sub-sector of the Processed Food in Negros Occidental which was conducted in Bacolod City on 26 September 2011.

For your reference.

Encl.:A/S

RLA/memo

Prudential Life Building, San Juan – Luzurriaga Sts. 6100 Bacolod City Philippines
Tel (634) 433 0250 / 704 2203 • Fax (634) 433 0250 • E-mail: dti_negocc@yahoo.com

DEPARTMENT OF TRADE & INDUSTRY PHILIPPINES

Reference No. BDD0911-SD7

MEMORANDUM

FOR : **DOMINIC P. ABAD**
Regional Director

2744

FROM : **REBECCA M. RASCON**
Provincial Director

DATE : 27 September 2011

RE : Post-Activity Report

We are submitting a Post-activity Report on the Planning/workshop of Strengthening and Direction-setting of Select sub-sector of the Processed Food in Negros Occidental which was conducted in Bacolod City on 26 September 2011.

For your reference.

Encl.:A/S

RLA/memo

Prudential Life Building, San Juan – Luzurriaga Sts. 6100 Bacolod City Philippines
Tel (034) 433 0250 / 704 2203 • Fax (034) 433 0250 • E-mail dti_negocc@yahoo.com

POST ACTIVITY REPORT

Activity Title: Strengthening and Direction-Setting of Select sub-sectors in the Processed Food in Negros Ocidental

Implementing Office: DTI – Negros Occidental

Partner Institutions: None

Target Beneficiaries/Participants: (1) Prawn growers, (2) Line agencies (3) LGU

I. Objectives:

a. General: (1) To strengthen the select processed food sub-sector to maximize their potential.

b. Specific: (1) To increase the number of MSMEs assisted in the sector to at least 5 at the end of 2011;
(2) To increase export sales by US$1.0M in 2011;
(3) To increase investments of at least Php2.0M at the end of 2011;
(4) To increase domestic sales by Php50.0M EOY2011;
(5) To keep track the progress of the industry as caused by the government interventions.

II. Expected Outcomes/Outputs

1. Strengthened organization and policy advocacy.
2. Improved access to relevant info. thru networking.
3. Improved productivity.
4. Improved management system as a result of the action planning and consultation.
5. Increased competitiveness of the industry.

III. Details of Activity

a. Roles of DTI

1. Conceptualized the program design by preparing the activity proposal.
2. Identified and selected the facilitator.
3. Facilitated all the pre-workshop tasks.
4. Facilitated the conduct of the planning.
5. Subsidized food of pax and some needed office supplies.

b. Expenses & Source of Funds

Particulars	DTI	MSMEs	Total
Honorarium of the facilitator	5,600.00		5,600.00
Meals of Pax	7,225.00		7,225.00
In-land transport	300.00		300.00
Total	13,125.00	0.00	13,125.00
	100%	0%	100%

c. Date Conducted & Venue
- *26 September 2011/Planta Centro Bacolod Hotel & Residences, Araneta St., Bacolod City*

d. Number of Participants
Male : 4
Female : 8
Total : 12

e. Facilitator
Mr. John P. Etabag
Human Resource Manager, HPCo.

f. Methodologies
A combination of lecture and workshop

g. Problems/Issues and Actions Taken
- Unavailable data on the previous Congresses (Shrimp) as benchmark data;
- Inadequate data sourced out from Negros Prawn;
- Non-attendance of other key stakeholders.

IV. Results: Outcomes & Outputs

Immediate results of the activity are the identification of concerns by the sub-sector. With this, the major players of the industry have somehow grasp and a macro view of what the sector is and where it is going.

V. Analysis*

The planning–workshop which was participated by other line agencies (e.g., BFAR, DOST, OPA) and the individual prawn growers gave an opportunity for the players in the industry to assess the current status of the sector. Also, the activity has given the attendees, especially DTI and other partner agencies to draw possible interventions where they can further the growth of the sector.

* Includes analysis of data/information, customer satisfaction feedback, describe the attributes which led to the success or failure of the activity.

VI. Learnings/Evaluations/Recommendations:

Evaluation

On the **course content**, a 4.37GWA (w/ a scale of 1 to 5, where 1 is the lowest and 5 is the highest) was the rating given by the participants to the workshop that includes the parameters of the coverage, relevance of topics discussed and sequencing of sub-topics.

An overall rating of 4.06 was achieved by the facilitator as rated by the participants. He got high scores in confidence as facilitator (4.33), and the ability to handle questions (4.22).

On the bases of time management, quality of training materials, responsiveness of secretariat services, accessibility of the venue, choice of food and availability of equipment, which is labeled training management, it got a GWA of 4.06.

Lastly, taking into considerations all the dimensions in the workshop evaluation, the final rating of the activity is 4.16.

A comment of participant was suggestive of promoting production of raw materials and sharing of knowledge and technology.

Recommendations

Next steps as follow through for this activity have been identified by the participants during the workshop. (Pls. see attached output). In fact, a TWG was formed to lead the group's initiative to achieve the desired sectoral goal.

TWG is composed of DTI, BFAR, Amelyn Bravo of Negros Prawn, Pearl Navarra of Orient Marine, TLDC, and Mr. Pacheco of Wellshare. The TWG will have plans that include meeting with the Governor to present the output of this planning activity, database building by BFAR and OPA.

Prepared by:	Reviewed by:
Romel L. Amihan/TIDS	Engiemar B. Tupas/OIC-BDD
Signature over printed name of Account Officer	**Signature over printed name of Director/Division Chief**
Position/Designation	Regional/Provincial Director/Division Chief

R06-GP-SF007
Issue: 00
2011-01-05

Post Activity Report - Page 3 of 3

APPENDIX D: Data set (see separately attached EXCEL file)

APPENDIX D (continued)

Milkfish Data Set Market (PhP '000)

Country Destination/Item	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Arabian Peninsula States											
Australia									16		
Austria											
Bahrain											
Belgium											
Bosnia											
BPI								4			
Brunei											
Canada		10		1	27	51	36	775	410	741	578
China											
Cyprus											
Czechoslovakia											
Denmark								2	2		
Egypt											
France											
French Indian Ocean Areas											
Germany											
Greece											
Guam											
Hawaii											
Hongkong				4					23	15	2
Indonesia											
Iraq											
Israel											
Italy											
Japan			2					0	1	10	5
Jordan											
Korea											
Kuwait											
Lebanon											
Macau											
Malaysia											
Marshal Islands											
Micronesia											
Nauru								108	61	30	
Netherlands			22						41	81	90
New Guinea											
New Zealand											
Norway											
Oman											
Palau											
Papua New Guinea											
Portugal											
Puerto Rico											
Qatar											
Sabah											
Saudi Arabia									34	142	337
Singapore									6	3	2
Spain											
St. Helen											
Sweden											
Switzerland											
Taiwan											
Thailand											
TTPI						0	1	4			
UAE											
UK									135	37	104
US	106	412	213	210	302	298	241	4,385	4,087	4,549	6,973
USSR											
Wake Island											
x Other Countries											
Total Export Milkfish	106	422	237	215	329	349	278	5,279	4,816	5,607	8,091
Total Domestic Milkfish	868,043	880,813	890,061	896,185	1,018,426	957,800	1,014,571	1,036,525	1,063,484	1,184,751	1,364,737

APPENDIX D (continued)

Milkfish Data Set Market (PhP '000)

Country Destination/Item	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Arabian Peninsula States					39		3	9		
Australia	6		7	2	23	14	771	59	347	574
Austria				2			1			3
Bahrain	4	6			9	150	8	55	206	264
Belgium										
Bosnia										
BPI										
Brunei				0						3
Canada	675	685	1,208	1,907	2,941	3,578	2,244	3,408	1,257	1,259
China	35	0								
Cyprus										
Czechoslovakia										
Denmark								72	22	4
Egypt										
France										
French Indian Ocean Areas										
Germany		130	39			3		105	188	228
Greece										
Guam										
Hawaii										
Hongkong	1	27	9	1	1					2
Indonesia				0						
Iraq	7	28								
Israel										
Italy										
Japan			11,091	70		1,328	76			58
Jordan										
Korea										
Kuwait	281	60	253	40	100	353	560	525	858	68
Lebanon										
Macau										
Malaysia										
Marshal Islands										
Micronesia										
Nauru			2	8	23	67	12	407	216	124
Netherlands	27	69				198	132	386	165	510
New Guinea		5	3		40					
New Zealand							6		3	3
Norway						2	4	6		
Oman							2			
Palau										
Papua New Guinea	6									
Portugal										
Puerto Rico										
Qatar	9									
Sabah										
Saudi Arabia	925	1,780	4,430	3,424	2,104	1,089	7,982	2,000	105	68
Singapore	2	3		249	3,372	12	64			
Spain								6		
St. Helen										
Sweden								1		24
Switzerland	0				0	3	302	13		17
Taiwan										
Thailand										
TTPI		3	36	126	82	236	1,542	302	114	624
UAE										
UK	105	27	170	34	34	88	215	263	317	415
US	6,851	10,145	17,859	21,135	27,948	42,998	27,255	35,511	32,981	25,441
USSR										3
Wake Island										
x Other Countries										
Total Export Milkfish	8,934	12,968	35,107	26,997	36,715	50,120	41,179	43,126	36,778	29,695
Total Domestic Milkfish	1,847,063	2,149,048	2,056,786	2,551,544	3,557,945	4,215,199	4,085,024	4,659,615	4,951,575	6,536,729

APPENDIX D (continued)

Milkfish Data Set Market (PhP '000)

Country Destination/Item	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Arabian Peninsula States										
Australia	338	388	126	454	230	279	122	83	220	1,170
Austria	2			20				2		
Bahrain	34	79	128	131					459	
Belgium			43	475		60				
Bosnia										11
BPI										
Brunei	4		8	38		2			13	
Canada	844	1,506	1,330	342	279	146	64	81	269	156
China										1
Cyprus										
Czechoslovakia		137								
Denmark	0						3			
Egypt										
France	3									
French Indian Ocean Areas										
Germany	14	32			6			1		
Greece		71	7	8	38				19	
Guam										
Hawaii										
Hongkong	6	21	12	252	57	122	94	317	284	931
Indonesia										
Iraq										
Israel										
Italy				40					19	
Japan	720	849	1,141	1,260	331	853	49	122	264	64
Jordan										
Korea									32	
Kuwait	18	758	493	934	837				7	
Lebanon							1			
Macau								5	6	4
Malaysia								2		
Marshal Islands										
Micronesia										
Nauru										
Netherlands	299	529	19	401	53	403				
New Guinea										
New Zealand		4		2				3		121
Norway	3	8	4	5			5			
Oman										
Palau	13	10	4	209		17	97	16	19	1
Papua New Guinea		2								
Portugal										
Puerto Rico										
Qatar										
Sabah						7				
Saudi Arabia			337	38	12	99				
Singapore		114	20	206	312	350	382	294	244	298
Spain										
St. Helen										1
Sweden	14									
Switzerland	86	64	52	50	30	11	36	41	8	
Taiwan							8	624		4
Thailand										
TTPI	1,576	2,645	2,474	1,807	579	552	219	86	38	12
UAE		2	75							
UK	55	14	18	57	41					481
US	10,029	18,059	24,240	8,415	10,769	7,158	6,367	9,145	9,038	8,407
USSR										
Wake Island										
x Other Countries										
Total Export Milkfish	14,058	25,294	30,529	15,145	13,575	10,058	7,449	10,820	10,939	11,662
Total Domestic Milkfish	7,216,829	5,760,220	5,272,074	7,084,362	7,378,757	8,118,874	8,046,054	7,464,557	8,349,953	10,040,565

APPENDIX D (continued)

Milkfish Data Set Production (PhP '000)

Milkfish Production Value by region	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
NCR	9,508	9,651	9,751	9,817	11,157	10,494	11,115	11,410	11,700	11,997	14,168
CAR											
I	58,510	59,392	60,003	60,414	68,661	64,576	68,398	70,214	72,000	75,897	88,985
II	1,463	1,485	1,500	1,510	1,717	1,614	1,710	1,755	1,800	1,566	1,776
III	193,816	196,737	198,761	200,123	227,439	213,909	226,567	232,585	238,500	305,892	352,634
IV	108,976	110,618	111,756	112,522	127,881	120,273	127,390	130,774	134,100	136,350	158,039
(IV-A)											
(IV-B)											
V	31,449	31,923	32,252	32,473	36,905	34,710	36,764	37,740	38,700	41,652	49,123
VI	304,254	308,841	312,017	314,155	357,036	335,796	355,667	365,114	374,400	413,874	472,087
VII	23,404	23,757	24,001	24,166	27,464	25,830	27,359	28,086	28,800	30,204	35,404
VIII	25,598	25,984	26,251	26,431	30,039	28,252	29,924	30,719	31,500	32,607	37,893
IX	55,585	56,423	57,003	57,394	65,228	61,347	64,978	66,704	68,400	69,507	80,692
X	16,090	16,333	16,501	16,614	18,882	17,758	18,809	19,309	19,800	20,691	24,164
XI	16,090	16,333	16,501	16,614	18,882	17,758	18,809	19,309	19,800	20,817	24,133
XII	23,404	23,767	24,001	24,166	27,464	25,830	27,369	28,086	28,800	29,304	33,731
CARAGA											
ARMM											

Milkfish Data Set Production (PhP '000)

Milkfish Production Value by region	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
NCR	7,370	8,107	9,038	10,267	14,347	16,914	14,252	14,855	13,848	21,554
CAR										
I	170,742	195,185	217,390	243,068	351,659	427,551	390,884	447,567	467,872	363,208
II	5,797	6,631	1,556	5,034	11,385	17,721	16,134	18,470	18,720	21,106
III	558,294	678,181	663,152	715,756	1,074,160	1,184,531	1,184,977	1,286,194	1,362,102	2,244,876
IV	202,037	222,241	222,526	141,869	258,635	273,176	233,333	248,909	249,477	406,072
(IV-A)										
(IV-B)										
V	55,869	73,774	74,117	91,080	127,779	170,806	146,892	106,146	109,046	135,437
VI	556,732	633,737	688,069	932,361	1,160,055	1,452,813	1,439,493	1,691,901	1,788,321	2,312,714
VII	44,935	52,780	48,933	56,983	102,696	176,533	150,666	170,777	186,406	155,350
VIII	41,998	56,338	33,686	36,731	66,184	57,114	48,998	60,471	64,668	100,460
IX	91,861	101,047	94,044	160,361	182,042	213,049	236,385	340,728	392,412	352,913
X	26,213	28,834	21,026	48,786	52,619	56,577	61,025	74,416	80,112	99,285
XI	46,882	51,570	71,649	80,332	124,400	132,353	131,412	155,969	165,511	224,433
XII	47,267	53,591	46,707	55,923	78,699	86,182	72,752	86,338	89,858	129,016
CARAGA										
ARMM										

Milkfish Data Set Production (PhP '000)

Milkfish Production Value by region	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
NCR	21,969	122,754	185,323	242,410	343,803	277,122	193,856	328,084	28,238	28,024
CAR										
I	662,076	719,820	593,990	819,984	1,196,160	1,100,436	931,123	717,498	993,488	1,118,563
II	28,540	970	4,711	5,532	10,479	11,590	12,656	11,900	15,692	16,395
III	2,001,060	1,425,281	1,507,633	1,816,416	2,140,205	2,240,760	2,330,398	1,864,058	2,102,462	2,862,925
IV	488,091	877,104	699,843	868,696	693,051					
(IV-A)						649,234	579,707	1,050,073	685,447	696,419
(IV-B)						188,087	164,970	168,070	141,644	151,364
V	140,076	124,102	132,175	84,396	86,627	86,789	79,908	69,843	79,544	77,004
VI	2,715,764	1,453,310	1,269,661	1,660,444	1,866,012	2,213,429	2,247,402	1,780,772	2,344,572	2,916,980
VII	151,157	327,519	250,362	427,687	267,300	363,833	343,398	279,994	306,068	307,570
VIII	102,356	46,113	66,868	101,961	92,619	92,122	86,106	82,981	93,460	102,180
IX	402,906	133,266	173,102	476,847	265,232	231,913	262,791	202,278	560,652	669,934
X	105,559	57,028	6,216	9,510	105,526	186,594	204,430	207,210	213,693	249,088
XI	273,838	417,437	296,445	393,507	214,722	237,409	259,841	228,914	257,059	289,205
XII	137,497	70,811	26,826	84,176	117,206	117,061	211,142	342,327	374,075	378,792
CARAGA			2,498	25,407	76,695	82,716	68,081	65,675	64,154	85,100
ARMM			89,050	92,646	26,695	49,847	77,696	75,700	100,644	103,684

APPENDIX D (continued)

Milkfish Data Set Fry Source (PhP '000)

Milkfish Fry requirements	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
NCR	961	966	976	982	1,116	1,049	1,111	1,141	1,170	1,200	1,417
CAR											
I	5,851	5,939	6,000	6,041	6,866	6,458	6,840	7,021	7,200	7,590	8,899
II	146	148	150	151	172	161	171	176	180	157	178
III	19,382	19,674	19,876	20,012	22,744	21,391	22,657	23,258	23,850	30,589	35,263
IV	10,898	11,062	11,176	11,252	12,788	12,027	12,739	13,077	13,410	13,635	15,804
(IV-A)											
(IV-B)											
V	3,145	3,192	3,225	3,247	3,691	3,471	3,676	3,774	3,870	4,165	4,912
VI	30,425	30,884	31,202	31,416	35,704	33,580	35,567	36,511	37,440	41,387	47,209
VII	2,340	2,376	2,400	2,417	2,746	2,583	2,736	2,809	2,880	3,020	3,540
VIII	2,560	2,598	2,625	2,643	3,004	2,825	2,992	3,072	3,150	3,261	3,789
IX	5,558	5,642	5,700	5,739	6,523	6,135	6,498	6,670	6,840	6,951	8,069
X	1,609	1,633	1,650	1,661	1,888	1,776	1,881	1,931	1,980	2,069	2,416
XI	1,609	1,633	1,650	1,661	1,888	1,776	1,881	1,931	1,980	2,082	2,413
XII	2,340	2,376	2,400	2,417	2,746	2,583	2,736	2,809	2,880	2,930	3,373
CARAGA											
ARMM											
Total Milkfish Fry	86,815	88,124	89,030	89,640	101,876	95,815	101,485	104,180	106,830	119,036	137,283
Milkfish Fry Gatherering	86,815	88,124	89,030	89,640	101,876	95,815	101,485	104,180	106,830	119,036	137,283
Milkfish Fry Hatchery											

Milkfish Data Set Fry Source (PhP '000)

Milkfish Fry requirements	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
NCR	737	811	904	1,027	1,435	1,691	1,425	1,486	1,385	2,155
CAR										
I	17,074	19,519	21,739	24,307	35,166	42,755	39,088	44,767	46,787	36,321
II	580	663	156	503	1,139	1,772	1,613	1,847	1,872	2,111
III	55,829	67,818	66,315	71,576	107,416	118,453	118,498	128,619	136,210	224,488
IV	20,204	22,224	22,263	14,187	26,864	27,318	23,333	24,891	24,948	40,607
(IV-A)										
(IV-B)										
V	5,587	7,377	7,412	9,108	12,778	17,081	14,589	10,615	10,905	13,544
VI	55,673	63,374	58,807	93,236	116,005	145,291	143,949	169,190	178,832	231,271
VII	4,494	5,278	4,893	5,698	10,270	17,653	15,067	17,078	18,641	15,535
VIII	4,200	5,634	3,369	3,673	5,618	5,711	4,900	6,047	6,467	10,046
IX	9,186	10,105	9,404	16,035	18,204	21,305	23,639	34,073	39,241	35,291
X	2,621	2,883	2,103	4,879	5,262	5,658	6,103	7,442	8,011	9,929
XI	4,688	5,167	7,165	8,033	12,440	13,235	13,141	16,597	16,551	22,443
XII	4,727	5,359	4,671	5,592	7,870	8,618	7,275	8,634	8,986	12,902
CARAGA										
ARMM										
Total Milkfish Fry	185,600	216,202	209,189	257,854	359,466	426,532	412,620	470,274	498,835	656,642
Milkfish Fry Gatherering	185,600	216,202	209,189	257,854	359,466	426,532	412,620	470,274	498,835	656,642
Milkfish Fry Hatchery										

Milkfish Data Set Fry Source (PhP '000)

Milkfish Fry requirements	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
NCR	2,197	12,275	18,632	24,241	34,380	27,712	19,386	32,808	2,824	2,802
CAR										
I	66,208	71,982	59,399	81,998	119,616	110,044	93,112	71,750	99,349	111,856
II	2,854	97	471	553	1,048	1,159	1,266	1,190	1,569	1,640
III	200,106	142,528	150,753	181,642	214,021	224,076	233,040	185,406	210,246	286,293
IV	48,809	87,710	69,984	85,860	69,306					
(IV-A)						64,923	57,971	105,007	68,546	69,642
(IV-B)						18,809	16,497	16,807	14,164	15,136
V	14,008	12,410	13,218	8,440	8,663	8,679	7,991	6,984	7,954	7,700
VI	271,576	145,331	126,966	166,044	186,601	221,343	224,740	178,077	234,457	291,598
VII	15,116	32,752	25,036	42,769	26,730	36,383	34,340	27,999	30,607	30,757
VIII	10,236	4,611	6,687	10,195	9,262	9,212	8,611	8,298	9,346	10,218
IX	40,291	13,327	17,310	47,686	26,623	23,191	26,279	20,228	56,066	66,993
X	10,556	5,703	622	951	10,563	18,659	20,443	20,721	21,369	24,909
XI	27,384	41,744	29,646	39,351	21,472	23,741	25,984	22,891	25,706	28,921
XII	13,750	7,081	2,583	8,418	11,721	11,705	21,114	34,233	37,408	37,879
CARAGA			260	2,641	7,670	8,272	6,808	6,568	6,415	8,510
ARMM			8,905	9,265	2,670	4,985	7,770	7,570	10,064	10,368
Total Milkfish Fry	723,089	577,561	530,260	709,961	739,233	812,893	805,350	746,538	836,089	1,005,223
Milkfish Fry Gatherering	723,089	577,561	530,260	709,961	739,233	812,893	724,816	597,230	585,262	603,134
Milkfish Fry Hatchery							80,535	149,308	250,827	402,089

APPENDIX D (continued)

Tiger Prawn Data Set Market (PhP '000)

Country Destination/Item	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Arabian Peninsula States											
Australia							277	25	416	108	703
Austria											
Bahrain											
Belgium											
Bosnia											
BPI											
Brunei											
Canada	1,079	690	1,265	781	592	132	355	245	24	39	10
China										0	
Cyprus											
Czechoslovakia											
Denmark					0		2	2			
Egypt											
France	61	24	40			21					
French Indian Ocean Areas											
Germany				18							
Greece											
Guam	55	206	303	525	212	513	541	486	426	444	581
Hawaii		6	105	2	21	44	232	290	184	118	95
Hongkong		236	253	321	150	13	152		10	11	20
Indonesia											
Iraq											
Israel											
Italy		18									
Japan	3,560	11,336	13,578	22,003	12,020	9,977	18,189	20,562	26,924	32,423	23,530
Jordan											
Korea											
Kuwait											
Lebanon											
Macau											
Malaysia											
Marshal Islands											
Micronesia											
Nauru											
Netherlands				5							
New Guinea											
New Zealand									20		
Norway									18		
Oman											
Palau											
Papua New Guinea											
Portugal											
Puerto Rico											
Qatar											
Sabah											
Saudi Arabia											291
Singapore								2	1	33	8
Spain						6					189
St. Helen											
Sweden											
Switzerland			17								
Taiwan											
Thailand											
TTPI							1	0			
UAE											
UK	7		1			465	54				122
US	471	1,198	2,548	3,944	3,003	3,876	2,420	1,329	777	1,283	657
USSR											
Wake Island								0			
x Other Countries											
Total Export Prawn	5,233	13,714	18,109	27,600	15,998	15,046	22,222	22,942	28,802	34,461	26,207
Total Domestic Prawn	3,407										

APPENDIX D (continued)

Tiger Prawn Data Set Market (PhP '000)

Country Destination/Item	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Arabian Peninsula States				20	1,165	1,756		2		
Australia	30	924	3,326	10,491	10,246	10,955	21,945	34,146	35,072	40,199
Austria									128	41
Bahrain			4							208
Belgium								16,258	8,559	
Bosnia										
BPI										
Brunei										
Canada	11	23	296	403	3,768	3,778	9,643	13,808	33,564	55,332
China		65	2,288	282	197	2,878	34		800	390
Cyprus							658			49
Czechoslovakia										
Denmark								125	5	
Egypt										
France						1,376	3,538	11,627	12,732	35,444
French Indian Ocean Areas										
Germany		12	300			4,941	2,647	5,387		1,872
Greece										2,571
Guam	589		6,876	6,162	14,103	13,679	16,784	34,590	45,582	84,539
Hawaii	5	2	51	154	2,469	31,783	32,260	33,379	47,292	47,052
Hongkong	17	147	2,287	4,268	5,253	4,729	7,956	6,013	18,668	9,730
Indonesia										
Iraq										
Israel										26
Italy						1,004	2,640	1,362	710	8,039
Japan	28,947	45,652	348,329	385,248	556,124	1,172,558	1,670,381	3,413,320	3,013,165	3,646,297
Jordan										
Korea										8,083
Kuwait										
Lebanon										
Macau										
Malaysia		0			1,361					
Marshal Islands										369
Micronesia										
Nauru					35			9		
Netherlands			886		824	3,158		1,486	1,002	
New Guinea										
New Zealand	11						4			
Norway								18		
Oman										
Palau										
Papua New Guinea										
Portugal										
Puerto Rico									1,043	
Qatar										
Sabah										
Saudi Arabia	40		2,014	20					2,246	
Singapore	38	30	913	1,001	335	2,096	1,614	1,638		2,348
Spain									1,869	5,010
St. Helen										
Sweden			5	34				1,205	4,082	3,589
Switzerland								172		
Taiwan								666		
Thailand						1,125				2,511
TTPI	2	11	247	120	73	132	532	1,808	7,414	7,731
UAE										
UK			8	6	436	7,246	1,266	1,783	11,216	5,764
US	182	1,949	58,994	138,840	165,287	250,265	285,718	634,433	923,207	740,401
USSR										177
Wake Island										
x Other Countries				1,051						
Total Export Prawn	29,874	48,816	426,825	548,103	761,674	1,513,459	2,057,620	4,213,236	4,168,358	4,707,772
Total Domestic Prawn			409,005	1,695,932	1,732,273	2,263,841	2,403,374	3,224,272	2,797,882	4,571,117

APPENDIX D (continued)

Tiger Prawn Data Set Market (PhP '000)

Country Destination/Item	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Arabian Peninsula States										
Australia	38,402	23,880	17,287	9,877	4,928	12	1,310			
Austria			333	700	44		530			
Bahrain			12	73						
Belgium		1,477						10,361		
Bosnia										
BPI										
Brunei										
Canada	38,500	33,995	33,033	22,840	36,192	31,201	32,503	31,185		
China			34	29,579			2,532	6,362		
Cyprus										
Czechoslovakia										
Denmark										
Egypt										
France	52,677	14,878		575	601			14,774		
French Indian Ocean Areas	596									
Germany	5,174	3,308	1,255	22		5,745	6	14,875		
Greece	83	539	865							
Guam	55,821	33,183	34,145	51,395	42,191	37,289	55,376	41,317		
Hawaii	47,021	33,772		10,330	20,937	11,584	3,385	4,846		
Hongkong	33,152	52,131	25,015	78,177	49,950	42,450	89,538	128,386		
Indonesia										
Iraq										
Israel				2,197			157			
Italy	3,376	2,028			1,711					
Japan	3,950,283	2,846,233	3,350,770	3,643,960	2,935,259	2,274,872	2,052,493	2,264,520		
Jordan										
Korea	21,408	44,337	54,603	233,016	316,692	377,019	301,706	37,526	101,620	228,150
Kuwait										
Lebanon										
Macau										
Malaysia										
Marshal Islands										
Micronesia										
Nauru				65						
Netherlands						4,185	1,065	4,499		
New Guinea										
New Zealand										
Norway										
Oman										
Palau	52	331	70	986			1,567	706		
Papua New Guinea										
Portugal	4,254	13,522								
Puerto Rico	5,546	3,395	2,983	4,769	5,512		1,094			
Qatar		39								
Sabah										
Saudi Arabia										
Singapore	299	8,170	5,465	14,099	1,361	4,323	668	3		
Spain	31,839	6,556						22,266		
St. Helen										
Sweden	3,083	4,083	4,562	8,034	15,766	4,868		28		
Switzerland		16	1,823	546	22	157	1,797	2,693		
Taiwan	793	7,596	27,137	31,974	21,716	16,147	38,578	5,122		
Thailand							31	5,879		
TTPI	23,148	18,130	24,253	25,601	27,712	30,360	63,079	54,764		
UAE										
UK	1,989		9	16	3,291		8,075	22,471		
US	1,020,401	623,595	445,104	499,441	395,579	249,023	271,254	473,010	430,944	662,833
USSR										
Wake Island										
x Other Countries								3,011	315,524	402,755
Total Export Prawn	5,337,897	3,775,195	4,028,757	4,668,271	3,879,463	3,089,235	2,926,745	3,148,601	848,089	1,293,737
Total Domestic Prawn	2,908,671	8,697,244	11,591,092	14,672,936	15,451,448	14,951,338	8,499,984	7,858,266	10,012,088	10,497,566

APPENDIX D (continued)

Tiger Prawn Data Set Production (PhP '000)

Prawn Production by Region	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
NCR	84	86	87	79	117	145	178	220	271	117	143
CAR											
I	550	561	567	515	767	945	1,166	1,438	1,773	765	897
II	13	13	13	12	18	22	27	34	42	18	20
III	2,218	2,264	2,288	2,080	3,094	3,815	4,704	5,804	7,156	3,087	3,560
IV	989	1,010	1,020	928	1,380	1,702	2,098	2,589	3,192	1,377	1,591
IV-A											
IV-B											
V	304	310	313	285	424	523	645	795	981	423	500
VI	3,007	3,070	3,101	2,819	4,194	5,172	6,378	7,869	9,701	4,185	4,773
VII	220	224	227	206	307	378	466	575	709	306	357
VIII	239	244	247	224	334	412	507	626	772	333	388
IX	504	515	520	473	704	868	1,070	1,320	1,627	702	816
X	149	152	153	139	207	256	315	389	480	207	245
XI	149	152	153	139	207	256	315	389	480	207	245
XII	213	218	220	200	298	367	453	558	688	297	337
CARAGA											
ARMM											

Tiger Prawn Data Set Production (PhP '000)

Prawn Production by Region	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
NCR	77	87						11,457	8,960	8,676
CAR										
I	1,727	2,021	34,200	131,541	193,599	293,625	321,004	641,750	602,400	518,442
II	55	62			282	540	1,102	2,148	3,040	2,741
III	5,643	7,016	51,660	1,057,439	1,170,897	1,723,950	1,129,990	1,910,575	1,929,280	3,053,610
IV	2,046	2,305	37,530	547,025	621,490	793,800	810,087	1,369,784	1,285,600	1,291,684
IV-A										
IV-B										
V	561	768	5,940	16,432	20,299	46,305	46,291	143,208	204,160	213,164
VI	5,621	6,558	649,440	421,614	405,899	788,670	1,978,102	2,983,918	2,511,840	3,356,140
VII	451	546	450	1,873	3,102	21,060	21,492	47,080	59,360	61,962
VIII	429	582	21,060	28,948	35,148	44,145	44,638	68,740	72,000	105,409
IX	924	1,042	450	2,214	4,229	6,750	8,955	36,160	58,880	299,738
X	264	298	4,590	9,195	7,425	9,450	10,471	19,691	24,960	45,961
XI	473	533		510	1,974	2,700	42,571	97,381	96,480	150,814
XII	473	558	30,510	27,244	29,603	46,305	46,291	105,616	109,280	170,548
CARAGA										
ARMM										

Tiger Prawn Data Set Production (PhP '000)

Prawn Production by Region	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
NCR	9,517	86,468	102,592	7,161	17,404	22,320	19,530	3,150	280	300
CAR										
I	534,186	119,611	199,600	68,101	213,563	172,509	99,006	62,038	50,237	53,985
II	4,436	2,086	2,099	5,962	15,317	23,570	32,250	31,280	19,421	21,020
III	2,622,789	2,766,484	2,103,275	6,288,660	6,177,432	6,104,565	5,755,269	5,514,867	5,270,369	5,468,287
IV	1,100,329	130,435	351,972	673,293	500,402					
IV-A						207,815	326,137	367,726	230,198	156,155
IV-B						141,510	158,690	208,001	306,245	280,727
V	207,410	331,392	239,485	215,304	197,286	151,449	100,517	90,357	114,126	125,419
VI	2,911,052	6,607,252	9,529,625	7,874,360	6,592,896	4,504,355	772,379	428,139	264,742	388,483
VII	63,424	670,096	770,429	452,281	1,011,331	1,304,837	711,527	807,597	590,051	696,888
VIII	96,146	91,615	90,059	41,299	94,822	81,363	56,435	50,870	51,942	51,046
IX	291,466	507,455	627,888	1,437,244	1,332,116	1,307,823	1,027,249	1,156,105	1,819,835	2,243,169
X	51,544	392,341	471,223	256,103	366,157	1,892,585	1,861,274	1,790,442	1,738,088	1,763,943
XI	177,036	559,865	281,904	1,124,018	1,247,426	204,297	27,895	7,469	12,814	9,881
XII	177,233	207,339	849,698	564,646	1,245,169	1,519,292	141,357	130,291	90,160	111,740
CARAGA				20,067	6,281	385,850	288,764	308,130	243,379	349,200
ARMM				312,708	313,309	16,433	48,450	50,405	58,290	71,060

APPENDIX D (continued)

Tiger Prawn Data Set Fry Source (PhP '000)

Prawn Fry requirements	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
NCR	17	17	17	16	23	29	36	44	54	23	29
CAR											
I	110	112	113	103	153	189	233	288	355	153	179
II	3	3	3	2	4	4	5	7	8	4	4
III	444	453	458	416	619	763	941	1,161	1,431	617	712
IV	198	202	204	186	276	340	420	518	638	275	318
IV-A											
IV-B											
V	61	62	63	57	85	105	129	159	196	85	100
VI	601	614	620	564	839	1,034	1,276	1,574	1,940	837	955
VII	44	45	45	41	61	76	93	115	142	61	71
VIII	48	49	49	45	67	82	101	125	154	67	78
IX	101	103	104	95	141	174	214	264	325	140	163
X	30	30	31	28	41	51	63	78	96	41	49
XI	30	30	31	28	41	51	63	78	96	41	49
XII	43	44	44	40	60	73	91	112	138	59	67
CARAGA											
ARMM											
Total Tiger Prawn Fry											
Tiger Prawn Fry Gatherering	1,728	1,764	1,782	1,620	2,410	2,675	2,932	3,165	3,345	1,202	1,110
Tiger Prawn Fry Hatchery						297	733	1,356	2,230	1,202	1,665

Tiger Prawn Data Set Fry Source (PhP '000)

Prawn Fry requirements	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
NCR	1,903	17,294	20,518	1,432	3,481	4,464	3,906	630	56	60
CAR										
I	106,837	23,922	39,920	13,620	42,713	34,502	19,801	12,408	10,047	10,797
II	887	417	420	1,192	3,063	4,714	6,450	6,256	3,884	4,204
III	524,558	553,297	420,655	1,257,732	1,235,486	1,220,913	1,151,054	1,102,973	1,054,074	1,093,657
IV	220,066	26,087	70,394	134,659	100,080					
IV-A						41,563	65,227	73,545	46,040	31,231
IV-B						28,302	31,738	41,600	61,249	56,145
V	41,482	66,278	47,897	43,061	39,457	30,290	20,103	18,071	22,825	25,084
VI	582,210	1,321,450	1,905,925	1,574,872	1,318,579	900,871	154,476	85,628	52,948	77,697
VII	12,685	134,019	154,086	90,456	202,266	260,967	142,305	161,519	118,010	139,378
VIII	19,229	18,323	18,012	8,260	18,964	16,273	11,287	10,174	10,388	10,209
IX	58,293	101,491	125,578	287,449	266,423	261,565	205,450	231,221	363,967	448,634
X	10,309	78,468	94,245	51,221	73,231	378,517	372,255	358,088	347,618	352,789
XI	35,407	111,973	56,381	224,804	249,485	40,859	5,579	1,494	2,563	1,976
XII	35,447	41,468	169,940	112,929	249,034	303,858	28,271	26,058	18,032	22,348
CARAGA				4,013	1,256	77,170	57,753	61,626	48,676	69,840
ARMM				62,542	62,662	3,287	9,690	10,081	11,658	14,212
Total Tiger Prawn Fry	1,764	1,782	1,620	2,410	2,972	3,665	4,522	5,575	2,405	2,774
Tiger Prawn Fry Gatherering										
Tiger Prawn Fry Hatchery	1,649,314	2,494,488	3,123,970	3,868,241	3,866,182	3,608,115	2,285,346	2,201,373	2,172,035	2,358,261

Tiger Prawn Data Set Fry Source (PhP '000)

Prawn Fry requirements	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
NCR	15	17						2,291	1,792	1,735
CAR										
I	345	404	6,840	26,308	38,720	58,725	64,201	128,350	120,480	103,688
II	11	12			56	108	220	430	608	548
III	1,129	1,403	10,332	211,488	234,179	344,790	225,998	382,115	385,856	610,722
IV	409	461	7,506	109,405	124,298	158,760	162,017	273,957	257,120	258,337
IV-A										
IV-B										
V	112	154	1,188	3,286	4,060	9,261	9,258	28,642	40,832	42,633
VI	1,124	1,312	129,888	84,323	81,180	157,734	395,620	596,784	502,368	671,228
VII	90	109	90	375	620	4,212	4,298	9,416	11,872	12,392
VIII	86	116	4,212	5,790	7,030	8,829	8,928	13,748	14,400	21,082
IX	185	208	90	443	846	1,350	1,791	7,232	11,776	59,948
X	53	60	918	1,839	1,485	1,890	2,094	3,938	4,992	9,192
XI	95	107		102	395	540	8,514	19,476	19,296	30,163
XII	95	112	6,102	5,449	5,921	9,261	9,258	21,123	21,856	34,110
CARAGA										
ARMM										
Total Tiger Prawn Fry									1,692	1,728
Tiger Prawn Fry Gatherering	1,125	895	16,717							
Tiger Prawn Fry Hatchery	2,624	3,580	150,449	448,807	498,789	755,460	892,199	1,487,502	1,393,248	1,855,778

APPENDIX E: Computation results (see separately attached EXCEL file)

APPENDIX E (continued)

Sustainability, Efficiency and Resilience

Index values	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Milkfish										
Sustainability	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Efficiency	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.50	0.50	0.51
Resilience	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.50	0.50	0.49
Tiger Prawn										
Sustainability	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Efficiency	0.41	0.46	0.44	0.45	0.45	0.43	0.44	0.45	0.46	0.52
Resilience	0.59	0.54	0.56	0.55	0.55	0.57	0.56	0.55	0.54	0.48
Brackish-pond										
Sustainability	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Efficiency	0.52	0.52	0.52	0.53	0.52	0.52	0.53	0.53	0.53	0.53
Resilience	0.48	0.48	0.48	0.47	0.48	0.48	0.47	0.47	0.47	0.47
Absolute Values	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Milkfish										
Sustainability	6,433,885	5,519,563	5,574,230	5,612,060	6,379,178	6,000,223	6,354,168	6,570,870	6,733,665	7,420,768
Efficiency	2,749,335	2,790,777	2,819,479	2,838,803	3,226,288	3,034,356	3,213,919	3,299,282	3,383,192	3,769,737
Resilience	2,684,549	2,728,786	2,754,751	2,773,257	3,152,889	2,965,867	3,140,249	3,271,588	3,350,473	3,651,032
Tiger prawn										
Sustainability	90,939	96,787	110,806	116,115	128,357	151,825	191,388	217,672	264,848	144,034
Efficiency	37,633	44,552	49,196	52,810	57,729	64,993	85,151	98,959	122,747	74,226
Resilience	53,306	52,235	61,610	63,305	70,628	86,832	106,237	118,713	142,101	69,808
Brackish-pond										
Sustainability	5,677,193	5,802,078	5,898,097	5,990,508	6,736,643	6,392,492	6,852,413	7,128,463	7,402,501	7,909,161
Efficiency	2,936,653	3,018,330	3,078,981	3,151,205	3,509,975	3,338,577	3,606,999	3,742,686	3,919,275	4,191,963
Resilience	2,740,540	2,783,748	2,819,115	2,839,303	3,226,668	3,053,915	3,245,413	3,385,778	3,483,227	3,717,198

Sustainability, Efficiency and Resilience

Index values	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Milkfish										
Sustainability	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Efficiency	0.51	0.51	0.51	0.50	0.51	0.51	0.51	0.51	0.51	0.51
Resilience	0.49	0.49	0.49	0.50	0.49	0.49	0.49	0.49	0.49	0.49
Tiger Prawn										
Sustainability	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Efficiency	0.47	0.51	0.51	0.49	0.50	0.49	0.47	0.46	0.45	0.44
Resilience	0.53	0.49	0.49	0.51	0.50	0.51	0.53	0.54	0.55	0.56
Brackish-pond										
Sustainability	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Efficiency	0.52	0.53	0.53	0.63	0.64	0.63	0.63	0.63	0.61	0.60
Resilience	0.48	0.47	0.47	0.37	0.36	0.37	0.37	0.37	0.39	0.40
Absolute Values	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Milkfish										
Sustainability	8,588,232	11,566,850	13,479,121	13,189,817	15,948,093	22,455,826	26,712,161	25,589,889	29,069,566	30,750,987
Efficiency	4,347,600	5,877,745	6,846,874	6,624,802	8,165,964	11,383,905	13,507,810	13,067,245	14,893,079	15,797,582
Resilience	4,240,632	5,689,105	6,632,247	6,565,015	7,782,129	11,071,921	13,204,351	12,522,644	14,176,486	14,953,405
Tiger prawn										
Sustainability	157,978	185,763	245,029	8,102,293	18,789,236	21,165,324	33,689,992	43,243,051	73,292,792	69,949,276
Efficiency	74,687	94,269	124,535	3,972,718	9,388,358	10,362,990	15,891,262	19,857,277	32,796,190	30,432,269
Resilience	83,291	91,494	120,494	4,129,575	9,400,878	10,802,334	17,798,730	23,385,774	40,496,601	39,517,006
Brackish-pond										
Sustainability	9,065,734	12,154,046	14,279,351	25,013,172	43,609,467	55,141,489	74,883,086	80,598,378	116,753,700	116,775,359
Efficiency	4,747,790	6,382,521	7,540,571	15,700,940	28,105,560	34,961,228	46,911,385	50,420,220	71,083,963	70,211,762
Resilience	4,317,944	5,771,525	6,738,779	9,312,232	15,503,906	20,180,261	27,971,701	30,178,157	45,669,737	46,563,597

Sustainability, Efficiency and Resilience

Index values	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Milkfish											
Sustainability	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Efficiency	0.53	0.52	0.50	0.49	0.49	0.50	0.49	0.49	0.47	0.48	0.49
Resilience	0.47	0.48	0.50	0.51	0.51	0.50	0.51	0.51	0.53	0.52	0.51
Tiger Prawn											
Sustainability	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Efficiency	0.44	0.43	0.46	0.47	0.46	0.46	0.46	0.48	0.48	0.54	0.52
Resilience	0.56	0.57	0.54	0.53	0.54	0.54	0.54	0.52	0.52	0.46	0.48
Brackish-pond											
Sustainability	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Efficiency	0.61	0.60	0.61	0.62	0.60	0.60	0.60	0.61	0.60	0.63	0.63
Resilience	0.39	0.40	0.39	0.38	0.40	0.40	0.40	0.39	0.40	0.37	0.37
Absolute Values	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Milkfish											
Sustainability	39,331,920	43,758,866	36,731,104	33,978,431	46,077,941	46,982,442	52,475,515	52,284,125	50,045,869	55,067,313	65,055,401
Efficiency	20,795,165	22,899,448	18,290,437	16,792,778	22,483,382	23,410,727	25,743,461	25,504,585	23,642,053	26,478,053	31,834,331
Resilience	18,536,755	20,859,418	18,440,667	17,185,653	23,594,559	23,571,714	26,732,054	26,779,540	26,403,816	28,589,260	33,221,070
Tiger prawn											
Sustainability	92,079,677	83,838,494	123,457,946	152,233,243	184,599,657	184,682,936	166,977,505	96,615,877	91,444,339	79,148,028	89,358,055
Efficiency	40,545,793	35,961,565	56,549,673	71,974,379	85,400,798	84,060,639	76,552,813	46,012,045	43,863,992	42,954,399	46,829,881
Resilience	51,533,883	47,876,929	66,908,273	80,258,864	99,198,859	100,622,296	90,424,692	50,603,832	47,580,347	36,193,630	42,528,174
Brackish-pond											
Sustainability	152,562,795	150,447,287	172,745,770	190,877,304	248,752,445	254,708,948	252,644,516	188,831,132	181,222,110	177,984,600	203,588,036
Efficiency	93,043,820	90,950,625	105,154,642	117,507,757	149,578,274	151,721,930	150,515,555	114,379,566	108,373,229	112,983,905	128,393,949
Resilience	59,518,976	59,496,662	67,591,128	73,369,547	99,174,171	102,987,018	102,128,961	74,451,566	72,848,881	65,000,695	75,194,087