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PAPUSSA

Production in Aquatic Peri-Urban Systems in Southeast Asia

**<u>Title</u> : AN ASSESSMENT OF THE SUSTAINABILITY OF TILAPIA CULTURE IN CENTRAL THAILAND**

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## TITLE : PRODUCTION IN AQUATIC PERI-URBAN SYSTEMS IN SOUTHEAST ASIA

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**CONTENTS**

## 1 INTRODUCTION

The Nile tilapia *(Oreochromis niloticus)*, is arguably the most significant of Thailand's cultured freshwater fish species. Tilapia contribute around one third of all freshwater fish farm production (DOF, 2005) and are grown in every Thai province (Falvey, 2000) in a range of water bodies that includes ponds, rice fields, irrigation ditches, canals, rivers and reservoirs (Dey at al, 2005). Production systems for tilapia are probably also more diverse than those for any other fish cultured in Thailand, in terms of their intensity and their role in the agro-ecologies that they occupy. As a product, the fish occupies a broad range of markets from low-value staple food to high-end cuisine (Fitzsimmons, 2004). Tilapia production and marketing systems in Thailand are highly dynamic and have diversified significantly over the past decade, with the emergence of trends including; contract farming, manipulation of physical characteristics, use of formulated feeds, live sale, and processing and distribution by mobile traders (Belton et al, 2005). Production of tilapia is associated with both rural and peri-urban environments, has evolved in part in response to the resources and constraints that each generates, and is dependent on transport, communications and market linkages between the two. Tilapia culture therefore supports a variety of livelihoods in a dynamic landscape and produces, and is produced by, change within this setting (Little & Edwards, 2003, Robbins, 2004). Central Thailand is the country's major tilapia producing region. It is also its most affluent and urbanized (Table 1) As a result, land use and livelihoods here are prone to extremely rapid change and development (Yoonpundh et al, 2005, Greenberg, 1994).

**Table 1 Tilapia production by region** (DOF, 2005, NSO, 2005)

| Region | Central | Southern | Northern | Northeastern | Kingdom |
|---|---|---|---|---|---|
| **Population living in municipal area (%)** | 51 | 22 | 19 | 15 | 29 |
| **Monthly per capita income (Bt)** | 6583 | 3900 | 3455 | 2680 | 4237 |
| **Tilapia production as % of total** | 51 | 3 | 23 | 22 | 100 |

Despite the important role played by tilapia culture in Central Thailand, there is to date a very limited literature documenting and accounting for its status and implications. A study of tilapia farming in the Central Region therefore represents an opportunity to evaluate the nature of changes occurring within this dynamic agricultural sub-system and their consequences for the livelihoods of associated actors. It also offers the chance to contextualize these changes within broader circuits of macro and meso scale-economic, social and ecological change and development in which they are embedded. A number of key ideas from the discourse of sustainable development provide analytical tools with which to evaluate the nature of tilapia culture systems and their relationship with agrarian and urban change. The concept of sustainability therefore provides a practical framework with which to compare the qualitatively different elements of tilapia culture systems - human, technical, institutional, financial, commercial, and biological. Moreover, the traditional connotation of the term sustainable – the ability of something to persist indefinitely – may be of critical importance to those whose livelihoods depend on tilapia production.

The study explores two premises in detail; that a) the location, and b) the intensity, of tilapia culture systems are likely to play an important role in determining their sustainability. Central Thailand is undergoing rapid economic transformation and growth. According to Greenberg (1994), this has resulted in a 'chaotic tapestry of urban and rural landscape', and generated severe economic and environmental pressures on the Region's agricultural sector which bring its long term viability into question. These two issues therefore warrant detailed attention, and are the focus of much of the research presented in this report. Additionally, a considerable literature casting a variety of intensive aquaculture practices as unsustainable exists (e.g. Weber, 2003, Naylor et al, 1998, Belton, 2004). Such an exploration is timely since certain sectors of tilapia culture in Thailand are intensifying, and Naylor et al (2000) express concern that widespread intensification of herbivorous fish culture could have serious negative environmental consequences.

In order to achieve this goal this report is arranged as following: An overview of tilapia culture and culture systems in Thailand is given in Chapter Two. Sustainability is examined and defined in Chapter Three. Methodology informing the research and analysis contained in this report is explained and justified in Chapter Four. Chapters Five to Seven present fieldwork results and analysis as composite case studies, organized under the following titles 'Region Based Urbanization and Livelihoods', 'Farm Economics', 'Environment'. Chapter Eight offers discussion pertaining to the significance of these results with reference to criteria for sustainability.

## 2 THE HISTORY AND STATUS OF TILAPIA CULTURE IN THAILAND

The Nile tilapia was introduced to Thailand in 1965 as an official gift to the King, and was subsequently distributed to farmers by the Department of Fisheries (DOF) through government run fisheries stations. This effort was successful in part because the fish performed well in the traditional greenwater polyculture systems operated by ethnic Chinese who were major practitioners of aquaculture at the time. The fish was popular for its high reproductive and growth levels, ease of culture, robustness, tolerance of a range of environmental conditions, and its palatability (Falvey, 2000). Although high rates of self-recruitment were originally seen as one of the Nile tilapia's most valuable characteristics, the sub-optimal growth and low or variable size (and market value) of mixed-sex tilapia acted as a constraint to commercial development of the species and led to efforts to develop all-male fish (Little & Edwards, 2004). Work on broodstock management regimes conducted at the Asian Institute for Technology (AIT) in the late 1980s and early 1990s made sex reversal of fry viable on a commercial scale (Little et al, 1995). Since this time all male fish, which grow more rapidly and to larger sizes than populations of mixed sex fish, have been adopted by increasing numbers of farmers. Availability of the two alternatives has widened the range of management choices available to producers (Belton et al, 2005). Since the 1980s, private hatcheries have come to dominate fry production, largely superseding DOF in this role. Another notable change has been the introduction of the GIFT strain of tilapia developed by an Asian Development Bank (ADB) and United Nations Development Fund project. The fish, which reportedly exhibits superior performance to traditional strains, have also been widely adopted (ADB, 2005).

Promotion of a strain of red tilapia (*Oreochromis spp*.) by the agro-industrial conglomerate Charoen Pokphand (CP) is another significant development. CP introduced a contract farming system for red tilapia (the first of its kind in Thailand for a freshwater fish) in 1999. The company produces red tilapia fry and formulated feeds which are provided to farmers for growout in cages at high densities. Contract production is managed by feed dealerships affiliated to CP. Dealership staff harvest fish for their customers when they attain a relatively large size, typically 700-1000g. These are marketed live, commanding a significantly better price than pond raised Nile tilapia. The popularity of red tilapia among producers and consumers has grown rapidly since the introduction of the contract farming, and cage culture now claims a significant portion of the tilapia market, accounting for as much as 10% of total production. More recently, other feed companies operating in a similar manner have entered the market, and independent farmers buying seed and feed from other sources have increased in number (Mariojoules et al, 2004).

The majority of Nile tilapia production in Thailand continues to take place in greenwater polycultures. These contain a variety of herbivorous/omnivorous species which obtain nutrients from blooms of phytoplankton produced by fertilizing pond water with manure or alternatives. Stocking several herbivorous species with complementary or minimally competing feeding habits and different ecological requirements, is intended to facilitate efficient utilization of nutrients inputs, resulting in maximum fish production for given input quantities (Sharma et al, 1999). Tilapia are typically the most important polyculture species by volume, with other popular co-cultured species including silver barb (*Barbodes gonionotus*), rohu *(Labeo rohita)*, Chinese major carps and silver striped catfish (*Pangasianodon hypophthalmus*). Management regimes are extremely diverse, depending on the knowledge, resources and opportunities available to farmers, and vary in terms of species mix, stocking density, pond inputs and supplementary feeds, culture periods, size and value of fish at harvest, and marketing strategies. Supplementary feeds are used to improve growth rates, and include agricultural byproducts (e.g. rice bran, low grade maize), organic residues from industrial processes (e.g. fish sauce waste, brewery waste), waste food from canteens and, more recently, commercial formulated animal and fish feeds (Belton and Little 2006a).

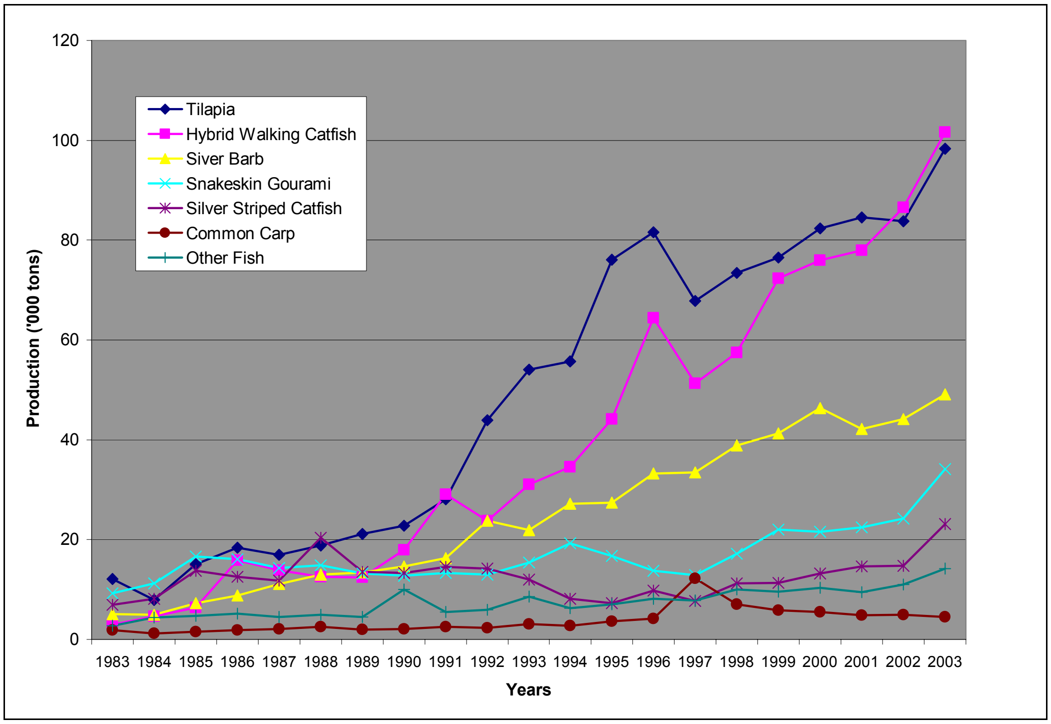


**Figure 1Selected Thai freshwater fish farm production, 1983-2003** (DOF, 2004, 2005)

Most pond based tilapia culture can be considered either directly or indirectly integrated. Integrated aquaculture links fish production to other human activities in order to capitalize on their byproducts, and is defined by Edwards (1998) as the 'concurrent or sequential linkages between two or more human activity systems (one or more of which is aquaculture), directly on-site, or indirectly through off-site needs and opportunities, or both'. In Central Thailand, directly integrated tilapia culture typically involves locating fish ponds underneath or next to feedlots for intensively reared poultry, allowing manure to fertilize algal blooms in the pond and spilt feed to be utilized as a supplementary food source. Indirectly integrated tilapia culture exploits organic byproducts from off-farm activities as fertilizers and supplementary feeds. Most of these inputs are cheap in comparison to commercial aquatic feeds, allowing tilapia to be produced at relatively low cost, a factor which contributes significantly to the fish's appeal to consumers. It is instructive to consider wastes utilized for fish culture as 'resources out of place' (Taiganides, 1979). The rapid expansion of tilapia production post 1990 (Figure 1) is in large part due to the increasing availability of these resources, farmer access to them, and improving access to markets (Belton et al, 2005). These factors, have made Central Thailand the country's most important site for tilapia aquaculture; a result of the intensive and diversified of agriculture found in the region, the industrial processing of agricultural goods, favourable climatic and bio-physical factors, excellent irrigation and road networks (Figures 2 and 3), and proximity to large and relatively affluent markets in Bangkok and the surrounding provinces. It should also be noted that the vast majority of Thai tilapia is produced for domestic consumption, although modest amounts are exported, whole frozen or as fillets, to markets in Australia, the Middle East, Europe and the USA (Belton and Little, 2006b).


**Figure 2 Road and water networks in Central Thailand** (www.multimap.com)

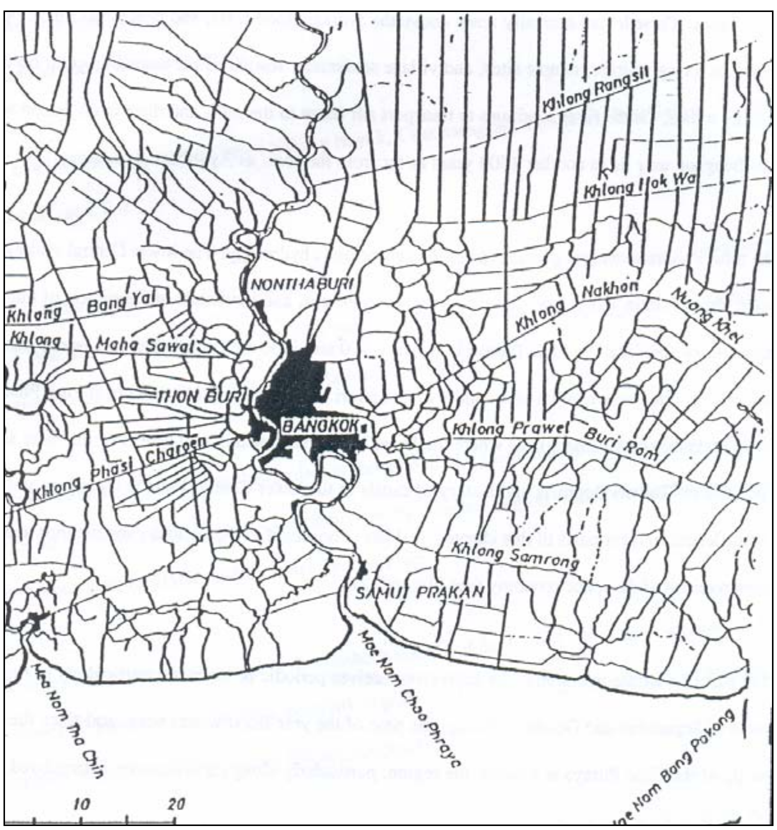


**Figure 3 Canals in the Greater Bangkok Metropolitan area** (Donner, 1978)

## 3 SUSTAINABILITY

As noted in Chapter One, the sustainability is used throughout this study as a framework under which to draw together, compare, and provide an account of the qualitatively different elements which together make up tilapia culture systems. A brief examination of the general concept of sustainability and its specific applications in this report is given below to provide clarity to the reader.

### 3.1 Defining Sustainability

Almost all conceptions of sustainability have as their basis a number of core elements, all of which are directly relevant to this study:

**1)** They involve the understanding that the environmental, social and economic aspects of any system are inextricably bound together and are ultimately dependent on one another (Fresco & Kroonenberg, 1992).

**2)** There is recognition that sustainability 'is not a fixed state of harmony, but rather a process of change… consistent with future as well as present needs' (WCED, 1987).

**3)** Sustainable development should foster equity within and between generations (e.g. WCED, 1987). Systems which will lead to increasing disparities or reductions in human welfare, either immediately or in the future, are therefore not likely to be sustainable. Opinions differ sharply as to whether or not overall declines in environmental quality (natural capital) are acceptable providing that total capital stock (economic and natural) available to humanity is maintained[1]

**4)** Sustainability has spatial and temporal elements: spatial in the sense that the boundaries of any system assessed for its sustainability must be defined, and temporal in that the choice of time scale over which a system is assessed may dramatically affect conclusions about its sustainability (Bell & Morse, 1999)

| Approach | Summary |
|---|---|
| **Food miles** | Analyzes the environmental costs to the farmgate for food commodities, the additional environmental costs of transporting foods to retail outlets, and then to consumers' homes, and the cost of disposal of wastes [1] |
| **Ecological footprints** | Takes a "strictly utilitarian view on society–nature interaction by comparing the amount of bio-productive area available to the amount required to maintain the resource flows of a defined human population" [2] |
| **Life cycle assessment** | Calculates indicators of environmental impacts linked to products and supports the identification of opportunities for pollution prevention and reductions in resource consumption [3] |

**References**: 1. Pretty et al, 2005, 2. Editorial, 2004, p195, 3. Rebitzer et al, 2004
**Table 2 Approaches to measuring sustainability**

Sustainability requires measurement in some way if it is to be recognizable, yet meaningful measures of sustainability are elusive because it represents the sum of a vast number of possible interactions between biophysical and human factors. Proxies, commonly referred to as sustainability indicators, are therefore employed for this purpose. Use of indicators may be problematic however since selection of a relatively small number as the basis with which to describe the total state of a complex system is liable to generate oversimplification and misrepresentation. Furthermore, "scoring systems including social, economic and environmental components have the problem that the choice of components and the

[1] For an example of the former 'strong' view of sustainability see Goodland & Daly (1996), for an example of the latter 'weak' view see Barbier (1997)

assignment of weight are subjective and that the aggregation of different dimensions is often not meaningful" (Heuting & Reijnders, 2004). A selection of methods for enumerating and expressing sustainability in ways relevant to this study are summarized in Table 2. Although some of these approaches have been applied to aquaculture (see for instance Tydemers, 2000, and Kautsky et al, 1997 for ecological footprint analysis, Folke et al, 1998 for life cycle assessment), each has as its central focus the measurement of anthropogenic impacts of the environment, and fails to adequately address the kind of everyday social and economic realities that determine livelihood sustainability for actors in tilapia culture systems.

The sustainable livelihoods framework (SLF, Figure 4) deals with these issues more explicitly, concerned as it is with 'putting people at the centre of development' (DFID, 2001, 1.1). The framework views people as operating in a context of vulnerability. Livelihoods are conceived as being comprised of 'the capabilities, assets (including both material and social resources) and activities required for a means of living' Carney (1998). Assets, or different types of 'capital', mediate the ability of individuals, households or communities to resist the shocks, trends and seasonal events that make them vulnerable. They also determine what 'livelihood strategies' are available to them. These strategies are also influenced by 'structures' (e.g. markets, government agencies) and 'processes' (e.g. cultural norms and laws). In totality, the interaction of these factors generates 'livelihood outcomes'. Increased income and wellbeing, reduced vulnerability, improved food security, and more sustainable use of the natural resource base are viewed as desirable livelihood outcomes.

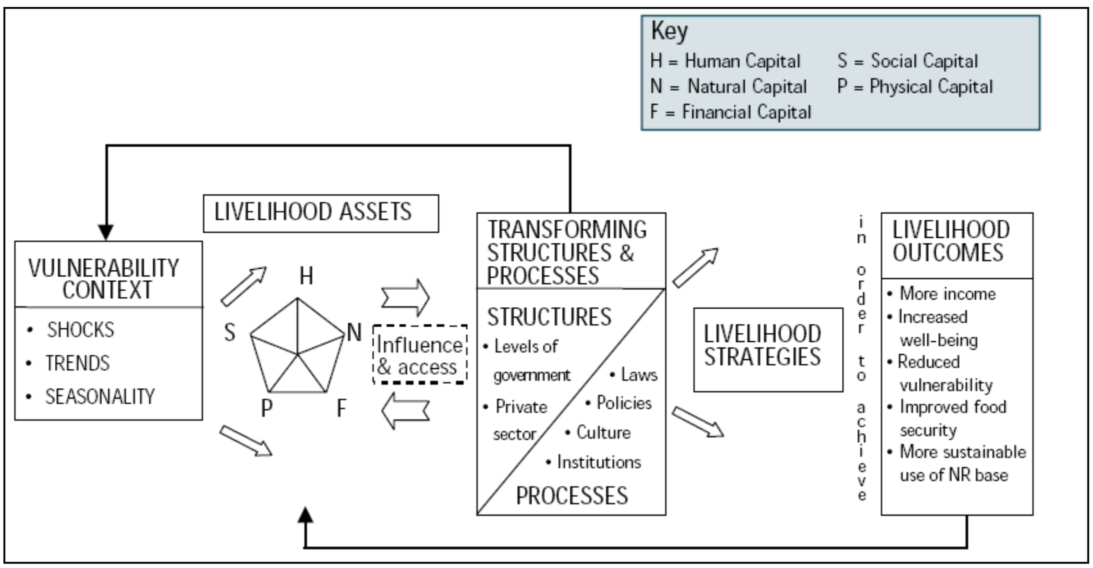


**Figure 4 The Sustainable Livelihoods Framework** (DFID, 2001)

Under the SLF, 'a livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base' (Carney, 1998). This definition comes closer to reflecting the realities of what sustainability means to the actors in tilapia production and marketing systems than any other reviewed during this study. However, tilapia culture systems by nature include a large biological component which the SLF is unable to fully account for. A suite of participatory research methods are usually associated with the SLF. These are designed with the explicit goal of including and privileging stakeholders whose livelihoods are under consideration in creation of knowledge pertaining to their situation (Bell & Morse, 1999). Whilst this stance has many benefits, it was unfortunately beyond the limitations of this study to apply these techniques effectively.

### 3.2 Sustainability in Aquaculture

Sustainability has become an important issue in aquaculture (in part because of the criticisms leveled at intensive production systems by environmental NGOs), and a number of books and symposia have tackled the issue (e.g. Bagarinao & Flores, 1994, Reinertsen & Haaland, 1995, Svennevig et al, 1999). These efforts have a tended to focus on environmental management issues (e.g. Boyd & Schmittou, 1999), although explanations with a broader development led focus exist (e.g. AIT, 1994, Figure 5). Accounts such as these have a tendency to be partial however, and do not thoroughly integrate the range of factors that together determine total system sustainability. Additionally, assertions on sustainability made by bodies within the aquaculture industry may be unhelpful. For example, New's (2003) statement that sustainable aquaculture 'is profitable aquaculture with a conscience' is both vague and uninstructive.

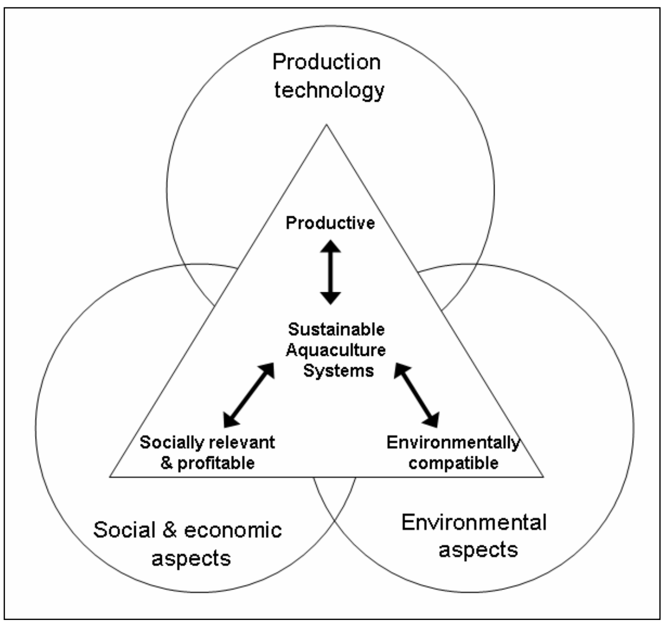


**Figure 5 The three inter related aspects of sustainability in aquaculture systems: production technology, social and economic aspects, and environmental aspects** (AIT, 1994)

It is should be clear from the previous section that numerous definitions and perceptions of what constitutes sustainability exist, underlining the subjective nature of the concept, and it has been argued that the term needs to be interpreted and refined on a case-by-case basis (Kaiser, 2000). Therefore, rather than rely on an existing definition of sustainability or model for measuring it, this study will attempt to qualify the sustainability of different tilapia culture systems in Central Thailand on the basis of criteria that reflect their specific characteristics. Furthermore, it should be noted that this research is not concerned with the sustainable development of tilapia culture systems *per se*, (i.e. with determining ways in which tilapia culture systems could be tempered by political action to ensure their sustainability in the long term), since such an objective is probably unrealistic given the unregulated circumstances under which culture occurs. Rather, it represents an attempt to document the overall state and range of effects of different tilapia culture systems, to assess their likely trajectories in the immediate future and to understand their role in the broader development context.

## 4 METHODOLOGY

As noted in 3.1, due to the differing emphases and methodological requirements of approaches to sustainability and the limits within which this study was conducted, a composite approach which draws on the conceptual underpinnings of several models for sustainability is adopted here. Mollenhorst (2005, p9) states that 'assessment of the contribution of animal production systems to sustainable development implies four steps: (1) description of the situation; (2) definition of relevant economic, ecological and societal issues; (3) selection and quantification of suitable sustainability indicators; and (4) final assessment of the contribution to sustainable development'. Chapters One and Two have already briefly described the situation pertaining to tilapia culture in Central Thailand. This Chapter defines relevant sustainability issues and the selection of sustainability indicators, details the research methods used to obtain data relating to them, and sets out the rationale for analysis of this information. The following chapters provide and overarching description and assessment of the sustainability of tilapia systems in Central Thailand.

As indicated above, at the outset of the research it was necessary to identify issues considered likely to influence sustainability in tilapia systems. The four key sustainability issues selected as relevant to this task are summarized in Table 3, and form the basis of the cases studies presented in Chapters Five to Seven. A range of indicators were selected to build a picture of land use in the vicinity of farms in order to assist understanding of their characteristics and the pressures or influences that region based urbanization might exert on tilapia systems and the livelihoods of those involved in them. Farm profitability was taken to be a key issue in determining livelihood viability, and a range of economic factors which might affect it were chosen accordingly. The impact of tilapia culture on the environment and vice versa is another critical area given the focus of the study, and several indicative characteristics of culture systems were selected accordingly. Finally, a variety of other issues that potentially impacted livelihoods were investigated using indicators intended to provide a picture of the relative importance of tilapia culture in producer livelihood portfolios and assess the activity's likely role in long term developmental trends. In practice, urbanization and livelihood issues were found to be intimately linked, and the two are analyzed together in Chapter Five.

| Key Issues | Key Indicators |
|---|---|
| Region based urbanization | Predominant land uses near farm, Changes in land use near farm, Distance to amenities, Degree of urbanization, Marketing, Labour, Land tenure |
| Farm economics | Returns on investment, Cost of inputs, Product value, Land rental costs, Loss of income, Product harvest and marketing arrangements |
| Environmental issues | Culture system, Type & quantity of inputs used, Stocking density, Length of growout cycle, Yield, Monosex or mixed-sex production, Disease, Pollution |
| Livelihood issues | Age, Former occupation, Children's occupation, Alternative income generating activities, Education, Credit |

**Table 3 Key sustainability isues and indicators of tilapia producers**

These issues and indicators are bound to the economic, ecological and societal aspects of sustainability. Farm profitability issues relate principally to economic sustainability, environmental issues relate principally to ecological sustainability, livelihood issues relate principally to societal sustainability, and region based urbanization relates to a combination of all three. However, it should be recognized that given the interconnectivity of these spheres rigid categorization may be unhelpful. For example, although the type of inputs used in fish culture have major environmental ramifications they also impact the economics of production and marketing, thereby strongly influencing farmer livelihood strategies and consumer access to aquaculture products. The research was also intended to reflect some of the aspects of sustainability intrinsic to the SLF, and the exploration of certain themes had multiple purposes. For instance; questions aimed at drawing out long term shifts in the cost of farm inputs and seasonal fluctuations in price and productivity related not only to farm profitability, but to the vulnerability context in which farmers operate. Particular attention was also paid to discerning temporal patterns of change in the state of each indicator in order to develop a picture of the general direction in which system sustainability was progressing rather than a snapshot limited to a single point in time. Once key issues and their indicators had been determined, primary research was conducted in two main phases; field work and administration of a closed questionnaire.

**4.1 Rapid Appraisal**

Most data was collected using a 'rapid appraisal' approach. According to Greenberg (1994) rapid appraisal has the following features: triangulation, inter-disciplinarity, flexibility, informality, qualitative description, and is cyclical. This made it an ideal research method for the purposes of this study. Interviews with many different stakeholders in tilapia culture and marketing systems allowed the perceptions and observations of respondents to be cross checked for validity and accuracy. The selection of such a broad range of sustainability indicators and issues for investigation made an interdisciplinary approach essential. Flexibility allowed for decisions regarding field work to be made on an ad-hoc basis (e.g. if a visit in a particular locale not yielding useful information the choice was usually made to visit an alternative site, and any passing opportunity that arose to communicate with new informants was taken). The relaxed and friendly nature of most interviews meant that more and different information was elicited than might have been possible in a more formal setting. Observation of landscapes and peoples' behavior throughout the duration of the research period helped to construct a more qualitative understanding of the issues at stake than would be possible from reliance on literature and raw data alone. The cyclical nature of rapid appraisal made it possible to adjust and refine the focus of research as new trends and ideas emerged. Finally, as the name suggests, the approach is designed to generate as much information as possible within a limited timeframe. This was of key importance to this study as the main body of field work took place over the course of six weeks. The enactment of a rapid appraisal is based largely on three core techniques; semi-structured interviews, direct observation, and use of secondary data. All of these played an important role. Use of questionnaires usually falls outside the purview of rapid appraisal because of their rigid nature, but it was decided that use of a questionnaire during field visits to farmers would be helpful in generating standardized quantitative information, and to serve as a point of entry into more detailed semi-structured interviews. A questionnaire was also administered to customers of a tilapia hatchery in order to elicit supporting information.

The first research phase involved 13 days of field visits to stakeholders in tilapia production and marketing systems in Central Thailand. Questionnaires based on the indicators listed above were used to gather information from farmers engaged in semi-intensive (pond based) and intensive (cage based) aquaculture. Questions were revised during the initial stages of fieldwork to arrive at a format that interviewees could easily respond to, and to take into account emerging information that had not been anticipated at the design stage. The questionnaires were intended to elicit a standard set of responses from each informant which could be easily compared. Farmers' responses to these basic questions provided a point of entry from which more qualitative interviews commenced. These were aimed at drawing out detail, exploring points of interest and trends that had emerged during administration of the questionnaire, and cross referencing opinions and statements given by other informants. This format made it possible to construct a far more detailed picture of the livelihoods of individual farmers and characteristics of the systems under scrutiny than would have been possible with only the questionnaire.

Thirty four pond farmers and 12 cage farmers from close to 20 districts in 11 provinces of Central Thailand were interviewed during this stage of the field work. In most instances an area where fish culture was known to occur would be visited and occupants of fish farms visible from the road would be asked to participate. Other interviewees were identified by key informants (staff from two tilapia hatcheries, and questionnaire respondents) and contacted by telephone prior to home visits. Five interviews were carried out by telephone where it was not possible to make field visits. Site selection for interviews was made on the basis of knowledge of areas where tilapia culture was known to occur, and on the degree of urbanization believed to be evident in these settings. Attempts were made to ensure that farmers operating as broad and representative a range of systems as possible were interviewed. Fewer cage farmers were approached because of the lower diversity of management techniques employed and more limited geographical distribution of the activity relative to pond farming. Interviews with marketing participants and other stakeholders organized somewhat differently. Given the variety of activities they were engaged in it was not possible to design a standard questionnaire, and because most were approached at markets whilst they were working it was usual to engage in lengthy discussions. Interviews were therefore generally brief and unstructured. A total of 21 marketing participants and stakeholders were interviewed in several provinces. See Appendix 1 for a complete list of interview dates and locations.

Working in association with a large commercial monosex tilapia hatchery (Nam Sai Farm) provided the opportunity to access its customer base. A short questionnaire was designed which would yield information relevant to this study in addition to being of commercial interest to the farm. Sixty questionnaires were administered by staff to customers purchasing fry at the farm's two branches in Prachinburi and Nakorn Pathom. In this way it was possible to dramatically increase the volume of information obtained and broaden spatial distribution of respondents. The questionnaire is a modified version of that used during the field work. Some questions were rephrased in light of experience with the earlier questionnaire in order to improve respondent comprehension. It was shortened because customer visits to the farm are brief, and its emphasis was largely on technical and economic aspects of production, reflecting Nam Sai farm's interests. Most questions are completely closed to assist rapid administration and data processing. Some results from the field work and customer questionnaires can be aggregated, whilst others provide complementary information, with the customer survey lending itself better to descriptive statistical analysis because of its design and larger sample size.

**4.2 Data Analysis**

Case studies form the primary unit of analysis in this study, and are intended to be broadly indicative of the state of the systems they describe. Data is qualitative, or of a semi-quantitative nature (i.e. quantitative data is used descriptively and is not subject to rigorous statistical analysis). This is because sustainability in this context is most appropriately defined as a qualitative problem given the relativity of the concept and difficulties inherent in meaningfully aggregating data relating to the economic, ecological and societal aspects of any system. Three composite case studies relating to the four key sustainability issues identified above are presented in Chapters five to seven: Region Based Urbanization and Livelihoods, 'Farm Economics' and 'Environment'. Chapter five has the broadest scope, covering a range of inter-related social, economic and cultural issues impacting livelihoods. These are understood here as being bound together by the overriding influence of Central Thailand's urbanization and analyzed accordingly. Chapter six, as the title suggests, deals with economic sustainability issues at the micro-level. Chapter seven addresses the impacts of different forms of tilapia culture on the environment and vice versa.

## 5 REGION BASED URBANIZATION AND LIVELIHOODS

An initial intention of this study was investigate and compare tilapia systems based in rural and peri-urban areas. Interviews were designed to reflect the hypothesis that each would be subject to different sets of pressures that would affect their sustainability. However, following preliminary analysis of results from field work, observations made whilst traveling between Bangkok and surrounding provinces, and a review of literature, it became apparent that these distinctions were problematic. There are difficulties inherent in the characterization of locations as either rural, or urban, and Allen (2003, p135) sees these distinctions as 'artificial' and potentially misleading. The growing recognition that patterns of development, particularly in Asia, do not reflect a neat rural/urban dichotomy has led to adoption of the expression "peri-urban". The term is used to describe the complex patterns of mixed land use (possessing some of the qualities of usually associated with both rural and urban environments) that have emerged adjacent to cities. Perhaps the most ubiquitous and symbolic image found in peri-urban areas around Bangkok is that of rice paddies nestling directly beneath the walls of new factories and housing estates. There is however, 'no universally accepted definition the term of peri-urban', and 'the transition or interface from rural to peri-urban to urban is regarded as a continuum' (Leschen et al, 2005, p2). This means that whilst representing a progression from over-simplistic conceptions of an unambiguous rural/urban divide, and describing a clearly observable phenomenon, the term remains vague and its meaning is subject to interpretation. This made it extremely difficult to characterize the areas visited during field work as definitively peri-urban or rural.

Edwards et al (2002) describe rural aquaculture as occurring in systems which meet the needs of, and fit the resources available to, small-scale farming households. Accordingly, the authors regard rural aquaculture in much of Asia as 'low cost extensive and semi-intensive husbandry for household consumption and income'. They also recognize that, 'rural aquaculture defies simple definition', and that more intensive systems of production are evident in rural areas (*ibid*, p324). In contrast, urban or peri-urban aquaculture is normally seen as more intensive and commercially oriented in nature as a result of constraints and opportunities including land prices and market access, although there are many examples of it becoming extensified for various reasons and 'urban [fish] production systems may be relatively distant from urban centers' (Little & Bunting, 2005, p25). It became obvious during the course of research that tilapia aquacultures practiced in most of the areas visited displayed many characteristics pursuant to both rural and (peri) urban aquaculture as defined above, although tended somewhat more towards the latter. Little & Edwards (1999) find that rural areas are typically nutrient poor, whilst peri-urban areas are nutrient rich, with corresponding effects on the forms of aquaculture that they support. However, little or no evidence emerged during field visits to suggest that farmers in locations most distant from Bangkok were constrained by lack of nutrient inputs to their systems, although the inverse may be true. Leschen et al, (2005) find that peri-urban aquaculture generally occurs in a more dynamic environment than that in rural areas and is therefore subject to a greater range of pressures, including conflicts over land and water use, which may threaten its long term existence. However, all the areas visited displayed transitioning land use to varying degrees and conflicts, or discords, between competing land and water users were evident in a range of locations and were not confined solely to provinces closest to Bangkok. Finally, Chunnasit et al (2000, p2) note that competition for natural resources use, but also complementarity in the production/consumption chain, are the two main trends which characterize urban – agriculture relationships. 'This specificity has been used as the basic guideline to define the peri-urban agricultural sector'. This observation, although incisive, brings us no closer to isolating rural aquaculture in the sites visited since it applies in some measure to all of them.

This is not to suggest that any of the characterizations made by the authors above is incorrect. Rather, it points to the conclusion that in Central Thailand it is difficult to distinguish precisely what constitutes rural and peri-urban and if indeed entirely rural provinces or districts persist. This contention is supported by Molle & Srijantr (1999), who find that high heterogeneity of agro-ecological and development conditions in the Central Region mean that it is difficult to draw conclusions from data aggregated at the regional or provincial level. Chunnasit et al (2000) go further, stressing that agricultural specialization is such that the *tambon* (sub-district) level is the most relevant unit of analysis for unveiling the heterogeneity of land use in any *Changwat* (province). In an extremely prescient PhD thesis, Greenberg (1994) employs an expression which is perhaps more usefully applied as a general descriptor of land use and dynamics in the Central region. The term 'Region Based Urbanization' (RBU) is used to describe 'an urban form which is emerging at Bangkok's edge, extending up to 100 kilometers from the central city, which is neither city nor countryside. It is a settlement system characterized by intense land use mix, where agriculture, industry, housing, and recreation all inflect upon each other'. Greenberg identifies 13 provinces as belonging to the Extended Bangkok Metropolitan Region (EBMR), five in an inner ring and eight in an outer ring. These are depicted in Figure 6. This study (conducted 12 years on and in the wake of an extended period of recession that followed the Asian economic crisis in the late 1990s) finds that at least three other provinces, Ang Thong, Nakorn Nayok, and Prachinburi, should be added to this list. The decision to adopt Greenberg's typology in this report by no means constitutes a rejection of the existence of either peri-urban or rural environments in the area studied. It is a reflection of the tendency for inaccuracies to arise when generalizations pertaining to either are made.

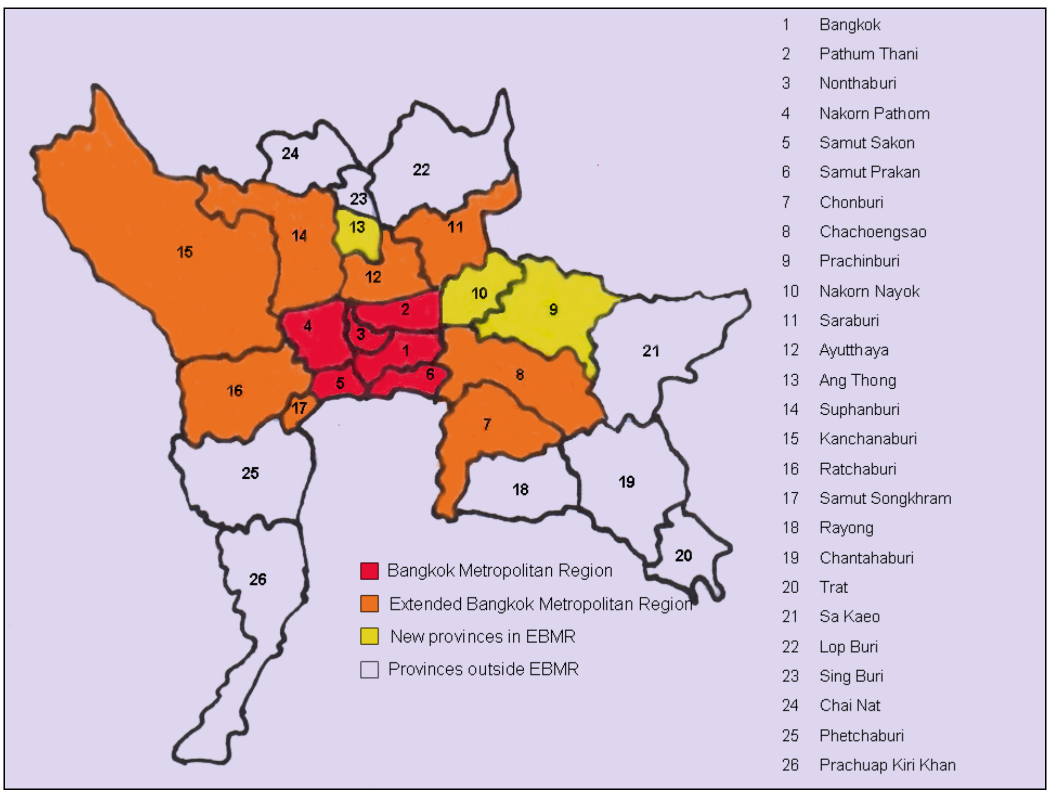


**Figure 6 The Bangkok Metropolitan Region and Extended Metropolitan Region**

An example derived from the field work is given below. Khlong 13 in Nong Sua, Pathum Thani was originally selected for a case study on red tilapia cage culture on the assumption that, being relatively close to Bangkok, it was a peri-urban area. 'Situated about 30 kilometers north of Bangkok, Pathum Thani province is one of the most dynamic suburban areas of Bangkok City…The economic structure of the province has changed dramatically during the last decade due to the relocations of industries from Bangkok. Pathum Thani is well connected with Bangkok Metropolis. This together with well-developed road network has added additional urban expansion pressure from Bangkok on the province' and led to high economic growth and rapid suburbanization (Hung & Yasuoka, 2000, pp3-4). Amphoe Bang Sang in Prachinburi Province and Amphoe Pramoke in Ang Thong Province were selected for the same purpose on the assumption that, being located 100km or more from Bangkok in provinces dominated by agriculture, they would display rural characteristics. A summary of selected provincial data which appears indicative of these characteristics is given in Table 4.

| **Province** | **Item** | | |
|---|---|---|---|
| | % of population in Municiple area* | % of population in agricultural sector* | % of population employed in factories† |
| Pathum Thani | 47 | 14 | 24 |
| Prachinburi | 17 | 39 | 11 |
| Ang Thong | 27 | 39 | 2 |

* Figures for 2000, † figures for 2003, adapted from NSO 2005

**Table 4 Selected provincial characterisitcs** (NSO, 2003, 2005)

In practice, when examined at district level these distinctions were far from clear cut (see Table 5). All interviewees in Pramoke considered the area to be urban, and land uses in the area and distance to amenities support this perception, showing it to be more urban than either of the other sites. The majority of respondents from Nong Sua considered the area rural. Almost all cage farmers in the amphoe had been, or still were engaged in activities in the agricultural sector prior to taking up red tilapia culture, and the location was visually the most rural of the three. This can be seen when the landscape in Figure 7 is carefully compared to that in Figures 8 and 9. All interviewees in Ban Sang felt that their farm was in a rural area, but only one had been employed in agriculture, the other two having worked in the service sector. There was noticeably more residential development evident in the surrounding area than in Nong Sua, and telephone masts, a large bridge, and a hospital chimney can all be seen in Figure 8.

| | **Distance to…. (km)** | | | | | |
|---|---|---|---|---|---|---|
| **Location** | Factory | 7-11[2] | Provincial market | Supermarket | Tambon office | Bangkok |
| Pramoke | 1 | 12 | 12 | 12 | 1 | 100 |
| Ban Sang | 8 | <1 | 20 | 50 | <1 | 100 |
| Nong Sua | 10 | 10 | 30 | 30 | 2 | 40 |

**Table 5 Distance to selected amenities**

[2] Seven-eleven is a large chain of franchised convenience stores in the style of an American mini-mart, selling prepackaged processed food and drink and other products

**Figure 7 Rural landscape, Pathum Thani**

**Figure 8 Mixed land-use, Ban Sang.**

**Figure 9 Cage farm, urban Pramoke**

### 5.1 Impacts of Region Based Urbanization on Tilapia Systems

Having established in section 5 that it is difficult to disaggregate rural and peri-urban areas within the Extended Bangkok Metropolitan Region, and that coexistence of the two can be explained by the concept of region based urbanization, 5.1 sets out to identify the relationships between RBU and tilapia systems, and implications for the sustainability of the latter, using composite case studies based on field work. A number of observations are advanced, and developed using secondary sources. Tilapia markets and marketing are discussed in this section because of the crucial role that RBU has played in their development.

#### 5.1.1 Diversification of agriculture

It is widely recognized that agriculture in the more urbanized provinces of Central Thailand has diversified away from traditional Thai rice monocultures to encompass a variety of agricultural practices including horticulture, orchards, intensive livestock, and aquaculture (Falvey, 2000, Molle & Srijantr, 1999, Greenberg, 1994). This shift was evident at numerous sites visited. In *Tambon* Kokprajadee in the Nakorn Chai Sri district of Nakorn Pathom province this change had been initiated by the arrival twenty years previously of six ethnic Chinese families. Originating from Talan Chan, Bangkok, they rented parcels of rice paddy which were converted to intensive vegetable and fruit culture by construction of ditches and raised dykes. Local rice farmers were hired as labourers and, having learnt culture techniques by doing so, began conversion of their own land in order to benefit from higher returns and cash flows. Creation of ditch/dyke systems provided an agro-ecological niche which was exploited for aquaculture (see 5.1.2 for a more detailed explanation).

In the adjoining heavily urbanized districts of Lat Krabang (Bangkok), Bang Phli and Ban Saothong (Samut Prakan) a direct progression from rice to fish culture had occurred over preceding 20-30 years. The Lat Krabang area was prone to flooding, limiting rice production to a single annual crop, and rice farmers began to switch to fish farming at an early stage in the development of Thai aquaculture. The fathers of middle-aged interviewees in Lat Krabang had all begun growing carps at low intensity using cut grass as feed. Another farmer in Ban Saothong began converting land from rice to fish production 24 years previously, starting with extensively grown carps, experimenting with new species and adapting management regimes over the years. He reported that most other farmers in the area had followed a similar path. One informant noted that fish culture had originally emerged in a single village in Bang Phli and gradually been transmitted to others in the district. The scale of this transition was remarkable in Samut Prakan, in which 80% of agricultural land was under fish culture (calculated from NSO, 2005a, 2005b, DOF, 2005). Respondents unanimously reported better incomes from fish culture than rice farming.

In the Bang Lane and Muang districts of Nakorn Pathom, and *amphoe* Muang and Bang Phae of adjoining Ratchaburi Province, land use transition from rice to fish had occurred via a number of pathways. In some cases conversion of paddy to fish pond had been direct. Many respondents also reported that small-scale shrimp growers (who had originally farmed rice) converted ponds to tilapia production following the collapse of their operations. In other instances, farmers practicing intensive chicken farming had switched to fish culture; in one case directly following the failure of a large operation due to indebtedness, and in others via integrated chicken/fish culture that had become unviable with the onset of avian influenza in late 2003. The cases described above refer to pond culture. However, in *Amphoe* Nong Sua (Pathum Thani) numerous individuals had taken up cage culture of red tilapia in a canal following the failure of tangerine plantations which had been a major livelihood provider in the district. The industry's collapse was said to result from a combination of root disease, low product value, and intensive use of high cost chemicals. Prior to its transformation to orchard (following the introduction of tangerine farming, again by ethnic Chinese from Bang Mot, Thon Buri, close to Bangkok) the district had been dominated by wet-season rice culture (Hung & Yasuoka, 2000). Many cage farmers there also practice small-scale horticulture.

### 5.1.2 Labour

A visit to the sub-district of Kokprajadee, *Amphoe* Nakorn Chai Sri, Nakorn Pathom, revealed the labour dynamics driving the transition from fruit and vegetable to fish culture noted in 5.1.1. The extent and forms in which fish culture had been adopted by farmers in the *tambon* varied markedly. Around 30% of households raised fish in ponds. Of these there was a clear division between older and younger farmers. Older farmers were semi-retired and operated relatively small and extensively managed ponds. These were stocked with mixed-sex tilapia, sliver barb and rohu, and applied with limited quantities of low cost inputs and supplementary feeds (e.g. dried chicken manure, rice bran, household kitchen waste). Tilapia from these systems attained a weight of approximately 330g, and were marketed dead through Sapan Plah fish market in Bangkok. Younger (30-40 year old) fish farmers interviewed operated considerably larger areas of fertilized ponds, stocking sex-reversed tilapia in monoculture. These fish were fed a supplementary diet of commercial pig finishing pellets and omnivorous fish pellets, and harvested at a weight 500-700g for live sale in mobile markets (*talad nat)*.

Both groups of farmers had previously produced either vegetables or fruit, but had been constrained by lack of labour. Horticulture and orchards as managed in Kokprajadee are highly labour intensive. A labour deficit exists in the area as the majority of young people of employable age choose to work in factories, either by commuting or migrating, although some of these later return to farm in the area. This shortfall was made up to some extent by Burmese immigrants but this arrangement was regarded as unreliable since labourers often moved on once they had obtained official residence. As a result, there has been a tendency to mechanize or reduce the area under production and specialize in a particular crop. Fish culture provides a suitable form of specialization because of the low labour effort required. It therefore appeals to semi-retired farmers whose children are no longer available to assist with fruit or vegetable production, and provides a small stream of income. In more intensive forms it also offers a viable livelihood option for younger better capitalized farmers with insufficient labour to raise land crops. There had been a progression amongst this group from orchard to polycultures and then to tilapia monoculture, with monoculture described as offering the greatest returns provided mortality was low. Of those farmers in the *tambon* who did not raise fish in ponds, almost all obtained fish from the ditches integral to their crop production systems. Strategies and management varied widely. In most cases fish were stocked to provide a supplementary source of income, although in others they were used for household consumption, or simply to remove vegetation, and wild self recruiting fish were also caught for personal consumption.

For farmers in many other sites visited, labour deficits did not act as a primary driver conversion from agriculture to aquaculture, but rather the process resulted from the improved incomes that fish culture appeared to offer. For virtually all small and medium-scale pond and cage farmers, labour was not an issue since ponds could be effectively managed with an effort of just a few hours each day by a single individual or two, sometimes three, family members. Hired labour was only necessary where individual operations were large or (as was usually the case with bigger farms) distributed across two or more locations. In these instances it was usual to hire labourers on a live-in basis, providing free basic accommodation on the pond bank. Accommodation usually housed either an individual or a couple with young children. Often these workers were of Burmese origin, although some had emigrated from Northeast or Northern Thailand. Incomes were usually low, although not substantially less than average monthly household incomes (NSO, 2005). Employers often provided free food to their workers. In only one case (in the heavily urbanized district of Lat Krabang) did a farmer express difficulty in obtaining sufficient labour, and cited this as a reason for handing over management of 200rai of ponds to his relatives.

### 5.1.3 Livelihood strategies

This section details the importance of tilapia culture as one among multiple livelihood strategies and reviews its potential sustainability in the face of present and future challenges. Figure 10 provides a summary of farmers' major occupations prior uptake of pond or cage culture. The predominance of agriculture, particularly rice farming, is immediately apparent. This reflects the trend toward diversification into higher value specialized agrarian activities identified in 5.1.1. It was quite unusual for farmers previously engaged in agricultural activities to continue with them following adoption of aquaculture. Conversely, farmers who had previously worked in professions returning higher wages (e.g. construction, insurance, and some self-employed retailers) frequently continued with them, practicing fish culture because it afforded additional income at relatively low opportunity cost. For these individuals tilapia farming tended to contribute less to total household earnings than for those who still practiced some form of agriculture. A pond farmer who owned also worked in construction, for instance, stated that all income derived from fish culture was set aside as savings. Small-scale fish culture particularly appealed to retirees for reasons of low cost and labour effort discussed in 5.1.2 and 7.1.2. Interestingly, one interviewee, a wealthy retired senior policeman, operated what was in effect a hobby farm, spawning a variety of carps in a backyard hatchery for culture in a large pond. This experimental activity provided negligible returns but was evidently a source of pleasure. Quality of life issues were of clear importance to several of interviewees who stated that they preferred aquaculture to previous work in services and industry generating similar or higher incomes, as it offered a greater degree of personal freedom. That many Central Thais now have the ability to make choices such as these indicates the extent to which growth in the region has transformed livelihoods.

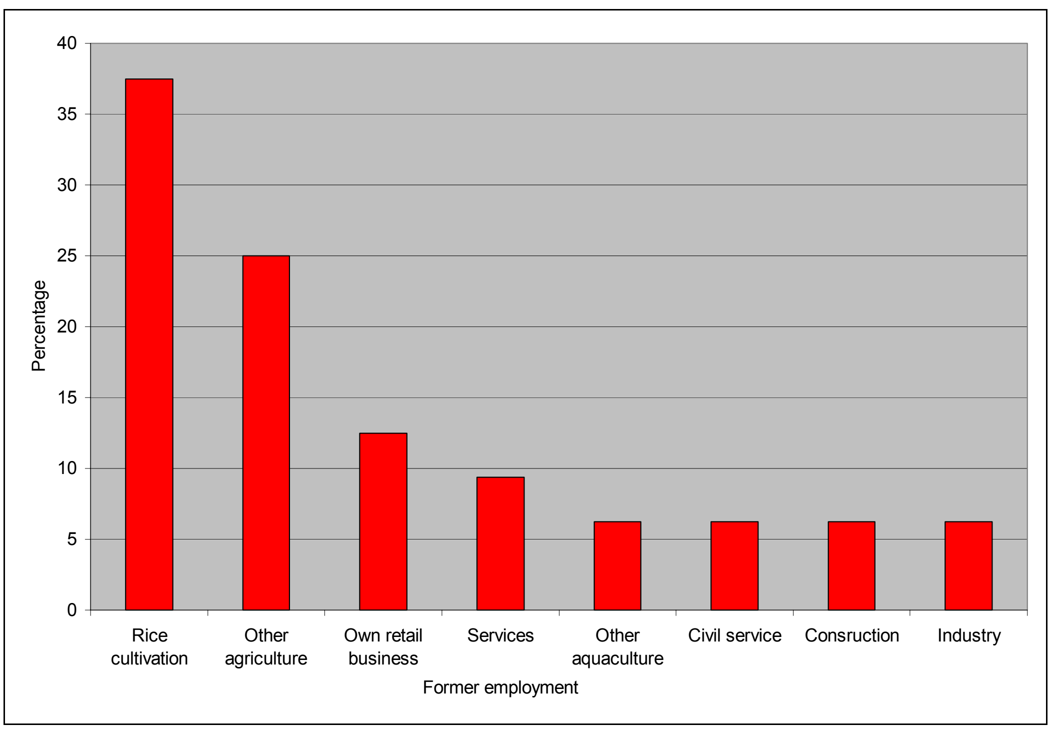


**Figure 10 Previous occupations of tilapia farmers**

For many interviewees tilapia culture had acted as a buffer to economic shocks of various kinds. One Nile tilapia farmer from Nakorn Pathom had amassed debts of several million baht following the collapse of his broiler farming operation 10 years earlier. Fish culture was established on rented land with the proceeds of pawned family jewelry, and feed and other inputs obtained on credit. This attempt was successful and the man has gone on to operate a 1000rai farm, paying off all debts in the process. A worker in a well paid job at a Mitsubishi car plant in Lat Krabang turned to pond culture after the factory relocated, using his redundancy pay to cover startup costs. A cage farmer in Ang Thong followed a similar route after his office job with a cement manufacturer was cut in the fallout from the economic crisis of the late 1990s. This pattern is by no means unique to aquaculture. According to Falvey (2000) many rural migrants to the Bangkok Metropolitan Area returned to work the land in their places of origin during the recession a decade ago, and the author notes that the strength of Thai agricultural sector has repeatedly cushioned the impact of economic shocks. This capacity underlines the continuing importance of activities such as fish farming. Tilapia culture can also offer potentially viable alternative livelihoods when other agricultural sub-sectors collapse, as indicated by its uptake by unsuccessful shrimp and tangerine farmers discussed in 5.1.1.

However, when asked about their children's current employment and future prospects, many interviewees felt that it was unlikely or, in some cases, undesirable that they would continue down the same path. A substantial portion of farming households had managed to send children to university with their earnings from fish culture, and for these there seemed to be little prospect of returning to continue the family business given the financial opportunities afforded them by their training. For others, educated to a lower standard, factories were the commonest choice of employment, although significant numbers did opt to farm fish close to their parents' homes, or assumed a management capacity in farming operations that had grown in scale to become high cash flow businesses. Despite the increasing opportunity cost of maintaining agrarian livelihoods in the face of possibilities off-farm employment, there remains a deep cultural attachment to the land (Falvey, 2000), particularly amongst those with hereditary ownership and ancestral roots. Some informants hoped for, or mentioned instances of, adult children with families of their own returning to birthplaces to resume agricultural activities and assist elderly parents. This occurrence may become increasingly infrequent in future however for both economic and cultural reasons; the attractiveness of relatively stable, high, risk free incomes from employment in manufacturing and services outweighing the unpredictability of biological and market elements in fish production; and familial roles and responsibilities evolving as an increasingly consumption driven society adopts more individualistic behaviour patterns (Mjelde-Mossey & Walz, 2006).


**Figure 11 Urban development in Bang Phli and Lat Krabang**

### 5.1.4 Relocation and expansion

The districts of Lat Krabang, Bang Phli and Bang Saothong lie close to Bangkok's newly constructed international airport, due to open later this year. Extremely high levels of construction and rapid development were evident along the main roads off which fish farms were to be found. Numerous new condominiums, housing projects and retail outlets could be seen, and the flow of construction traffic and heavy goods vehicles along the roads was continuous. There were also many recently established industrial and storage facilities in addition to older ones (see Figure 11). All but one of the farmers interviewed owned all or part of land on which they raised fish. Those with larger farms (60-100 rai) rented holdings additional to their own property. Rental costs had remained surprisingly low at Bt1000/rai (in part because all those who rented were long term tenants), but contract lengths had been reduced to one year since the airport neared completion. Many interviewees expressed uncertainty about the future of fish culture in the area once the new airport opened. Some feared that zoning might be enforced as part of government proposals to create a new province (Nakhon Suvarnabhumi), leading to the compulsory purchase of their land. So far however, compulsory purchase of land for construction around the airport had affected tenants rather than land owning farmers, and this property often remained undeveloped allowing the former tenants to continue farming there.

It was noted that 20 rai was the minimum area required to generate a reasonable household income. Since there was already a great deal of fish culture in the districts (many interviewees stated that 'every household' nearby farmed fish, amounting to more than 10,000rai of ponds in both Lat Krabang and Bang Phli) and land was in high demand for construction purposes farmers inheriting smaller parcels found it necessary to rent elsewhere. This increasing insecurity of land tenure and the inability of smaller farmers to expand operations. led to a pattern mentioned by all interviewees, whereby farmers had begun culturing fish in less densely populated areas of easily accessible provinces with more available agricultural land, particularly Prachinburi, Nakorn Nayok and Pathum Thani. Usually these individuals continued to reside and farm on their original land, hiring fulltime staff to tend the new operations. A farmer visited in Ban Sang, Prachinburi, confirmed this trend. He had recently constructed ponds on 120rai on rented unutilized rice paddy and wetland (Figure 12). He had had rented 70rai in Phanom Salakarm (Chachoengsao) for the past seven years, and retained

20rai in Samut Prakan where he continued to live. The decision to expand was economically motivated, and not related to development of the airport. Around 20 residents of Samut Prakan are currently absentee operators of farms in Ban Sang, renting a combined area of over 1000rai, and it was noted additional land for expansion in Ban Sang and Nakorn Nayok had become difficult to locate.

**Figure 12 Farmer from Samut Prakan by 60rai pond, Ban Sang**

The expansion of the aquaculture frontier into areas with greater availability of land resources was also noted during visits to *amphoe* Bang Lane and Muang (Nakorn Pathom), and Bang Phae in Ratchaburi province. Nakorn Pathom is in the Bangkok Metropolitan Region, and is highly urbanized in some areas, although agriculture continues to be a major employer and 46% of land is under agricultural holdings (calculated from NSO, 2005a, 2005b). Bang Lane is also one of, if not the, biggest tilapia producing district in Thailand. Although, as elsewhere, most fish production is on a small to medium scale, several farmers operate very large areas of ponds. Some of these farmers have leased parcels of land in the neighbouring province of Ratchaburi to the west of Nakorn Pathom in order to expand the area under production and take advantage of lower rents and economies of scale.

### 5.2 Markets and Marketing

The expansion of tilapia markets, marketing opportunities and marketing practices in Central Thailand have been inextricably linked to development patterns in the region (Belton & Little, 2006b). Economic growth has enhanced consumer spending power. As a result, although tilapia has declined as a proportion of total fish intake among more affluent classes of consumer, total expenditure on the fish by these groups has risen to exceed the per capita average (Table 6). At the same time, improvements in infrastructure and communication associated with economic growth have led to 'space-time compression' by reducing travel times and dramatically speeding up communication (Brunn & Williams, 1983). This effect has transformed access opportunities to marketing networks for farmers and other stakeholders in aquaculture. In conjunction with evolving lifestyle patterns, engendered by the shift toward industrial and post-industrial economies in provinces surrounding Bangkok, these changes have led to the emergence of new modes of marketing and consumption.

| **Type of Expenditure** | **Average Annual Expenditure (Bt/year)** | | | | |
|---|---|---|---|---|---|
| | Class I | Class II | Class III | Class IV | Average |
| Tilapia | 188.16 | 207.84 | 259.92 | 232.20 | 222.00 |
| Tilapia as % fish | 24.77 | 19.83 | 18.87 | 12.78 | 17.76 |

**Table 6 Thai annual per capita expenditure on tilapia classified by income group**
(Piumsombun, 2001)

### 5.2.1 Wholesale markets

The number of freshwater fish wholesale markets in Central Thailand has increased rapidly over the past 15 years, paralleling the expansion of fish culture. The first wholesale fish market, Sapan Plah, was established in Central Bangkok in 1953 by the Fish Marketing Organization, a government agency operating under the Ministry of Agriculture and Cooperatives (FMO, 2001). Trade at Sapan Plah was originally dominated by marine landings, but later grew to include aquaculture products. Talad Thai, located in *Amphoe* Khlong Luang, Pathum Thani, initiated fish sales in 1998. The venture is privately owned, and is the largest agricultural wholesale market in Thailand. Two other major private fish markets, Talad Bang Lane Thani in Nakorn Pathom and Talad Suwapan in Ang Thong (roughly 60km to the west of and 100km to the north Bangkok of respectively) also opened during the 1990's. All these markets trade in excess of 100t of freshwater fish per day, the vast majority of which is cultured. Interviewees referred to three further wholesale markets trading less than 100t of cultured fish daily; Talad Chompupong (Nakorn Pathom), Talad Numchok, eastern Bangkok, and Talad Paknum in Samut Prakan, southeast of Bangkok. The estimated volumes of freshwater fish, red and Nile tilapia sold at those visited during the study are listed in Table 7. Annual tilapia sales at just the four wholesale markets for which estimates were available equate to more than 110000t, considerably exceeding of the official figure for total national production. Smaller stand-alone wholesalers in the provinces have also increased in number recently. It was unclear how many of these exist, but a visit to a roadside wholesale shop in Amphoe Pan Thong, Chonburi, selling 4-5t of live fish of various species daily, mainly to vendors in the nearby towns, may point to the further decentralization of marketing infrastructure. A another indication of this trend was evident in Nakorn Pathom, where five middlemen with between four and ten pickup trucks each purchased live tilapia at the pond bank for daily delivery to *talad nat* in the surrounding provinces. This system bypasses the need to route fish through a central market, shortening the marketing chain and removing the need for repeated handling, thereby helping to maintain margins and product quality. Many red tilapia are distributed in a similar manner, being transferred by middlemen direct from cages to stallholders, restaurants and other retailers

| | | | Estimated daily sales (t) | | |
|---|---|---|---|---|---|
| **Market** | **Location** | **Number of stalls** | **All Species*** | **Nile tilapia** | **Red tilapia** |
| Sapan Plah | Central Bangkok | 14 | >100 | - | - |
| Talad Thai | Khlong Luang, Pathum Thani | 30 | - | 50 | 20 |
| Talad Bang Lane Thani | Bang Lane, Nakorn Pathom | 80 | 300 | 180 | 1 |
| Talad Suwapan | Muang, Ang Thong | 20 | 100 | 20 | 2 |
| Talad Numchok | Lat Krabang, Bangkok | 5 | 40-50 | 10 | 0 |

**Table 7 Daily sales of freshwater fish at five wholesale markets, Central Thailand**

All major fish markets (with the exception Sapan Plah, established when the city was far smaller) are located at the periphery of the most heavily urbanized part of the Bangkok Metropolitan Region or in provincial centres and, because of the region's excellent road network, are ideally situated to receive products from farms in outlying areas for distribution throughout Bangkok and adjacent provinces. They are by no means homogenous however, with each reflecting the types of production and markets for cultured fish in adjoining areas. The tilapia trade at Talad Thai is dominated by live fish, Nile and red, which are mainly cooked and sold at *talad nat* in and around Bangkok. The popularity of dishes such as those depicted in Figure 13 reflects the changing lifestyles of urban populations. Tilapia marketed in this way are more expensive than fresh fish, but are convenient, especially for the many urban consumers living in small apartments that lack cooking facilities. The majority of fish sold at Talad Bang Lane Thani are dead Nile tilapia, reflecting Nakorn Pathom's status as the major tilapia producing province in Thailand. Many of these fish are distributed to fresh markets (*talad sot*) and mobile traders within Central Thailand, but a significant commerce also exists with the North and Northeastern regions where demand exceeds production. A similar situation exists at Talad Numchok, from which dead fish from provinces directly to the east of Bangkok are dispatched to the southern and most easterly reaches of the country. This market also services factories clustered along the upper Gulf of Thailand which manufacture fish balls, fish sauce and fermented fish. Lower value cyprinid species are preferred for this purpose, with the result that relatively little tilapia is sold at the market. Interviews with farmers operating nearby suggested that carps accounted for a larger portion of polycultures than was typical in other provinces, perhaps reflecting this local aspect of demand.

**Figure 13 Red and Nile tilapia prepared for sale at a *talad nat***

### 5.2.2 Retail outlets

The number and variety of retail outlets for tilapia has increased as the product has diversified to penetrate new markets, and in response to underlying economic change. Perhaps the most ubiquitous and visible of these developments is the *talad nat*. These temporary markets operate for one or more days or nights each week at a fixed location in almost every settlement in Central Thailand with a population of more than a few thousand. This type of market has existed in the past, but rose to prominence following the economic collapse of 1997. The crisis generated high levels of joblessness, leading many of those affected to seek self-employment in the retail sector. Vendors with pickups or modified motorbikes purchase small quantities of fish daily, travelling to market sites where they pay a small fee to set up stalls. Much of the food sold in this way is cooked *en situ*, to demonstrate its freshness to would be consumers. Keeping live fish in tanks in view of potential customers adds to the attractiveness of the product, but fresh dead fish are also cooked and sold. This development has eroded the market share of traditional *talad sot* where most food is sold uncooked. Interviewees at a large fresh market in Rang Sit, Pathum Thani, all noted reductions in sales of between 20 and 50% in the last 12 months. A variety of reasons were given, including a recent downturn in the economy caused by political instability and rising oil prices. All acknowledged a longer term trend of decline in the face of competition from *talad nat* however. The same interviewees suggested that numbers of mobile traders, travelling door to door selling fresh food from pickup trucks, and mobile vendors, who cook and sell food on street corners, were also on the increase. This amounts to a cultural shift in the way much food is consumed, with consumers having sufficient resources to make the regular purchase of prepared fish and other products preferable to home cooking.

Supermarkets have also come to assume major importance in shaping consumption patterns and choice in urban centres, although have yet to penetrate less densely populated areas to a significant degree. Interviewees stated that supermarkets compete with other retail outlets on the basis of price, and use buyers to source fresh dead fish from wholesale markets rather than through contract arrangements with farmers. Microwavable ready meals are also increasing in importance, and are available through 7-11's (which are now found in nearly as many locations as *talad nat*) and supermarkets. It was unclear how fish used in these processed foods was sourced.

**5.3 Synthesis**

This section explores some of the issues raised by the case studies above in greater detail. Aquaculture represents a stage in an ongoing process of agricultural diversification occurring in Central Thailand. There is growing international competition from other rice producing developing countries which has placed pressure on Thai rice farmers and depressed the profitability of the activity compared to other forms of agriculture (Flaherty et al, 1999). This leads Greenberg (1994, p180) to dub rice cultivation a 'high risk venture'. Rising incomes in the EBMR (roughly two to three times greater than those in the Northern, North-eastern and Southern regions (NSO, 2005a)) have also triggered a shift in consumer demand from staple foods (e.g. rice) toward higher value goods such as meats, fruits, vegetables and fish, meaning that operations have become more specialized and intensive the farm level, and more diverse at the regional level (Pingali and Rosegrant, 1995). This situation has favoured the transition documented above from rice production toward fish culture.

Economic growth and urbanization have also increased off-farm employment opportunities and incomes, thereby increasing the opportunity cost of working in the agricultural sector (Pingali and Rosegrant, 1995). This point is nicely illustrated by Pradhan (2003), who finds that real wages in industry rose from Bt108.18 ($2.63)/day in 1977 to Bt206.46 ($5.01)/day in 1995, while real wages in agriculture stagnated at Bt63.99 ($1.55)/day until 1993. Urban development has radiated outwards from Bangkok along canals and roads in a ribbon-like form, and massive increases in public and private transportation (motorbikes, minivans, cars, pickup trucks, buses, taxis, *tuktuks*, *songtheaws*) have occurred concurrently. This configuration of development has made employment in industry and services easily accessible to individuals who might once have been limited by their geographical location to livelihoods in the agricultural sector (Greenberg, 1994), resulting in the situation observed in Kokprajadee where labour intensive forms of agriculture were constrained. Aquaculture requires a relatively low labour effort (a total of one to two, and three to four hours a day were typical for cage and pond farmers respectively). This characteristic may be unable maintain the attractiveness of aquaculture over the long term as employment opportunities in non-agricultural sectors and wage disparities between agriculture and non-agriculture increase. However, at present in locations such as Kokprajadee the low labour requirement demanded by aquaculture makes it comparatively advantageous among competing agricultural livelihoods.

The growing population and urbanization of Samut Prakan and Lat Krabang have created increasingly insecure tenure for farmers as landlords reduce contract lengths in anticipation of rising land prices. This speculative behaviour does not extend to increasing rents, tempered as it is by long term relationships with tenants, but is indicative of the increasing scarcity of land in the area. Yoonpundh (1997, p42), finds that snakeskin gourami farmers in the more heavily industrialized provinces of the Central region stock fish at higher densities, apply more inputs, and achieve greater productivity and profitability than their counterparts in less developed areas. The author notes that "pressure to intensify fish culture appears to increase as the area becomes more industrialized". Although tilapia culture in Samut Prakan and Lat Krabang has intensified over the years with the uptake of monosex fish and application of formulated pig pellets as a supplementary feed, this trend is not location specific, having occurred across the whole of the Central Region. Rather than attempting to extract more production from existing holdings, farmers in these districts have expanded production into areas in which land is a less constraining factor and low value rice paddy can be rented for conversion to ponds. That farmers are prepared to take these measures in preference to seeking alternative livelihoods suggests that tilapia culture is both a viable, if practiced on a sufficiently large scale, and a desirable occupation to many of its practitioners. Brunn & Williams (1983, p468) adopt the term ‘space-time compression’ to describe the way in which “places are moving closer together measured by travel time and communication time”. This effect explains why it is possible for village dwellers in apparently rural areas to adopt urban livelihoods (as for those commuting to work in factories from Kokprajadee), but also works in the opposite direction, facilitating ownership of farms in more rural locations by the inhabitants of highly urbanized districts close to Central Bangkok.

The diversification and atomization of tilapia markets and marketing reflects this underlying social, cultural and economic evolution. In study of fish marketing conducted 25 years earlier Nitsmer (1981) found that a handful of powerful wholesalers located in Bangkok held considerable power, allowing them to collude at certain times to control supply and raise price by delaying harvest from affiliated fish farmers. This is a far cry from the situation today where excellent transport and communications coupled to a vastly expanded aquaculture sector make the marketing of tilapia an extremely competitive activity in which producers, middlemen, wholesalers and retailers benefit from an ever growing array of opportunities. Tilapia has grown from a basic staple of the poor to fill numerous and diverse market niches. Peri-urban areas are noted for heterogeneity in the wealth of their inhabitants, and the country’s rapid economic growth has been attributed in large part to its ability to maintain low wage levels (Leschen et al , 2005). In association with technical developments in production these factors have allowed tilapia to become all things to all people in an increasingly segmented market. Fresh or simply prepared Nile tilapia remain important for consumption by the less-affluent at home or in the workplace, whilst larger live fish taken home and cooked, or elaborately prepared by vendors may represent a special meal to some and basic daily fare to others. Large red tilapia eaten at restaurants and during holiday celebrations have gained sufficient status to compete with traditional high value favourites such as snakehead and marine species. Belton & Little (2006c) suggest that the success of CP’s attempt bring live “plah taptim” to the domestic market arises partly from its coincidence with the economic downturn of the late 1990s which caused middleclass consumers to seek acceptable substitutes to prohibitively expensive marine fish. This convergence of factors has made the marketing of tilapia as a whole highly sustainable. This is likely to remain the case for the foreseeable future as production technologies and volumes, consumer spending power, public infrastructure, and retail outlets continue to diversify and grow. The impacts of tilapia marketing in terms of livelihood opportunities, income generation, and employment are difficult to assess because of their diffuse nature, but almost certainly generate an economic multiplier effect well in excess of that derived from culture alone.

The average age of farmers surveyed was 49. By far the youngest interviewed was 25, and several respondents were in their 70’s. This profile is consistent with that of agricultural household heads in Central Thailand, of whom 71% are between 35 and 64 years old and 16% 65 or over (NSO, 2005b). Fish farmers and those engaged other agrarian activities are therefore an aging population. Aquaculture based livelihoods are being shaped by the attractions of urban employment to younger members of the economically active population living within its reach, pressures on land use caused by the outward sprawl of RBU from its loci in Bangkok, agricultural diversification away from rice, and steadily improving infrastructure and access to markets. At the same time, expenditure on tilapia and demand for diversified tilapia products is growing in parallel to societal wealth. In light of Thailand’s remarkably dynamic entrepreneurial culture it may therefore be surmised that fish farming as a whole will not decline in response to meso-scale economic pressures, but will continue to provide viable new livelihood opportunities across an outward moving frontier approximately one province removed from the leading edge of the heaviest urbanization in the EBMR. An alternative and possibly complementary scenario is that intensified tilapia culture producing increasingly standardized high value products and demanding high capital investment will come to supplant traditional low input, low cost management regimes, leading to concentration of the means of production in the hands of fewer, larger operators, perhaps in partnership with agro-business (see 7.1.1 for a discussion of these issues).

For these reasons, tilapia farming within easy traveling distance of non-agrarian employment opportunities may become a less competitive livelihood strategy, and hence less sustainable, as the economic development of the Central Region progresses. This should not necessarily be viewed as problematic. Livelihood strategies are conceived of as sustainable where they offer favourable combinations of increased income and wellbeing, reduced vulnerability, improved food security, and more sustainable use of the natural resource base. Much small-scale tilapia production presently meets these requirements when compared to activities such as rice farming. Viewed through the lens of longer term prospects however, current forms of livelihood associated with tilapia culture may represent only a transitory stage in the capitalist development of Central Thailand. This-not-withstanding, it would be extremely premature to forecast the imminent demise of small scale tilapia farms close to more heavily developed areas of the region. This is unlikely in large part due of the tenacity of Thai farmers, as evidenced by the persistence of rice paddy generating negligible returns in the industrial and residential heartland of the BMR (Greenberg, 1994).

# 6 FARM ECONOMICS

This section addresses the economic performance of several tilapia culture systems and assesses the implications for system and livelihood sustainability. Budgets of intensive cage and semi-intensive pond culture (Budgets 3 and 4, Table 8) are derived from the mean responses obtained in a survey of customers buying fry from Nam Sai monosex tilapia hatchery, Prachinburi. Mean pond-farm size in this survey was 93 rai. The mode was roughly 30 rai. For cage farms mode and mean are similar. Although mean statistics for cage farmers can therefore be taken as broadly representative of typical farms, statistics given for pond farmers show a-typically high revenues. Moreover, there is a great deal of variability within semi-intensive tilapia culture, the subtleties of which are lost by aggregation of data. Budgets for small-scale traditional polyculture and more intensive monoculture (1 and 2, Table 8), estimated from information given by interviewees during field visits, are presented to provide a more complete picture of the economic ramifications of different semi-intensive production strategies adopted. Figures given in all the budgets are calculated per annum. This enables direct comparison of systems with different lengths of growout cycle. Figures given for ponds are in rai, the Thai unit of aerial measurement. One rai is approximately 0.16 hectares. Figures for cages are in $m^3$. Common units are not used here because difference in scale between ponds and cages is such that it was felt that doing so would make interpretation of data confusing.

## 6.1 Budgets for Cage and Pond Culture

Budget 1 is estimated for a farmer with a 6 rai pond, stocking mixed sex tilapia in polyculture. These are harvested at 330g after a ten month growout period, and are sold at Bt18/kg. Inputs are chicken manure and rice bran. Budget 2 gives figures for a 60 rai monoculture of monosex tilapia, harvested at 500g and marketed live. Greenwater is stimulated using ami ami, and the only feeds are commercial pig and herbivorous fish pellets. Fish from this system obtain a high price of Bt28/kg, and are harvested after nine months. It is assumed that the smaller farm has been operational for 10 years and is located on property inherited by the farmer. The more intensive system was initiated five years ago on rented land. Neither farm is big enough to require the hiring of permanent employees. In both cases harvesting costs are comprised of fuel for pond drainage and a Bt1/kg fee paid to a harvesting team. The 60 rai farm has higher fixed costs as a result of larger-scale more recent pond excavation than the 6 rai farm, and because ownership of a 12 inch water pump and pickup truck for transportation are assumed to be necessary. Feed costs per unit area are more than twice as high for the large farm due to use of commercial feeds. Feed and fertilization costs amount to 73% of total cost for the smaller farm because fixed and other variable costs are low. Returns per unit investment for the 6 rai operation are nearly twice those of the more intensive system. However, because investment per rai is around 50% greater and farm size ten times larger for the latter, both per unit and total returns are considerably higher. These features make small-scale polyculture as typically practiced in Central Thailand a relatively low risk, low return activity. Larger, more intensive systems, whilst offering potentially far greater incomes, are less suited to undercapitalized farmers, but have the potential to generate far greater wealth.

Budgets 3 and 4 are calculated on the basis of several assumptions. It is expected that all cages and ponds are stocked and harvested at the same time, and restocked immediately afterward. Farmers operating cages purchase and nurse fry rather than buying fingerlings from a nursery and do not need to rent land or pay for access to water bodies where cages are located. Farmers operating ponds are assumed to rent all the land they operate on. Certain fixed and variable costs are not accounted for. These include depreciation of assets, interest on loans, and incidental costs such as purchase of nets and antibiotics.

| | 1 Mixed-sex polyculture | | | 2 Monosex monoculture | | | 3 Monosex pond culture (mean) | | | 4 Intensive cage culture (mean) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Unit | Bt | Bt | % | Bt | Bt | % | Bt | Bt | % | Bt | Bt | % |
| Item | **Rai** | **Farm** | **Distribution** | **Rai** | **Farm** | **Distribution** | **Rai** | **Farm** | **Distribution** | **Cage** | **Farm** | **Distribution** |
| Variable costs | 10679 | 64073 | 88 | 22941 | 1376480 | 86 | 11412 | 1066354 | 85 | 86401 | 1382421 | 98 |
| Feed &/or fertilization | 8850 | 53100 | 73 | 18149 | 1088960 | 68 | 6187 | 578107 | 46 | 80171 | 1282729 | 91 |
| Stocking | 360 | 2160 | 3 | 1160 | 69600 | 4 | 1497 | 139832 | 11 | 2722 | 43554 | 3 |
| Rental | | | | 1500 | 90000 | 6 | 1138 | 106320 | 8 | | | |
| Harvesting | 1469 | 8813 | 12 | 1632 | 97920 | 6 | 2005 | 187345 | 15 | 3509 | 56138 | 4 |
| Fulltime labour | | | | | | | 586 | 54750 | 4 | | | 0 |
| Fixed costs | 1200 | 7200 | 10 | 1653 | 99200 | 14 | 1926 | 179923 | 14 | 1896 | 30330 | 2 |
| Construction | 1200 | 7200 | 10 | 2400 | 144000 | 9 | 1158 | 108224 | 9 | 1896 | 30330 | 2 |
| Vehicles & machinery | | | | 1333 | 80000 | 5 | 767 | 71700 | 6 | | | |
| Total cost | 10823 | 64937 | 100 | 24595 | 1475680 | 100 | 13338 | 1246278 | 100 | 88297 | 1412751 | 100 |
| | | | | | | | | | | | | |
| Gross revenue | 20736 | 124416 | | 37333 | 2240000 | | 31542 | 2947287 | | 140295 | 2244720 | |
| Revenue (tilapia) | 12960 | 77760 | 63 | 37333 | 2240000 | 100 | 27428 | 2562858 | 87 | 140295 | 2244720 | 100 |
| Revenue (other fish) | 7776 | 46656 | 37 | | | | 4114 | 384429 | 13 | | | |
| | | | | | | | | | | | | |
| Net profit | 9913 | 59479 | | 12739 | 764320 | | 15091 | 1410131 | | 51998 | 831969 | |
| Net profit (%) | | | 71 | | | 40 | | | 136 | | | 59 |

**Table 8 Annual budgets for: 1 Small-scale polyculture (estimate), 2 Semi-intensive monoculture for live sale (estimate), 3) Semi intensive pond culture (mean Nam Sai customer data), 4 Intensive cage culture (mean Nam Sai customer data)**

| **Item** | **1** | **2** | **3** | **4** |
|---|---|---|---|---|
| Number of years farming experience | 10 | 5 | 10 | 4 |
| Farmer's age | 65 | 40 | 501 | 47 |
| Number of units (cages/ponds) | 1 | 3 | 5.5 | 16 |
| Unit area (rai/$m^3$) | 6 | 20 | 16.8 | 61 |
| Total area (rai/$m^3$) | 6 | 60 | 93 | 975 |
| Growout cycle (months) | 10 | 9 | 7.6 | 4.1 |
| Stocking density per unit | 5000 | 3000 | 3256 | 1900 |
| Annual feed application (t/rai) | 1.2 | 2 | *1.6 | 4.2 |
| Annual yield, tilapia only (t/rai) | 0.7 | 1.2 | 1.3 | 3.5 |
| Annual yield, all species (t/rai) | 1.2 | 1.2 | 1.7 | 3.5 |
| Value of tilapia (Bt/kg) | 18 | 28 | 21 | 40 |

*Estimate based on interviews: rice bran only, excludes fertilization

**Table 10 Comparison of selected features of tilapia culture for budgets 1-4**

| **Item** | **3** | **4** |
|---|---|---|
| | 40 | 21.4 |
| Nutrient cost (Bt/kg)* | 3.8 | 18.9 |
| Nutrient cost (Bt per kg fish produced)* | 4.6 | 22.8 |
| Production cost (Bt/kg fish produced) | 7.3 | 24.2 |
| Cost ratio of nutrient cost : revenue* | 0.4:2.1 | 1.9:4 |
| Ratio of total cost : revenue | 1.1:2.8 | 1.4:2.3 |
| Mean ratio of losses: break even: profit | 1.5:1.6:6.9 | 2:2.2:5.8 |
| Farmers never having lost money on a crop | 55% | 0% |

* Nutrient costs are the cost of feed in the case of cages, and/or fertilizer for ponds

**Table 9 Comparison of selected features for pond and cage culture (budgets 3 and 4)**

Comparison of 3 and 4 shows that, on average, cage farms are comprised of more units than pond farms, but have a far smaller total area. Stocking density, feed application and yield per unit area are much higher in cage based farms and growout cycles are shorter, but absolute yields and feed volumes are higher on average in pond farms because of their larger total size. The average farmgate value of tilapia raised in cages is roughly twice that of those from ponds but production costs are more than three times as much. Nutrient inputs (feed and/or, for ponds, fertilizers) represent the major cost in both systems. These are much higher per unit in cage systems because of a complete reliance on commercially produced pellets. Stocking costs are greatest per unit in cage farms, but amount to a much lower proportion of total cost than they do for ponds. Land rental, which represents 8% of total cost for farms in which all land is leased, does not feature in the budget of cage farms. Total fixed costs of pond farms are approximately six times greater than those of cage farms, due to the expense of pond construction and vehicle and machinery ownership. Initial construction costs for the fairly large 16 cage farm represented in Budget 4 are Bt120000. This amount would only cover the construction of a small 10 rai pond farm. Net revenue per unit is much higher for cages than ponds, reflecting the larger yields per unit area possible in an intensive system and the higher market value of the product. Average net farm revenue is somewhat higher for pond farms however, reflecting their greater total area.

Table 10 summarizes additional information used to calculate the four budgets. Caution must be exercised in the interpretation of these results because the manner in which data was collected and the assumptions and omissions imposed in reconstructing each account. Budget 3, derived from information given by a very broad cross section of pond farmers is the most problematic because, as a report from DFID (2000, p8) suggests, whilst major costs such as seed, feed and labour are easily accounted for in an exercise such as this, other costs such as equipment, medicines, fuel, etc are likely to vary enormously from location to location and according to the scale of enterprise. As a result, returns calculated using incomplete or generic information are 'generally higher than would be achieved in practice'. Assuming that cages and ponds are immediately restocked following harvest may create distortions for a number of reasons: low market value may encourage better capitalized farmers to retain fish for longer than usual; disease and pollution events may promote preemptive harvest; depressed farmgate values may discourage restocking, particularly among cage farmers; and it is common practice for cage farmers to cease production at times of year when environmental or market conditions are unfavourable and restart in the event of more auspicious circumstances. Eighty seven percent of the cage farmers surveyed purchased 1inch red tilapia fry at Bt0.49 each, nursing for several weeks prior to stocking at 3-4 inches in length. It is rather more common for farmers to purchase fingerlings from an independent nursery or under contract from a feed dealership however. If 3 inch fingerlings are purchased outright stocking costs increase to Bt3655 per cage. It was stated by several interviewees that nursing fry rather than buying fingerlings reduced total operating costs.

Very few of the cage operators visited rented land adjacent to the water body in which they farmed. Most had either owned land in a suitable location prior to farming or gained access to water from public land at no cost. The customer survey indicated that 46% of pond farmers owned the all land on which they farmed, 27% both owned and rented, and 27% rented only. Farmers operating on their own land tended to have smaller holdings (averaging 59rai) than those renting some or all of the land on which they farmed (135rai and 112rai respectively). The large proportion of farmers leasing land suggests that neither rental costs nor lack of permanent tenure are a significant barrier to pond culture. It was clear from interviews that renting land allowed farmers with limited holdings to expand production, as is suggested by the relatively large size of wholly or partially rented holdings. Although some farmers undoubtedly purchase land, perhaps with the aid of a mortgage, most interviewees owning land had inherited from parents or family at no cost.

Fixed costs per annum are estimated by dividing the price of pond and cage construction, vehicles and machinery at 2006 prices by average length of farmer experience. In practice loans would often be used to cover large capital costs such as these. Farmers most commonly obtain loans from the Bank for Agriculture and Agricultural Cooperatives (BAAC) for this purpose. BAAC loans for 'general' clients have annual interest rate of 10% (BAAC, 2004). Credit is extremely important in both fish production and agriculture. NSO (2005) reports that 46% of farming households in Central Thailand have unpaid debts related to their agricultural operations, and that well over 80% of this credit is derived from public or community sources. Although credit can generate serious burdens its provision is undoubtedly an important driver in the development of Thai aquaculture (Belton & Little 2006a)

| Source | Cage | Pond |
|---|---|---|
| Calculated from customer survey | 59 | 136 |
| Farmer estimate | 21 | 54 |
| Piusombun et al, 2005 | 22 | 44 |

**Table 11 Mean net profits for cage and pond farmers (%)**

As a result of the omissions listed above the net profits given in Budgets 3 and 4 are unrealistically high. Profits in this range are by no means impossible however, and can be achieved given optimal input application, market prices and fish health. Several pond farmers reported having regularly made up to 200% returns on investment in previous years when input costs and the supply of tilapia were lower. Farmer estimates of profit from ponds and cages given during interviews are approximately three times lower respectively than those calculated in Budgets 3 and 4 however, and provide a more reliable indicator of probable returns. Puisombun et al (2005) quote profit margins for cage and pond farms similar to the estimates made by interviewees in this study. These are summarized in Table 11 above. Tables 12 and 13, p27, are also taken from Puisombun et al (2005), and are included below for comparative purposes. The authors ' accounting for cage culture is similar to that in Table 8 in terms of distribution of fixed and variable costs, with the exception of seed, which comprises 9.87% of costs, probably reflecting the purchase of fingerlings rather than fry.

Piusombun et al's budget for semi-intensive polyculture also provides a picture of the distribution of fixed and variable costs fairly similar to that in Budget 3. The authors' figure for labour costs is surprisingly high given the low labour effort required by most fish culture of this nature, but may include temporary labour for harvesting as well as hire of permanent staff. Budget 3 assumes permanent hired labour is required, whereas budgets 1, 2 and 4 do not include this as a cost. This is because field visits showed that, with the occasional exception of elderly farmers using employing part-time staff to carry out heavy physical tasks, the day to day operation of small and medium sized farms can be managed by farmers and members of their households. Budgets 1, 2, 3, and 4 calculate costs of temporary labour for harvesting at Bt1/kg of fish harvested. This figure was quoted by several interviewees. The feed and fertilization costs for pond culture given in Piusombun et al's paper come to 48.1% of total cost, a figure similar to that in Budget 3, but considerably lower than for Budgets 1 and 2. This disparity can be accounted for by the low operating costs other than feed in the low intensity operation and high feed cost resulting from use of commercial pellets in the larger farm.

**6.2 Other Cost Comparisons**

Table 9 (p28) presents various other features of intensive cage monoculture and semi-intensive pond polyculture for comparison. Cage farmers have been engaged in their activity for fewer years on average than farmers operating ponds. This should not be taken as indicative of the activity's sustainability however, since cage culture of red tilapia has only existed in its current form for approximately seven years (Belton & Little, 2006c). Neither is there a significant difference in the average ages of farmers practicing the two activities.

| Item | Red tilapia In cage |
|---|---|
| Unit area (m3) | 37.3 |
| Stocking rate (pcs/m3) | 27 |
| Survival rate | 86.6 |
| Rearing period (months) | 4.37 |
| Productivity (kg) | 16.35 |
| Total cost (USD) | 11.81 |
| Fixed costs (%) | 2.37 |
| Variable costs %) | 97.63 |
| Seed | 9.87 |
| Feed | 82.44 |
| Labour | 2.57 |
| Fuel | 0 |
| Others | 2.57 |
| Total revenue (USD) | 15.07 |
| Net profit (USD) | 3.26 |
| Average cost (USD/kg) | 0.72 |
| Average price (USD/kg) | 0.92 |
| Net profit (USD/kg) | 3.27 |
| Rate of return (%) | 27.68 |
| Factor share (%) | |
| Land | 0 |
| Labour | 2 |
| Current inputs | 74 |
| Operator's residual | 24 |
| Capital | 2 |
| Operator's profit | 22 |

| Item | Semi-intensive polyculture |
|---|---|
| Total cost | 1,429 |
| Distribution of costs (%) | |
| Fixed cost | 11.1 |
| Variable cost | 88.9 |
| Seed | 18.8 |
| Rice bran | 15.9 |
| Commercial | 16.5 |
| Labour | 15.7 |
| Manure | 10.8 |
| Other feeds | 4.9 |
| Harvesting cost | 2.5 |
| Others | 3.8 |
| Gross revenue | 2,555 |
| Net profit | 1,126 |
| Average cost (USD/kg) | 0.34 |
| Average price (USD/kg) | 0.6 |
| Net profit (USD/kg) | 0.27 |
| Rate of return (%) | 78.8 |
| Factor share (%) | |
| Land | 0.67 |
| Labour | 10 |
| Current inputs | 41 |
| Operator's residual | 49 |
| Capital | 5 |
| Operator's profit | 44 |

**Table 12 Cost, return and factor share for red tilapia cage culture** (Puisombun et al, 2005)
**Table 13 Cost, return and factor share for pond polyculture** (Puisombun et al, 2005)

Nutrient input costs per kg, and per kg of fish produced, are close to five times higher in cage culture than pond culture. Production costs per kg of pond raised fish are around three times lower than for those from cages, and farmgate value per kg of fish produced in ponds is roughly half that of cage raised fish. Accordingly, ratios of nutrient cost to revenue and total cost to revenue follow the same pattern. This is in keeping with Little & Muir's model (1987) illustrated in Figure 14. Figure 14 also indicates that where the ratio of fish price to feed costs is high it will be more profitable for farmers to produce fish using complete feeds than wastes. However, cage culture in Central Thailand is less profitable per unit investment than pond culture. The activity's popularity and rapid growth can be accounted for partially in terms of the relatively low opportunity cost to individuals able to exploit free access to public water bodies because of their proximity to them. Given these conditions cage culture can be established virtually overnight with no prior experience on the part of the farmer, and without the substantial investment in capital and time that would be required to initiate pond culture.

The final two items in Table 9 give an indication of the relative financial stability of the two activities. It is noteworthy that every cage farmer surveyed had lost money on a crop at some time in the past, whilst less than half of pond farmers had done so. This contrast is particularly stark given that the average length of cage operators' farming experience was four years, compared to the ten years of pond operators. Considering the disparity between the proportions of pond and cage farmers never having lost money on a crop, a comparison of the ratio of loss to breakeven to profit for each system is somewhat surprising. Whilst this indicates that cage farmers either loose money or break even on crops more frequently than pond farmers, the difference is smaller than might be expected. This would appear to indicate that whilst economic performance of a large portion of pond farmers is extremely stable, that of other groups is considerably less so, although the data revealed no consistent pattern that would explain why this was the case. The economic performance of cage farms tends to poorer overall although, on average, profits outweigh negative and neutral returns.

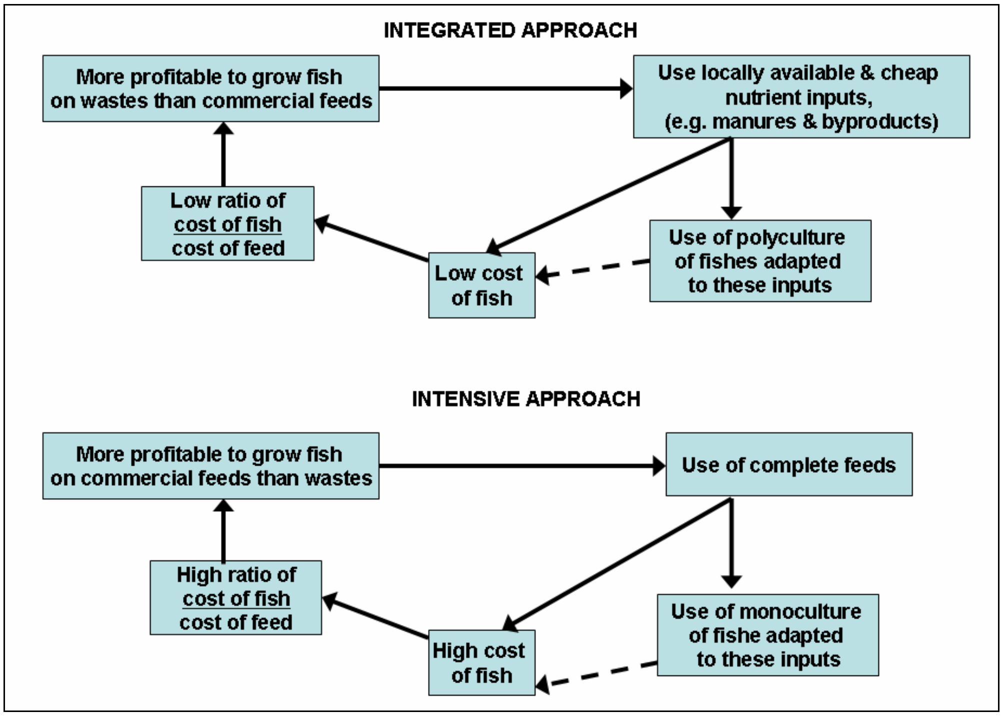


**Figure 14 Factors influencing the choice of inputs in fish farming**
(adapted from Little & Muir, 1987)

| Item | | Change | | |
|---|---|---|---|---|
| Feed costs | Cage | Increased:100% | Fluctuated or constant: 0% | Decreased: 0% |
| | Pond | Increased: 64% | Fluctuated or constant: 36% | Decreased: 0% |
| Farmgate price of tilapia | Cage | Increased: 9% | Fluctuated or constant: 73% | Decreased: 18% |
| | Pond | Increased: 16% | Fluctuated or constant: 68% | Decreased: 16% |
| Farm profitability | Cage | Increased:17% | Fluctuated or constant: 75% | Decreased: 8% |
| | Pond | Increased: 26% | Fluctuated or constant: 52% | Decreased: 22% |

**Table 14 Changes in feed cost, farmgate price and farm profitability since 2003**

Table 14 shows that every cage farmer interviewed reported increased feed costs over the preceding three years. Two thirds of farmers with ponds also reported this trend although for the remaining third feed prices were constant or fluctuated. No farmers indicated that the price of feed had fallen. Increases in the cost of all feeds can be ascribed in large part to the increasing price of oil which has risen substantially over the period. The impacts of elevated global oil prices have been accentuated in Thailand by the elimination of a 20% government subsidy on diesel in 2005 (BBC, 2005). This price rise affects all sectors of the economy including fish farming, but is likely to affect forms of aquaculture dependant on formulated feeds (production of which is relatively energy intensive) to a greater extent than those utilizing byproducts from other activities, for which most energy cost other than transport is effectively free. The long term trend in farmgate price for both cage and pond reared tilapia appears to be remarkably consistent overall, although subject to cyclical fluctuations. This is despite year on year growth in tilapia production. These points are nicely illustrated by the consumer price indices in Table 15 which show whilst the real price of both energy, raw foods and agricultural goods increased significantly between 2002 and 2004, increasing input costs for aquaculture, prices of fish stagnated.

| | **Consumer price index*** | | | **% Change** | | |
|---|---|---|---|---|---|---|
| Item | 2002 | 2003 | 2004 | 2002 | 2003 | 2004 |
| Energy | 123 | 130 | 142 | 0.7 | 5.7 | 9.0 |
| Raw food | 95 | 102 | 112 | 0.3 | 7.8 | 9.4 |
| Crops, meat, forestry products | 119 | 136 | 161 | 11.2 | 14.5 | 18.5 |
| Fish and fish products | 105 | 102 | 101 | 5.5 | -2.6 | -1.2 |

* Consumer price index for 2000 =100

**Table 15 Selected consumer price indices, 2002-2004** (NSO, 2005a)

Belton et al (2005) find that production increases have resulted in a decline in the value of tilapia when adjusted for inflation, and that the falling cost of the fish in real terms has stimulated its consumption. This is supported by the perception of several interviewees who felt that, whilst the monetary value of Nile tilapia produced in ponds had remained constant over the long term, in real terms returns it had declined and was unlikely to improve as production continued to grow. It should be noted that price fluctuations are more pronounced for cage reared red tilapia than for tilapia grown in ponds (Table 16), in part due to the short growout cycle which makes production highly responsive to demand and supply. This variability also reflects the finite market niche occupied by red tilapia, and makes producers more vulnerable to market fluctuations than farmers growing fish in ponds. Interestingly, the proportions of cage and pond farmers reporting changes in the profitability of their operations were fairly balanced, describing little change overall. This would suggest that for both systems feed prices are not a key determinant of profitability.

| | Ponds | | Cages | |
|---|---|---|---|---|
| Fish size* | Average farmgate price Bt/kg | Price range (Bt/kg) | Average farmgate price Bt/kg | Price range (Bt/kg) |
| Small | 17.3 | 14-20 | 27.7 | 15-37 |
| Medium | 22 | 18-30 | 37.7 | 28-47 |
| Large | 25.4 | 20-30 | 43.5 | 36-56 |

* For tilapia cultured in ponds small = 330g, medium = 500g, large = >500g. For cage fish small = <500g, medium = 500-700g, fish = >700g

**Table 16 Price variation in pond and cage reared tilapia**

This is born out by Figure 15, which illustrates the reasons given by farmers for obtaining negative returns on fish crops. It is immediately obvious that, as indicated earlier, tilapia farmers raising fish in cages loose money more frequently than those with ponds. The most common cause of losses to both groups is lower than average farmgate price, although pond farmers are less severely affected. It should be noted that increasing feed costs, whilst undoubtedly exerting downward pressure on returns, are a less significant cause of losses for both groups, particularly pond farmers. This can be accounted for by the higher proportion of total cost contributed by feed in cage systems and larger and more frequent price fluctuations in the value of cage produced fish. Changes in the price of fish have a more significant impact than changing feed prices because although feed prices trend upwards, cost increases are smaller in magnitude than the reduced revenues generated by downward fluctuations in tilapia prices.

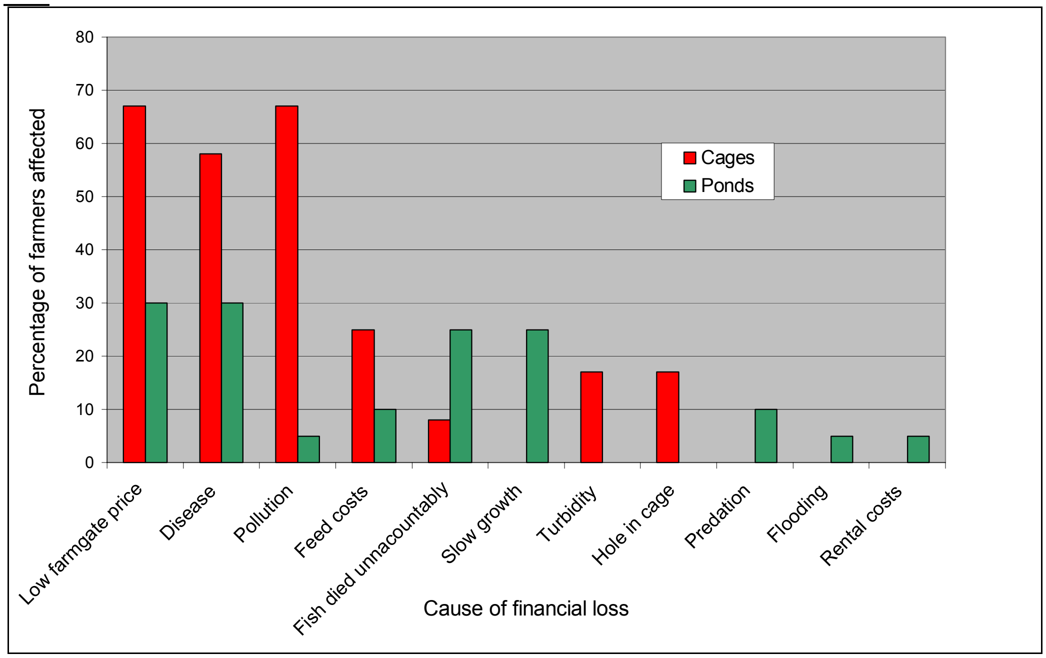


**Figure 15 Causes of financial loss for cage and pond farmers**

### 6.3 Synthesis

The key points outlined above can be summarized as follows: On average, rates of return from semi-intensive polyculture are considerably higher than cage monoculture. This conclusion is consistent with that of Piusombun et al (1995), who find that the rate of return for polyculture is substantially greater than for more intensive monoculture systems. Budgets 1 and 2 show that this effect also occurs across semi-intensive systems, with the less intensive end of the spectrum yielding higher margins but lower absolute returns per unit area than more intensified alternatives. Large and frequent price fluctuations and the high cost of feed as a proportion of total costs make cage culture a risky financial proposition, since profit margins may be slim. One interviewee estimated her investment costs at Bt34-35/kg, meaning that 10% drop in average price resulted in very little or no income. The owner of a feed shop felt that cage farmers who lost money did so not because of poor management practices, which tended to be rather uniform. Instead, she believed that failure usually resulted from a combination of factors, the most important of which were harvest coinciding with low market value and high mortality. Price fluctuations for pond raised fish are less dramatic, and the low ratio of nutrient cost to revenue offers a greater margin of security to producers. As a result, cage farmers return profits less frequently than owners of semi-intensive operations, and the former activity provides a considerably less stable source of income. This is not to suggest that cage culture is necessarily economically unsustainable however since, on average, positive returns outweigh negative. The activity is however, considerably more risky than pond culture. In a study of cage culture in Bangladesh DIFD (2000) the activity's risk rating based on an composite index of the following factors: prevalence and impact of diseases, the length of the production cycle, minimum start-up capital required, profit margin, price variation and payback period. In the Thai case short growout cycles and low fixed costs relative to pond culture are risk reducing factors, but are offset to a significant extent by high prevalence of disease, low profit margins and high price variation

A number of other factors mediate the degree of risk involved in pond and cage production. It was apparent from field visits that, typically, the smaller the numbers of cages operated, the less economically viable a farm was likely to be. Interviewees from Khlong 13, Pathum Thani, owning only three or four cages painted an almost unremittingly gloomy picture of the activity. These farmers could not afford to buy feed outright and were dependent on credit from a contract farming company which increased their operating costs. More importantly however, ownership of such a small number of production units limited the flexibility and resilience of operations to shocks. A farmer with 25 cages can stagger crops, harvesting five cages each month, thereby offsetting to some extent the risk posed by fluctuating farmgate value and ensuring a regular cash flow, whereas farms with only four cages will typically perform a total harvest. If timing of the harvest coincides with low market value then losses or minimal returns are likely to result. One informant felt that, where cage culture on a limited scale provided a household's sole source of income, irregular cash flows would make it necessary to withdraw money from the business during the growout cycle to cover living expenses, making it difficult to repay debts or reinvest at the end of the production cycle and increasing the chances of business failure.

This trend was less immediately apparent for pond based farms as a result of their inherently greater economic stability, although one interviewee noted that 20rai was the minimum area required to guarantee a 'reasonable' household income. Small operations may provide viable sources of income to small operating households however as the popularity of 'backyard' fish culture among the elderly shows. Piusombun et al (2005, p282) observe that economies of scale exist for farms practicing semi-intensive fish culture, finding ponds generate successively lower returns as unit area decreases. They note that this 'may be largely attributed to the decreasing cost of inputs for the marginal increase of area', although none of the cage and pond farmers interviewed in this study reported discounted prices for bulk purchases of feed or other inputs. The operator of an extremely large farm (1300rai) did note however that there are economies of size associated with maintaining large areas of ponds at a single site as opposed to several disbursed ones, because fuel and labour costs are minimized by doing so.

Despite the number and magnitude of potential problems affecting cage culture the activity offers certain advantages over pond culture since start-up capital is lower and access to public water bodies is free. Were it necessary for farmers to pay for either water use or bank side access, it is likely that the activity would become economically unviable in many instances, particularly for smaller operators. It could be argued therefore that open access to public water resources, on which cage culture is in large part reliant, generates an essential subsidy, unpaid costs of which are externalized to the environment.

## 7 ENVIRONMENT

This chapter assesses the environmental sustainability of intensive and semi-intensive tilapia farming from two perspectives; by considering 1) the activities' effects on the environment, and 2) the effects of environmental conditions on the activities. Analysis relating to the former is mainly drawn the extensive literature on the subject, whilst information on the latter is derived from interviews with farmers, and to a lesser extent, a survey of the customers of Nam Sai tilapia hatchery. A specific focus on the dichotomy of intensive and semi-intensive systems was adopted because it was believed that each was likely to produce, and be impacted by, differing sets of conditions. Discussion of system intensity as it relates to sustainability also offers the opportunity to explore variation between different types of semi-intensive system and associated culture practices and to document change occurring within them.

### 7.1 Intensive and Semi-intensive Aquaculture

Differences between semi-intensive and intensive culture systems are the distinction on which this chapter is based. Edwards (1993, p141) defines the two forms of aquaculture thus: 'semi-intensive systems depend on fertilization to produce natural feed *in situ* and/or on feed given to the fish, supplementary feed, to complement the natural feed which develops. A significant amount of fish nutrition is derived from the natural feed'….. 'Intensive systems depend on nutritionally complete feeds…. with fish deriving little or no protein from natural feed produced *in situ*.' 'If a semi-intensive system is given feed as well as fertilizer as the biomass of individual fish and the total weight of fish in the pond increase, the proportion of fish nutrition derived from natural food… declines'. Finally, 'the degree of intensification is defined according to feeding practice but intensification may be accompanied by increasing amounts of capital, labour and mechanization' (Figure 16). The level of intensity of any fish culture system is likely to affect its sustainability for a number of reasons. These include implications for the cost, quantity and type of resources required as inputs, efficiency of resource use, cost of market entry and participation for producers, and cost implications for aquaculture products which dictate their accessibility to consumers. Extensive and extremely intensive systems are not considered here because of the negligible contribution they make to Thai tilapia production. Unless otherwise stated, production occurring in ponds is categorized as semi-intensive and production in cages as intensive.

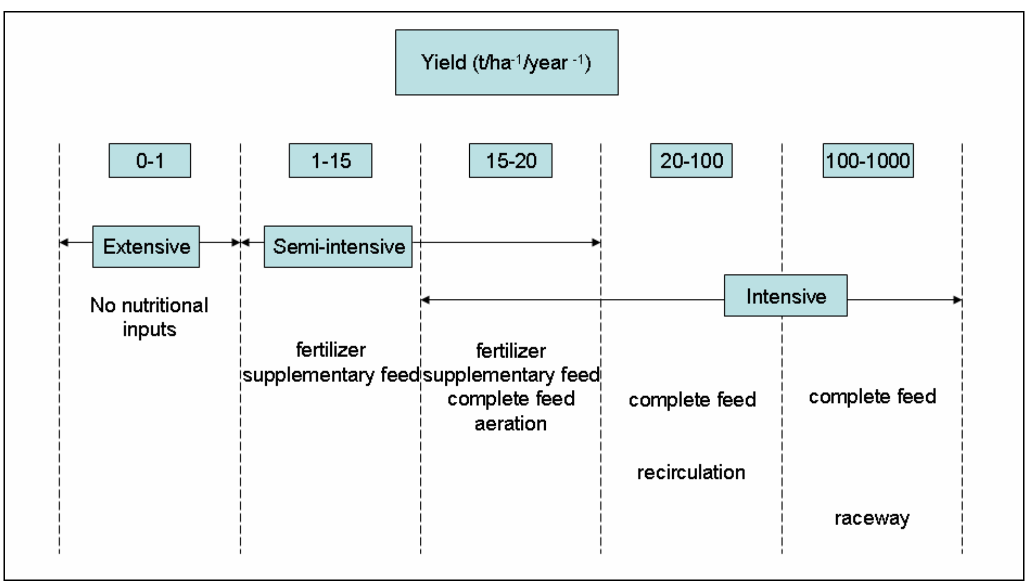


**Figure 16 Intensification of aquaculture systems** (Edwards, 1993)

### 7.1.1 The intensification of pond culture

A key trend emerging during the research is an ongoing process of intensification in pond culture through use of formulated feeds. This challenges traditional perceptions of Thai tilapia culture. The extent and intent of commercial feed application is influenced by a number of drivers. Management strategies associated with these feeds can be separated into three main groups

***a) Supplementary feeding:*** Most commonly, pig finishing pellets are employed as a supplementary feed that complements the use of rice bran and other agricultural byproducts. The reasons for this are twofold. Pig pellets are relatively inexpensive, at around Bt7/kg. Rice bran, the most commonly used agricultural byproduct, costs between Bt5 and Bt6/kg. The protein content of pig feeds is low (12-12.5%), and is similar to that of some grades of rice bran (Tacon, 1990, gives rice bran a crude protein content of 12.2%). Pig pellets are probably more palatable however, fulfilling a fuller range of dietary requirements and, for reasons discussed in 7.2.2, giving higher conversion efficiencies. As a result, farmers operating both poultry/fish and indirectly integrated polyculture systems often feed pig pellets in the last two months of growout to fatten fish prior to harvest. Edwards & Allan (2004) note in a review of feeding practices that Thai farmers recognize the superiority of commercial feeds over alternatives but find their costs are prohibitive. Use of pig pellets during the later stages of growout appears to offer an effective solution to this problem.

***b) Live sale:*** Another distinct trend in intensification involves monoculture of 500-600g tilapia for live sale in which commercial pellets are the main supplementary feed. These fish are usually marketed live at *Talad nat* and have a farmgate value approximately Bt5/kg higher than dead fish of a similar size. Management varies, but typically involves promotion of greenwater throughout the crop cycle, with application of pig pellets and complete herbivorous fish feeds throughout the second half of growout. Herbivorous fish feeds are more costly than pig pellets but have a higher protein content (around Bt9-10/kg for 15% protein, Bt12/kg for 25% protein). Other more traditional supplementary feeds may also be applied. This system is particularly prevalent in the province of Nakorn Pathom, where it appears to have originated 10 years ago, and in the neighbouring provinces of Suphanburi and Ratchaburi. Tilapia are usually stocked in monoculture in this system because culture of lower value cyprinids would be economically inefficient given production costs of more than Bt20/kg. The main points of sale for live Nile tilapia are Bangkok itself and adjoining provinces to the north and west, and the increasing popularity of live Nile tilapia in the Central Region appears to have been occurred in tandem with the growth of *Talad nat*.

***c) Export:*** Production of tilapia for export sits at the extreme end of the semi-intensive spectrum, shading into or becoming intensive as greenwater is reduced to the earliest stages of growout or abandoned in favour of exclusively formulated diets. Interviewees stated that fertilization is not employed because import customers demand fish free of off-flavour. The owner of one large farm reported that the buyer of fish for export placed restrictions on the management practices that could be employed for this reason. In reality however, there may be often be little difference in the sensory quality of between fish raised in fertilized and unfertilized systems (Eves et al, 1999). A senior export company employee felt that in order to increase its appeal to foreign buyers it was necessary to re-brand Thai tilapia as a “modern fish” by removing associations with chicken manure. Although tilapia production in this manner accounts for a small portion of total output it indicates the possible direction of future trends. Four or five large companies currently process and export tilapia to Europe and the US as frozen fillets. These operate with varying degrees of vertical integration, and fish production is either ‘in-house’ or contracted out to handful of very large farms (1000-2000rai) to the south and west of Bangkok. A senior employee of one of these firms estimated that annual exports exceeded 10t. Recent declines in shrimp production may make export oriented intensive tilapia production attractive to agro-industrial companies with excess processing and storage capacity, particularly since it offers the potential for feed sales.

**7.1.2 The Implications of Mixed and Monosex Tilapia**

Farmers using commercial feeds to produce tilapia for live sale or export exclusively stock monosex fry because the high growth rates, and to a lesser extent larger ultimate weights, attained are an economic necessity. Most farmers employing pellets as supplementary feed use monosex fry for similar reasons. However, mixed-sex tilapia stocked in lower intensity systems remain extremely important although less immediately visible. Little et al (1994) estimated an output of 150-300 million mixed-sex fry per year from the country's main producing area. Belton et al (2005) visiting the same location eleven years on, found that the number of fry producing groups had doubled. There are six large-scale monosex tilapia hatcheries in Thailand, of which four are in the Central Region. Average monthly output for two of these, Nam Sai and Manit Farm, is approximately 10 million fry each, and annual production of red tilapia fry alone by CP is 120 million (*ibid*). Leaving aside all smaller producers and hatcheries, a crude calculation suggests that in Central Thailand outputs of mixed and monosex fry are, very roughly, even, with somewhere in the region of 450 million of each produced annually.

Mixed and monosex fry production bring with them different implications. Monosex hatcheries are highly intensive in terms of labour, capital investment and inputs. Nam Sai Farm for instance, requires 2-4t of catfish pellets per month for broodstock maintenance alone (Little et al, 1997), and an additional 4t of fishmeal for sex reversal and nursing of fry. Infrastructure includes over 90 ponds, several offices, staff housing and hatchery facilities all of which were specially constructed. Startup costs were Bt5 million, and the hatchery employs 170 staff fulltime staff, with additional staff employed for piece work such as egg collection. Traditional mixed-sex fry production as practiced in Chachoengsao and Chonburi is far less capital and input intensive: broodfish are held in shallow ponds, fertilized with pig manure and excavated from rice fields at little cost; few special facilities are required and little there is generation of primary employment other than for producers themselves.

Management of mixed-sex tilapia growout is typically less intensive than for the systems outlined in 7.1.1, principally for economic reasons since they attain a small average size (around 350g), and a hence low value, unless steps such as partial harvest and restocking are taken. It therefore makes sense to minimize input costs and stock in polyculture to optimize efficiency of nutrient use. Mixed-sex fish are popular with older and poorer farmers, and with those for whom either fish culture or tilapia culture represents a minor source of income. There are various reasons why this is so. Older farmers may be unfamiliar with management practices needed to successfully raise monosex fish (e.g. pond drainage to remove fish between cycles), and be risk averse. Mixed-sex fry are approximately five times cheaper than monosex at Bt0.06 each. This makes them attractive to poorer farmers, particularly since self-recruitment means that complete restocking may not be required for each crop cycle. This aspect also appeals to farmers for whom tilapia are a minor element of polyculture (since it is not necessary to devote time, capital and attention to their management), and to those livestock/fish farmers and horticulturalists raising fish in ditches for whom fish provide only a minor supplementary income.

The differences between mixed and monosex producers and production were most vividly illustrated in *Tambon* Kokprajadee, Nakorn Chai Sri, Chachoengsao. On one side of a road retired fruit growers raise mixed-sex tilapia with rohu and silver barb in small household ponds to provide a basic income, using small quantities of chicken manure, rice bran and kitchen waste as inputs and harvesting at 300g. On crossing the road one encounters the new face of Thai aquaculture; better capitalized farmers in their late 30's, operating 40-60rai of ponds fertilized with large quantities of ami ami. These contain monocultures of all-male tilapia fed only commercial pellets for live sale at a weight of 500g (Figures 17 and 18).

**Figure 17**

17 & 18: The two faces of tilapia culture, Kokprajadee, Nakorn Pathom

### 7.2 The Environmental Impacts of Tilapia Culture

This section details a number of possible environmental impacts of tilapia culture. These include; use of land and water resources, water quality, energy efficiency, and effects on biodiversity.

#### 7.2.1 Land and water resources

Beveridge et al (1994, p498), note that 'aquaculture consumes a lot of water, irrespective of how such use is assessed'. In ponds this can occur via seepage, or evaporation which can cause 1-3% of pond volume to be lost each day. Substantial intensification typically requires associated increases in water consumption to prevent declines in water quality caused by high concentrations of fish excreta and uneaten feed. Little & Muir (1987) provide a summary of water consumption in three relevant culture systems (Table 17). Roberts & Muir (1995, p147) state that, 'requirements for land may also be significant, though intensive aquaculture operations may demonstrate quite high area based yields in comparison with other food production systems', particularly when compared to less intensive forms of aquaculture. As a result, intensive systems are more likely to be constrained by lack of sufficient water resources, and semi-intensive systems by insufficient land resources. This pattern was evident from field visits. Some interviewees stated that expansion of cage culture was prevented by lack of available space in public water bodies, whilst in highly urbanized districts of Samut Prakan and Bangkok local continued expansion of pond culture was impossible due spatial competition. Thailand's Central Plain is blessed with abundant agricultural land however and in many areas, population densities are relatively low (Falvey, 2000), making establishment of new operations in neighbouring land rich provinces possible (see Chapter 5).

| System | $M^3$ water/t fish |
|---|---|
| Semi-intensive pond culture of carp and tilapia | 500-1000 |
| Intensive pond tilapia pond culture | 2000-5000 |
| Intensive cage culture (species unspecified) | 10000-20000 |

**Table 17 Water use in aquaculture**

Ponds are typically dug on land already utilized for rice paddy or, in some cases, where soil has been removed for construction purposes. This option is simpler than conversion of wetland, meaning that little habitat or biodiversity is likely to be lost as a result. Depletion of groundwater is a serious issue in certain areas in the vicinity of Bangkok (Greenberg, 1994), but few interviewees reported lack of water inhibiting or resulting from production in ponds. Little et al (1994) observe however that on the borders of Chachoengsao and Chonburi rice farming became unfeasible after widespread pond construction made effective management paddy water levels problematic. These issues not withstanding, Beveridge et al (1994) and Muir and Roberts (1995) both suggest that the land and space resources occupied by agricultural production facilities are often of lesser significance than the ecosystem areas (ghost hectares) required to sustain them.

### 7.2.2 Water quality

Beveridge et al (1994, p498) assert that aquaculture, 'borrows' water, 'returning it in a more degraded form'. Pillay (1999, p22) makes an important counterpoint however, stating that 'there are very few forms of food production and indeed any form of human activity that does not affect the environment in some way'. This makes it necessary to examine the extent to which aquaculture is responsible for environmental degradation, and whether any resultant damage can be traded off against possible benefits. According to Roberts & Muir (1995) some of the main environmental issues associated with aquaculture include; waste and nutrient loadings; outputs of solids, Nitrogen (N), Phosphorous (P), vitamins and minerals; outputs of husbandry/disease management chemicals, antibiotics, and; effects of waste materials on adjacent benthos and the water column. The severity of each of these will vary dependent on a variety of factors including: the volume of production (Ackefors, 1999); type, quantity, quality and regularity of feed applied (De Silva, 1999, p221); system openness (i.e. the degree to which it interacts with the surrounding environment); stocking density and product value; and capacity of the recipient water body (Ackefors, 1999). The latter two points are important because since serious outbreaks of disease or parasites are most likely to occur at high density and the value of fish produced will influence the decision to apply expensive chemotheraputants, and because deterioration of benthos and water column is likely to be more severe in static water and confined locations than in water bodies with a strong currents or greater assimilative capacity (Ostrowski et al, 2001).

Nutrient utilization is more efficient with complete diets than in wholly or partially fertilized systems. This is because, in the latter 'there is at least one extra step involved in the conversion of nutrients to fish through natural feed production in the pond', whereas commercial feeds are 'formulated according to the nutritional needs of the target species' (Edwards, 1993, p154). However, in terms of weight of N and P released to the environment per kg of fish produced, intensive systems are 7-31 and 3-11 times more polluting than semi-intensive systems. This is because, 'in contrast to most intensive systems which are "open" in the sense that they have water exchange and therefore contribute nutrients to the adjacent environment, semi-intensive systems are usually "closed" or static water systems with little or no exchange of water with the surrounding area except when the pond is drained" (*ibid*, p155*)*. As a result, in a model developed by the author, 83% or N and 86% of P inputs to semi-intensive fish culture are removed by the system and do not pollute the environment as a result of immobilization in sediments on the pond bottom. 'In contrast, no nutrients in the intensive system are sequestered by the culture system and pass through the system in the water, 73% N and 86% P, to pollute the external environment'. It is difficult to gage what difference the discharge of nutrients into the environment makes in practical terms. Lower reaches of the large tropical rivers, in which most of the questionnaire respondents and interviewees operated their cages, are naturally eutrophic and subject to anthropogenic eutrophication from other sources (Petts, 1984). Eutrophication emanating from cage culture is likely to generate less severe ecological impacts under these conditions than in more nutrient sensitive environments. Additionally, the scale on which cage culture would have to occur to exceed the assimilative capacity for nutrients of a high discharge river such as the Chao Phya is unknown, but there are no obvious indications that this threshold has been breached by current production levels. There are documented instances of this occurring in reservoirs (e.g. Abery et al, 2005), and the likelihood of change in benthic communities caused by deposition of solid waste is higher lentic waters than in rivers with high flow volumes, but in Central Thailand cage culture in reservoirs is far less common than in other locations.

### 7.2.3 Feed and energy efficiency

As outlined in the previous section, feeding efficiency is greatest with complete feeds. However, as Little & Edwards (2003, p146) point out, 'broader definitions of efficiency may be more relevant'. Intensive aquaculture is heavily reliant on fossil-fuel energy inputs (Folke, 1988). The steps involved in production of complete fish feed, each requiring combustion of hydrocarbons, is outlined below (Figure 19). This is in marked contrast to directly or indirectly integrated forms of semi-intensive aquaculture for which, other than transport, nutrient inputs are effectively energy neutral since they are the byproducts of other independent processes. Hepher (1978) first observed that there is a net loss of protein associated with intensive fish culture using high protein feed. The argument that fishmeal based feeds are inefficient in this regard is made most famously by Naylor et al (1998), who find the extraction of protein from marine fish stocks to produce smaller quantities of cultured fish to be unsustainable.

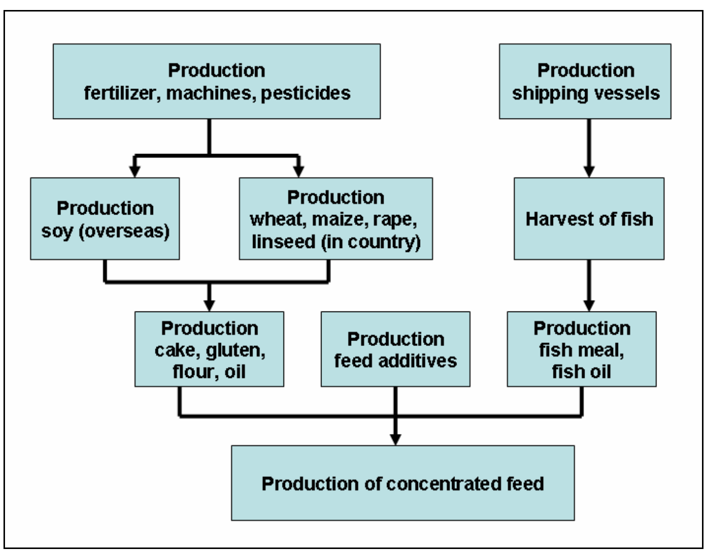


**Figure 19 The lifecycle of salmonid feeds** (adapted from Papatryphon et al, 2004)

Responses from customers of Nam Sai hatchery indicated that 39% used commercial formulated feeds in combination with other supplemental feeds or fertilizers (see Table 18). All farmers operating cages used commercial pelleted feed. It was not possible to determine exact composition of these feeds given the proprietary nature of the information and variation between brands. However, all contain some fish meal, though most of the protein content is derived from vegetable sources, particularly soy, along with small quantities of animal protein (e.g. bone and blood meal). Typical protein content for each is as follows; pig finishing pellets 12%-12.5%; herbivorous fish pellets 15%, 25%; hybrid walking catfish pellets 25%, 30%; tilapia pellets 25%, 30%, >30%. Soy bean meal is cheaper than fish meal, costing Bt12/kg and Bt22-25/kg respectively in Thailand in 2005 (USDA, 2005). This encourages feed manufacturers to minimize inclusion of fishmeal as far as is nutritionally efficient. Inclusion of soy is not entirely unproblematic however, as its production is often viewed as unsustainable. WWF, (2003) lists the following as occurring in Brazil; widespread deforestation, massive pesticide application, concentration of land into large enterprises that force out small farmers, neglect of staple food production for local consumption, and increasing cultivation of genetically modified soybeans bearing risks for the environment and human health. Furthermore, Thailand experiences production deficits for both products, with the result that over 60% of fish meal is imported, with Peru, Korea, Japan and Denmark the main exporters (USFCS, 2003). Around 85% of soy is also imported, principally from Argentina, Brazil and India (USDA, 2005). This means that food miles and fuel consumption associated with intensively reared tilapia will be far greater than those from semi-intensive systems.

| Feed or fertilizer | Percentage of farmers utilizing | |
|---|---|---|
| | Pond | Cage |
| Chicken manure | 61% | 0% |
| Agricultural byproduct | 49% | 0% |
| Formulated feed | 39% | 100% |
| Pig manure | 32% | 0% |
| Fertilizer* | 22% | 0% |
| Canteen waste | 7% | 0% |
| Homemade feed | 5% | 0% |
| Industrial byproduct | 5% | 0% |

* Includes ami ami

**Table 18 Feeds and fertilizers used by customers of Nam Sai tilapia hatchery**

At the more extensive end of the spectrum, many pond based systems in Central Thailand use fertilization to produce phytoplankton in the pond, typically by the application of poultry or pig manure, ami ami (a nitrogen rich byproduct of monosodium glutamate production), or in some cases inorganic agricultural fertilizer. In terms of energy use, directly integrated greenwater systems (where livestock is housed over fish ponds) are least intensive. Other indirectly integrated farms may use only fertilization but are reliant on importation of manure or other fertilizers from off-farm, requiring somewhat higher energy expenditure. Indirectly integrated systems, typically combing fertilization with a variety of low cost supplementary feeds, are most common in Central Thailand and represent a step up in intensity, but utilization of agricultural and industrial byproducts is typically energy efficient since, apart from transportation, no fossil fuel is required for their conversion to feed stuffs. Kautsky et al (1997, p761) conclude that wastes utilized as feed should not be considered as requiring ecosystem space to produce since ‘these areas are already appropriated for current production… for human consumption, and will not increase if the waste is used by semi-intensive pond farming. On the contrary, there will be more food produced per ecosystem area’. Recycling nutrients in this manner may actually produce a positive environmental benefit since in addition to improving the overall efficiency of nutrient use in farming systems the sequestration of organic wastes in fish production effectively extends the assimilative capacity of the environment (Little and Edwards, 2003). The concentration of intensive livestock production and processing in peri-urban areas generates volumes of waste too large to be used as traditional land fertilizers or too costly to transport, and integrated aquaculture provides a mechanism by which these pollutants can be treated (Little & Edwards, 1999). Figure 20 illustrates the range of feeding and management practices associated with semi-intensive tilapia culture in Thailand

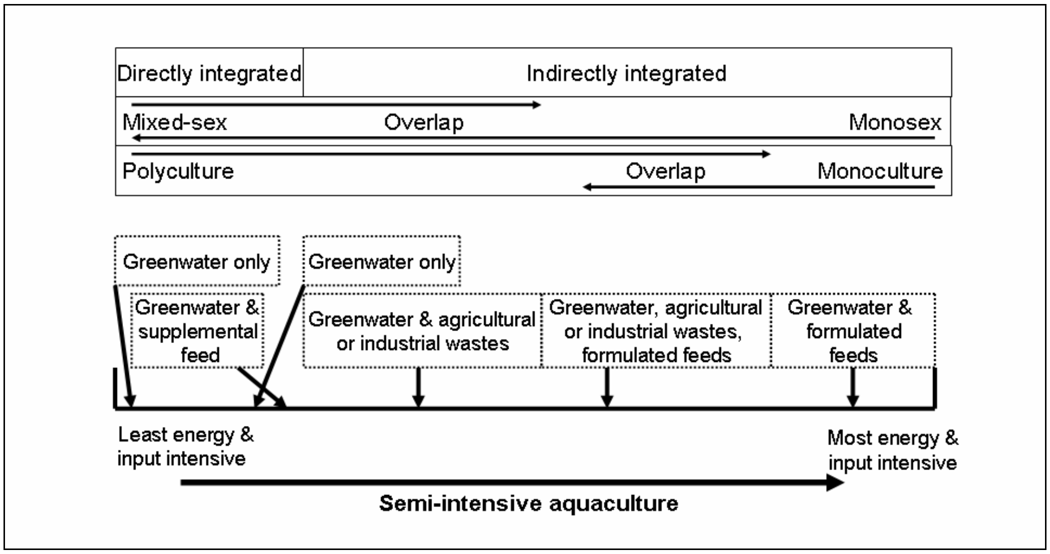


**Figure 20 The spectrum of intensity of semi-intensive aquaculture in Central Thailand**

**7.3 Environmental Constraints to Tilapia Culture**

This section examines the impacts of a number of environmental parameters on pond and cage culture. Examination of Figure 21 shows that, with the exception of farmgate price and feed costs, the major problems experienced by producers are environmental in origin. Fish disease and associated problems, and pollution are discussed below. The implications of avian influenza are also addressed.

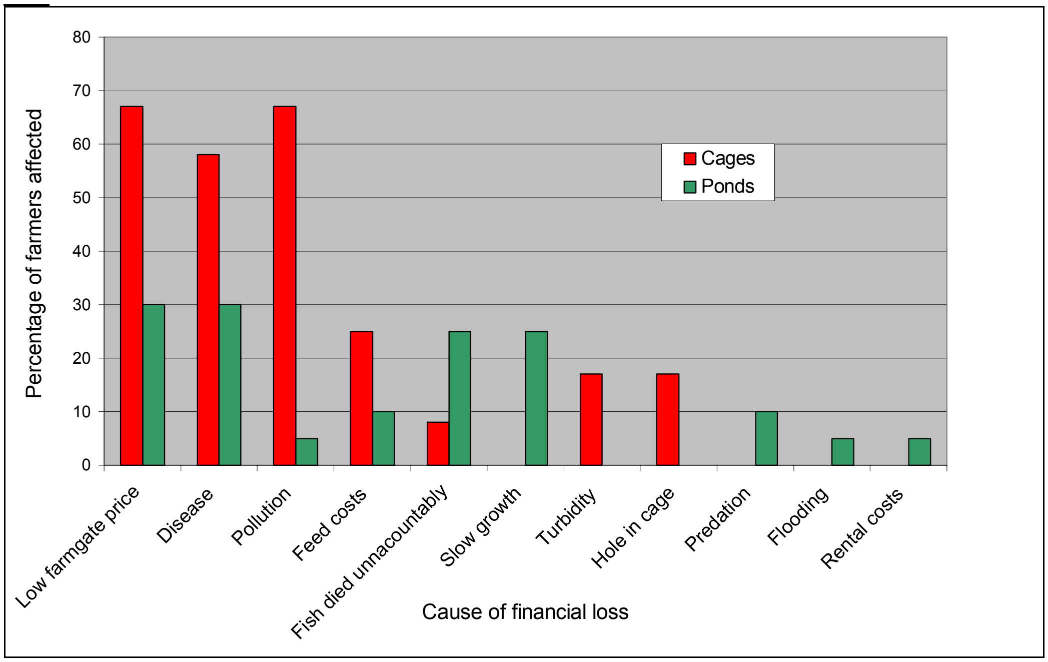


**Figure 21 Causes of financial losses for cage and pond farmers**

### 7.3.1 Disease and related problems

When the responses of cage and pond farmers in Figure 21 are aggregated, disease emerges as the second most important reason for farmers returning negative profits. Two other major causes of financial loss (fish dying without symptoms, and slow growth) may also be disease related. Interestingly however, no farmers operating cages report slow growth as a reason for loosing money, suggesting that it may be linked in part to poor pond management (e.g. insufficient nutrient application or overstocking). Disease is a particularly important issue for cage farmers due to the economic implications of high feed prices in the event of suboptimal harvest. It also reflects the risk of exposure to pathogens inherent in open systems, and perhaps the animal welfare implications of high stocking densities and less robust qualities of red tilapia strains compared to Nile tilapia. Interviewees reported disease events to be most prevalent during the hot dry season (March, April, May), though by no means exclusive to it. Low flows in rivers and canals at this time often result in poor water quality by causing concentration of pollutants and low dissolved oxygen levels, and making tidal areas prone to saltwater intrusion. Whilst none of these factors is necessarily lethal in its own right, they are likely to place fish stocked at high densities under added stress, and may well increase their susceptibility to infection (Bunch & Bejerano, 1997). High water temperatures during the dry season can also induce stress in both cage and pond fish, and are often associated with outbreaks of *Streptococcus*, which is the most common cause of disease induced mortality in farmed tilapia in Thailand (personal communication, Warren Turner). Numerous interviewees operating both cages and ponds expressed the opinion that disease outbreaks had become particularly acute over the previous two years. Whilst this might represent the beginnings of a significant trend it is more likely to be a temporary upward tangent in a larger oscillating trajectory, and a knowledgeable hatchery owner linked the severity of recent outbreaks to higher than average temperatures during preceding the cool seasons.

### 7.3.2 Pollution

Pollution caused negligible economic impacts for farmers with ponds, but was the single most important reason for financial losses reported by cage farmers. This illustrates again the poor bio-security of open cage systems. The severity of pollution varied between sites visited, with the Ban Pa Kong River in Prachinburi experiencing the most damaging effects. It appeared that water quality in river was declining year on year, partly as a result of new industrial development along its banks. At least two interviewees seriously questioned whether cage culture could persist there in the medium to long term, and all considered pollution a more serious problem than disease. Canals are potentially even more vulnerable to water quality problems because they carry relatively small volumes of water possessing a lower assimilative capacity than large rivers. Closed canal lock gates can also prevent the passage of toxic discharges downstream. This occurred in Khlong 13, Pathum Thani, in 2005 when impoundment of wastewater discharged from the city of Saraburi resulted in a major fish kill for which farmers were later compensated Bt10,000 each. Farmers in the canal also experience an annual pollution event resulting from pesticide treatment of golden cherry snails by rice farmers. Farms in Ban Sang on the Ban Pa Kong suffer regular fish kills following discharges from a paper mill located upstream. A middleman noted that water quality in the Chao Phya River in Ang Thong, was significantly better than in the Bang Pa Kong. Interestingly, disease problems also appeared to be less prevalent in Ang Thong, suggesting a circumstantial link between disease and pollutants.

### 7.3.3 Avian influenza

Avian influenza (AI) is now endemic to much of Southeast Asia (Feare, 2006). The disease first reached epidemic proportions in Thailand in late 2003, and has re-emerged very recently (OIE, 2006). Table 18 (p42) indicates that chicken manure is used by 61% farmers, making it the most commonly applied input among pond operators. The ramifications of AI for tilapia culture are therefore of potentially major significance. Integrated chicken/fish farmers are the most directly impacted group. Broiler production is controlled by several vertically integrated agro-industrial companies and organized on a contract farming basis, whereas egg production is less oligopsonistic. Although around two-thirds of the broiler chickens produced in Thailand are consumed domestically production for export is concentrated in the provinces surrounding Bangkok (Belton & Little, 2006b, Falvey, 2000). Belton et al (2005) found that following the 2003/2004 AI outbreak, agro-industrial firms demanded that broiler producers under contract to them convert open hen houses to closed systems intended to exclude possible vectors of the disease (wild birds and insects). This procedure, motivated by the need to comply to standards in importing countries, is costly in terms of both fixed and variable costs, but farmers unable to comply were refused essential supplies of day-old chicks. Interviews during this study confirmed that several in areas this had the expected effect of concentrating broiler production in the hands of the largest operators, and an informant in Nakorn Pathom believed that only 5% of broiler farms in the province had survived. In Pan Thong, Chonburi, some farmers had abandoned chicken production, whilst others had been able to switch to contract duck farming, thus maintaining direct integration.

For integrated chicken/fish farms that were forced to completely cease poultry production it was usual to convert to indirectly integrated fish culture by importing manure from remaining farms and increasing supplemental feeding. Layer farms were less strongly affected as large firms exercise incomplete control over the organization of egg production and many farms operating semi-closed systems have continued. Regulations introduced during the AI outbreak by the Department of Livestock Development also impacted indirectly integrated fish farms using chicken manure. Initially this occurred because movement of material between farms was prohibited. This restriction was later relaxed and although access to poultry farms is now more tightly controlled movement of manure is not prevented. The extent to which chicken manure prices have been affected was unclear from interviews, although the general trend in prices for all feeds and inputs is up (Table 14, p32). Farmers in Lat Krabang using dried chicken blood as a supplemental feed reported that its cost more than doubled in the period during and after the outbreak. Future epidemics of avian influenza may well impact farms reliant on chicken manure by forcing up production costs. Knud Hansen et al (1993) find that application of inorganic fertilizers may actually be cheaper per unit of primary productivity than chicken manure however, meaning that any future ban on the movement of poultry manure might not be as serious for greenwater farmers as it first seems. AI also had some positive effects regarding fish culture. The elevated price of chicken and public health scare that accompanied the outbreak caused consumers to substitute, with the effect that average farmgate value of cultured fish jumped 14% between 2003 and 2004 (Belton et al, 2005).

**7.4 Synthesis**

The ecological sustainability of tilapia culture systems must be understood in terms of their environment impacts in both directions. On each count cage systems perform less sustainably than ponds because their high degree of openness to the surrounding environment makes discharge and intake of pollutants and pathogens inevitable. Whether cages generate significantly detrimental impacts in large rivers and canals is questionable however since many are already heavily degraded by pollution from other anthropogenic sources. Because of their semi-closed nature ponds are more isolated from other aquatic environments. Lower stocking densities of hardier strains and less frequent exposure of these fish to other potential sources of stress may account for the apparent lower severity of disease in these systems. This-not-withstanding, disease and associated problems remain the primary cause of negative returns in semi-intensive systems representing a serious problem, the full extent of which may only just be coming to light. Roberts & Muir's (1995, p175) contention that 'diseases in aquaculture almost invariably indicate a poorly balanced production system' with the result that disease is 'an ecological issue as much as a veterinary one', is illuminating in this regard. It is worth noting that cage farmers may not be sufficiently well informed to accurately distinguish between disease and pollution except in the most severe cases and may therefore mistake one for the other, but the consequences for system sustainability are effectively the same. Furthermore, timing of the survey and interviews coincided with the end of what is typically the worst period for both disease and pollution events in both cages and ponds, and could have tempered respondents' opinions as to their ultimate significance. This should not detract from the serious sustainability implications raised however.

Cage systems are more intensive than ponds in terms water consumption, although being located in existing water bodies they engender no implications for increased evaporation or fuel consumption for water exchange. Ponds are more intensive in terms of land use, but because they are rarely establish in 'virgin' habitats this has minor implications for biodiversity. More important, as both Roberts & Muir (1995) and Beveridge et al (1994) point out, is the appropriation of 'ghost hectares' or ecological capacity caused by production and use of inputs including feed, fuel and machinery. The relative sustainability of different feeding practices is perhaps the most difficult issue to unpack. There is a clear trend toward intensification occurring in semi-intensive systems, although the extent of commercial feed application and strategies governing its use vary a great deal. Use of marine fish meal and soy products cultivated for use in feed is associated with ecological impacts including loss of biodiversity and high fossil fuel consumption. For many of the commercial feeds utilized for tilapia culture in Thailand inclusion of fish meal will be low, but several authors, most prominently Naylor et al (2000) express concern that utilization of fishmeal for production of omnivorous and herbivorous fishes will have increasing negative cumulative consequences. How severe these consequences will ultimately remains to be seen. At the lower end of the intensity scale directly and indirectly integrated aquaculture offer a high degree of ecological sustainability in terms of resource use and may even improve environmental quality by recycling wastes and sequestering nutrients that would otherwise be lost.

## 8 CONCLUSION

This chapter reviews key points that have emerged from discussion in the previous three chapters. Strengths, Weaknesses Opportunities Threats (SWOT) analysis is used to summarize major sustainability issues for four tilapia culture systems in Central Thailand. Pointers toward the future sustainability of these culture systems are suggested.

### 8.1 Review

This study was initially intended to focus on the possible implications of urbanization on tilapia based livelihoods by examining pressures affecting culture systems in both rural and peri-urban locations. It became clear during the course of field work that a clear distinction between the two was difficult to maintain. Greenberg's (1994) typology of Region Based Urbanization (RBU) was therefore adopted as a more appropriate framework for the analysis of Central Thailand's changing human geography with respect to aquaculture. Five factors linked to RBU were found to exercise a particularly important influence over the sustainability of tilapia culture and associated livelihoods. These were; the diversification of agriculture away from traditional Thai rice monocultures toward more specialized, higher return enterprises; the growth of employment opportunities in other sectors of the regional economy; the ability of aquaculture to provide a cushion against economic shocks and trends impacting alternative livelihoods; competition for land in heavily urbanized areas, and; the expansion of market access in response to improving transport and communication infrastructure, increasing urban consumer spending power and cultural shifts in the consumption of food.

In many instances the conditions of RBU produce two-way effects regarding sustainability. With regard labour for instance, tilapia farming is viable among competing agricultural livelihoods because of the low labour effort required to successfully maintain ponds or cages. At the same time, incomes from small to medium-scale operations are generally lower and less reliable than those generated by employment in manufacturing and services. As a result, whilst comparing favourably to other agrarian livelihoods, aquaculture is unable to match the attractiveness of 'urban' employment opportunities, particularly to younger segments of the labour force with increasing levels of education, less parochial outlooks, and weakening cultural attachment to the land. In some instances RBU is very largely positive for livelihoods linked to tilapia culture. This is most pronounced in the case of marketing, where demand from urbanizing areas has been a critical driver in the overall expansion of tilapia farming and the diversification of tilapia products and culture systems. One possible interpretation of observations made throughout the course of this research is that tilapia farming in Central Thailand is not simply a product of region based urbanization; it also, at one level, a *producer* of RBU. Cause and effect are closely bound together in this regard, but time and again during field visits a pattern of rural/urban succession, from rice to fish to industry to residential and commercial, was seen to be occurring in more or less advanced stages. It could be argued therefore that tilapia culture plays a small role in the genesis of conditions which simultaneously facilitate and threaten its own existence and accelerate its evolution and development. It should be noted that threats posed to the sustainability of aquaculture by processes associated with RBU are not necessarily problematic if, at the same time they also provide new livelihood opportunities offering potentially greater benefits.

From a micro-economic standpoint, Chapter six showed that culture systems of differing intensities generate a variety of implications for economic sustainability, but that these must be understood in the context of the opportunities and needs of their practitioners. In a broad sense, intensive cage systems performed poorly compared to all the semi-intensive systems analyzed. This resulted from a number of environmental and economic factors, principle among which were a high sensitivity to price fluctuations and disease and pollution related events. In each case this sensitivity derived from the high cost of feeds, with sub-optimal market value and reduced yields generating similarly negative impacts on returns. This in itself does not necessarily make cage culture unsustainable. On average, farmers returned profits more frequently than making losses or breaking even, and large operations tended to perform relatively successfully. Furthermore, low fixed costs and operating costs other than feed, the ready availability of commercial credit, and the simplicity and extremely low labour requirement of cage culture make its adoption by those living in suitable locations a relatively low risk in terms of opportunity cost when compared to alternative agrarian livelihoods. In addition, these factors made it possible for producers to pursue other livelihoods whilst operating cages. Cage culture is least sustainable for its poorest adopters who are least able to withstand the shocks and trends it is frequently subject to.

Semi-intensive systems, as noted above, tended to perform in an economically sustainable manner when compared to cage systems. This generalization obscures a great deal of variability within and between semi-intensive forms of culture however. Traditional small-scale greenwater polyculture systems supplemented with cheap agricultural byproducts have low operating costs and generate high returns to investment in percentage terms. At a superficial level this makes them more sustainable than more intensive pond based systems using high inputs of commercial feed. For these, yield is the major determinant of profit, resulting in pressing need to produce sufficient quantities of fish to recoup outlay on feed. However, whilst profit margins in more intensive systems are lower and risk is greater, absolute returns per unit area are far higher. The two activities are appropriate to different groups of farmers. For poor or elderly households, or those that derive most of their income from other agricultural activities, the low costs and risks involved in less intensive systems make them viable where lack of financial, human or physical capitals might constrain adoption of high input culture practices. The inverse may also be true for farmers who possess or can access the substantial financial capital needed to establish and maintain more intensive operations and wish to support several family members on the basis of fish culture alone. Most pond culture falls somewhere between these two poles. Farms stocking monosex fish with small quantities of carps and using greenwater supplemented with byproducts and some formulated feed are common and, depending on the scale on which they are practiced, may be appropriate to the livelihood strategies of a variety of groups with differing goals and needs. Different needs, capital and opportunities can therefore make one particular form of fish culture a sustainable livelihood option for one household and untenable for another. This situation reinforces the observation made in Chapter 3 that sustainability needs to be interpreted and refined on a case-by-case basis.

Ecological sustainability issues relating tilapia culture are of two types; those generated directly or indirectly by the activity itself and those emanating from the external environment. For the former, each increasing step in intensity generates progressively greater impacts in terms ecosystem space appropriated and energy consumed. Directly integrated livestock/fish systems where no supplementary feed is applied may be very nearly neutral in this regard, and are arguably even positive, because the major energy requirements are derived from sunlight and resources produced on-farm as incidental byproducts of existing activities. Indirectly integrated systems utilizing wastes imported from off-farm also generate low impacts for similar reasons. The use of formulated feeds containing global commodities such as fish meal, soy, and other proteins and carbohydrates from crops cultivated specifically for use in feed, increases the level of ecosystem support and energy inputs required to produce each kg of tilapia. Thus, as reliance on formulated feeds increases tilapia culture gradually becomes less environmentally benign. Other trends associated with intensification, e.g. production of sex-reversed fry, also require a step up in energy consumption. Cage culture is not only the most highly resource consumptive form of tilapia culture assessed here, but the most polluting, due to the openness of cages to the surrounding environment. Whether or not the wastes discharged from cages should be regarded as a problem in the Thai context is difficult to gage. Open cages also render fish housed in them more vulnerable to pathogens and toxins transmitted from the surrounding environment than the fish in pond based systems. Intensive agriculture as a whole has been subject to recurrent shocks resulting from ecological factors. In this study alone, the impact of disease on intensive shrimp culture, feedlot chicken production and tangerine plantations in Thailand has been evident. Disease is also becoming one of, if not *the*, major factor in determining the economic sustainability of more intensive forms of tilapia culture.

**8.2 SWOT analysis**

This section summarizes sustainability issues for the four main systems assessed in this report; low, medium, and high input semi-intensive pond culture and intensive cage culture. Because of the inherent difficulty in aggregating disparate sustainability indicators (ecological, economic, societal), and in recognition that sustainability is time, space and context specific, no attempt is made to rank the systems in terms of their absolute sustainability. It is suggested that a moderate view of sustainability which allows for some degree of trade-off between environmental cost and societal good is the most pragmatic way to approach livelihoods linked to tilapia culture. It is left to the reader to draw their own conclusions based on interpretation of the evidence presented throughout this report as to which, if any, trade-offs produce the most desirable, sustainable outcomes.

| **Low input pond polyculture** | |
|---|---|
| *Strengths:* low operating costs, large profit margins, low labour effort, low energy consumption, increases efficiency of resource use in some farming and food processing activities | *Weaknesses*: small financial returns |
| *Opportunities:* suitable for elderly, poor, and as supplementary source of income | *Threats:* shifting consumer preferences toward larger fish, uncompetitive compared to ‘urban’ livelihoods & land uses |

| **Medium input pond polyculture** | |
|---|---|
| *Strengths:* good alternative livelihood to rice farming and other agriculture, increases efficiency of resource use in farming and food processing systems, relatively low labour effort | *Weaknesses*: high fixed costs |
| *Opportunities:* suitable for a farmers with a variety of goals depending on scale of culture, expansion & relocation away from ‘urban’ to ‘rural’ areas, conversion of abandoned shrimp ponds | *Threats:* declining value of tilapia in real terms, disease, increasing input costs, uncompetitive compared to ‘urban’ livelihoods & land uses |

| High input pond monoculture | |
|---|---|
| *Strengths:* potential to generate high incomes, good alternative livelihood to other agricultural activities | *Weaknesses*: high fixed and operating cost, formulated feed expensive, inefficient use of resources compared to systems using wastes as feed, unsuitable for farmers with less capital |
| *Opportunities:* market for large live tilapia & export quality fish expanding | *Threats:* disease, uncompetitive compared to 'urban' livelihoods & land uses, market saturation |

| Cage culture | |
|---|---|
| *Strengths:* low fixed costs, easy market entry, low opportunity cost to those near public water bodies, very low labour effort | *Weaknesses*: open systems vulnerable to disease & poor water quality, source of pollution. Production of high protein formulated feed consumes ecological space and hydrocarbons, high operating costs. |
| *Opportunities:* viable for larger operators, as an additional source of income, or in less polluted water bodies, may have potential in ponds | *Threats:* Fluctuating product value, finite market for red tilapia, increasing incidence of pollution and disease at some sites |

**8.3 The Future of Tilapia Culture in Central Thailand**

This study has shown that tilapia culture in Central Thailand is an extremely diverse, dynamic, and rapidly developing activity that is responsive to the opportunities and constraints afforded by economic, environmental, social and cultural change in urban and agrarian settings. This characteristic, combined with high domestic demand for tilapia products, makes the activity as a whole a sustainable one with regard the likelihood of its continued persistence into the future in various forms. The activity is trending toward supplying higher value products and products to which value is added by basic processing. The elevated market value of these products compared to traditional cheap, fresh, dead fish has made use of formulated feeds in tilapia production economically viable for the first time. Given sustained economic growth it is likely that the demand for these goods and the concomitant intensification of their production will continue. This aspect should not be overstated however. Marked heterogeneity in the distribution increasing societal wealth in the Central Region, the intrinsic economic efficiency of producing fish in systems utilizing only wastes, and the attractiveness of cheap tilapia products, mean that indirectly integrated systems will continue be the major source of tilapia for the foreseeable future. In these systems small degrees of intensification (e.g. by application of pig pellets in the latter part of the growout cycle) may help to improve productivity whilst keeping costs low, thereby returning benefits to both producers and low-income consumers and retaining many positive environmental features. The role of technological developments and agro-industry in shaping the future of production should not be ignored. Innovations such as the advent of commercial-scale sex reversal and the introduction of genetically improved strains have already extended the production and market potential of tilapia, and as the fish's global profile and importance continues to grow further developments of this nature are likely. The influence of vertically integrated companies, once minimal, is also set to expand given the increasing use of formulated feeds. This might eventually have profound consequences on the organization of tilapia production though not necessarily desirable ones from the standpoint producers should the specific needs and goals embodied in their strategies be overridden by corporate interests.

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## APPENDIX 1

**Sumary of stakeholders intervined during field work**

| Stake holder | Date | Location (district and province) | No. of interviews | Notes |
|---|---|---|---|---|
| Pond farmer | 30/5/06 | Muang, Pathum Thani | 3 | |
| Pond farmer | 1/6/06 | Nong Sua, Pathum Thani | 1 | |
| Pond farmer | 6/6/06 | Ban Sang, Prachinburi | 1 | |
| Pond farmer | 7/6/06 | Lat Krabang, Bagkok | 3 | |
| Pond farmer | 7/6/06 | Bang Phli, Samut Prakan | 3 | |
| Pond farmer | 8/6/06 | Bang Phli, Samut Prakan | 1 | |
| Pond farmer | 8/6/06 | Pan Thong, Chonburi | 4 | |
| Pond farmer | 9/6/06 | Ban Sang, Prachinburi | 1 | |
| Pond farmer | 14/6/06 | Bang Lane, Nakorn Pathom | 3 | |
| Pond farmer | 21/6/06 | Visetchaichan, Ang Thong | 1 | |
| Pond farmer | 22/6/06 | Bang Phae, Ratchaburi | 3 | |
| Pond farmer | 21/6/06 | Visetchaichan, Ang Thong | 1 | Telephone interview |
| Pond farmer | 28/6/06 | Bang Bo, Chachoengsao | 1 | Telephone interview |
| Pond farmer | 30/6/06 | Pakphli, Nakorn Nayok | 1 | Telephone interview |
| Pond farmer | 30/6/06 | Ban Sang, Prachinburi | 1 | Telephone interview |
| Pond farmer | 3/7/06 | Bang Ban, Ayuttaya | 1 | Telephone interview |
| Pond farmer | 21/7/06 | Nakorn Chai Sri, Nakorn Pathom | 5 | |
| Cage farmer | 1/6/06 | Nong Sua, Pathum Thani | 7 | |
| Cage farmer | 6/6/06 | Ban Sang, Prachinburi | 2 | |
| Cage farmer | 9/6/06 | Ban Sang, Prachinburi | 1 | |
| Cage farmer | 21/6/06 | Pramoke, Ang Thong | 2 | |
| Marketing participant | 2/6/06 | Talad Thai, Pathum Thani | 8 | Wholesale market |
| Marketing participant | 2/6/06 | Talad Rang Sit, Pathum Thani | 3 | Retail market |
| Marketing participant | 7/6/06 | Talad Numchok, Bangkok | 2 | Wholesale market |
| Marketing participant | 8/6/06 | Pan Thong, Chonburi | 1 | Wholesaler |
| Marketing participant | 14/6/06 | Talad Bang Lane, Nakorn Pathom | 1 | Wholesale market |
| Marketing participant | 21/6/06 | Talad Suwapan, Ang Thong | 1 | CP middleman |
| Other stakeholder | 9/6/06 | Ban Sang, Prachinburi | 2 | Feed dealership, red tilapia nursery |
| Other stakeholder | 14/6/06 | Bang Lane, Nakorn Pathom | 1 | Marketing manager |
| Other stakeholder | 22/6/06 | Bang Phae, Ratchaburi | 1 | Betagrow, tilapia processing &export |
| Other stakeholder | 21/7/06 | Rang Sit, Pathum Thani | 1 | Hatchery |