UBON RATCHATHANI UNIVERSITY

A COMPARISON OF FISHERY PRODUCTION FROM NATURALLY RECRUITED AND STOCKING OF HATCERY REARED SEED IN CULTURE-BASED FISHERIES IN LAO PEOPLE'S DEMOCRATIC REPUBLIC

AKHANE PHOMSOUVANH

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Akhane Phomsouvanh

Researcher

บทคัดย่อ

เรื่อง : การเปรียบเทียบผลผลิตทางการประมงจากปลาที่แทนที่ตามธรรมชาติกับปลาจากโรงเพาะฟักที่เลี้ยงในระบบการปล่อยเลี้ยงในธรรมชาติในสาธารณรัฐประชาธิปไตยประชาชนลาว

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คำสำคัญ : การประมงแบบปล่อยเลี้ยงในธรรมชาติ, แหล่งน้ำขนาดเล็กที่มีน้ำไม่ตลอดทั้งปี, ระดับความหนาแน่นที่เหมาะสมในการปล่อย, ค่าอัตราการเติบโตจำเพาะ ค่าปัจจัยสภาวะ

การประมงแบบปล่อยเลี้ยงในธรรมชาติ (Culture-based fisheries, CBF) ได้มีการดำเนินการและประสบความสำเร็จในหลายประเทศทั่วโลกในการเพิ่มผลผลิตในการประมง ซึ่งชี้ชัดให้เห็นว่าปลาจากระบบฟาร์มเพาะเลี้ยงที่นำไปปล่อยเลี้ยงสามารถมีส่วนสำคัญในการช่วยผลผลิตในธรรมชาติ นอกจากนี้ยังเป็นการสร้างงานและรายได้ในชุมชน การศึกษาในครั้งนี้ได้ทำการทดลองที่จังหวัดเวียงจันทร์และบอลิคำไซ โดยทำในแหล่งน้ำขนาดเล็กที่มีน้ำไม่ตลอดทั้งปีที่เป็นแหล่งน้ำที่สำคัญของชุมชนทั้งในเรื่องการเพาะปลูก ชลประทาน และกิจกรรมอื่นๆ ของครัวเรือนรอบๆ อ่างเก็บน้ำ การศึกษาได้ดำเนินการตั้งแต่ 2 ถึง 5 รอบการเลี้ยง ซึ่งระยะเวลาในแต่ละรอบการเลี้ยงใช้เวลา 6 ถึง 8 เดือน ในทุกๆ กรณีศึกษา พบว่าผลผลิตทางการประมงและรายได้ในชุมชนที่ได้จากกิจกรรมประมงเพิ่มขึ้นอย่างมีนัยสำคัญ รวมถึงการเพิ่มขึ้นของรายได้และการบริโภคอาหารจากปลาสำหรับแต่ละครัวเรือน ข้อมูลที่ได้จาการศึกษาอีกส่วนได้ทำการคัดเลือกแหล่งน้ำในโครงการจำนวน 14 แหล่ง เพื่อทำการศึกษารูปแบบและผลสัมฤทธิ์ของชนิดปลาที่ทำการปล่อย รูปแบบของการปล่อยจะประกอบด้วยปลาสามชนิดหลักที่มีการปล่อยเป็นปรกติในการประมงแบบปล่อยเลี้ยงในธรรมชาติ ได้แก่ ปลานิล ปลาไน และปลาตะเพียน ศึกษาควบคู่ไปกับรูปแบบการปล่อยที่มีปลากะโห้เทศและปลาลิ่น โดยศึกษาถึงอิทธิพลของการปล่อยในรูปแบบต่างๆ ที่จะมีผลกระทบต่อผลผลิตของปลาในธรรมชาติ ซึ่งพบว่าถึงแม้นว่าจำนวนชองลูกปลาที่ปล่อยลงเลี้ยงในธรรมชาติจะเพิ่มขึ้นในทุกๆ ปี (รอบการปล่อยเลี้ยง) แต่จะพลความผันแปรน้อยมากและไม่พบความแตกต่างทางสถิติในผลจับปลาธรรมชาติ นอกจากนี้ ยังพบว่าระดับความหนาแน่นที่เหมาะสมในการปล่อยจากทุกแหล่งน้ำที่ทำการศึกษาให้ค่าประมาณจำนวนลูกปลาที่ปล่อยรวมทุกชนิดอยู่ที่ 3,000 – 5,000 ตัวต่อแฮคเตอร์ สำหรับการติดตามค่าอัตราการเติบโตจำเพาะ (specific growth rate; SGR) พบว่ามีค่าสูงที่สุดในปลานิล แต่ไม่พบความแตกต่างอย่างมีนัยสำคัญกับปลาตะเพียนขาว ในขณะที่ปลาไนมีค่าอัตราการเติบโตจำเพาะต่ำที่สุดและแตกต่างอย่างมีนัยสำคัญกับปลาสองชนิดแรก สำหรับในการประเด็น

ค่าปัจจัยสภาวะ (condition factor; K) พบว่ามีแนวโน้มไปในทางเดียวกับค่าอัตราการเติบโตจำเพาะ โดยมีค่าจากมากที่สุดไปน้อยที่สุดจาก ปลานิล, ปลาตะเพียน และปลาไนตามลำดับ และแตกต่างอย่างมีนัยสำคัญระหว่างแต่ละชนิด ผลจากการศึกษาในครั้งนี้จะเป็นแนวทางพื้นฐานในการดำเนินการการประมงแบบปล่อยเลี้ยงในธรรมชาติเพื่อประโยชน์ของชุมชนในอนาคตและสร้างความยั่งยืนในการพัฒนาดังกล่าว

ABSTRACT

TITLE	: A COMPARISON OF FISHERY PRODUCTION FROM NATURALLY RECRUITED AND STOCKING OF HATCERY REARED SEED IN CULTURE-BASED FISHERIES IN LAO PEOPLE'S DEMOCRATIC REPUBLIC
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KEYWORDS	: CULTURE-BASED FISHERIES, NON-PERENNIAL WATER BODIES, APPROPRIATE STOCKING DENSITY, SPECIFIC GROWTH RATE, CONDITION FACTOR

Culture-based fisheries (CBF) have been successfully developed across the world in order to increase productivity of capture fisheries; fish farming has showed to be an important contributor to national food security, rural employment and income generation. The study was conducted in Vientiane and Bolikhamxay province, and reservoirs coves and small non-perennial water bodies that are central to the communities, primarily for rice paddy irrigation and other household needs, around these. A minimum of two cycles to a maximum of five cycles, each of 6 to 8 months duration, were successfully completed in all the selected water bodies. In all instances the income of the communities from CBF activities was significant higher that obtained from un-organized fishery activities of the respective water bodies, and there were significant improvement in gain the fish production and financial gains as well as the food fish supplies for household consumption. Data are presented on CBF, an extensive aquaculture practice of community managed stocked and recapture, conducted in 14 water bodies of varying sizes in Lao PDR. The pattern of

combination, three fish species were commonly stocked in CBF practices in Lao PDR *viz*, tilapia, common carp, and silver barb. The combinations of stocking regimes were tested on the possible effects of wild fish yield. Although the numbers of stocked seeds were higher from cycle to cycle, less variability and non-significant difference in total wild fish yield. The yield of the stocked species in all studied water bodies obtained the appropriate stocking density should range between 3,000-5,000 fingerlings/ha. In term of the specific growth rate (SGR), the results showed that tilapia has the highest SGR but not significant to silver barb. Meanwhile, common carp showed the lowest SGR significantly different to the other two species. The condition factor (K) also showed similar trend as SGR and the order of the species from the highest to lowest K is as tilapia, silver barb, and common carp, in which the K-values of all the three species were significantly differently to each other. Such studies provide valuable baseline information, which help CBF to be placed on a more scientific footing, and ultimately enable rural communities to benefit even further and make the process more sustainable in the long term for development strategies for the country to establish sustainable culture-based fisheries.

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CHAPTER I
INTRODUCTION

1.1 Introduction to the research problem and its significance

Lao PDR is among the countries that still the least dense population with average 27 people per square kilometer and the total population is of 6.5 millions in 2012 (Ministry of Planning and Investment, 2012:1-3). Lao PDR is currently classified as a lower-middle income economy country and is one of the fastest growing economies in the East Asia and Pacific region (World Bank, 2015: 3-5). However, despite steady economic growth in the 21st century, the country remains a food-deficit country, ranking 138th out of 187 countries on the 2011 and approximately one-quarter of the population lives in poverty, mostly in rural and remote areas, in which malnutrition is among the critical concerns for the country (Figure 1) as it struggles with stubbornly high rates of stunting (44%) and underweight (27%) (WFP, 2013: 1-2).

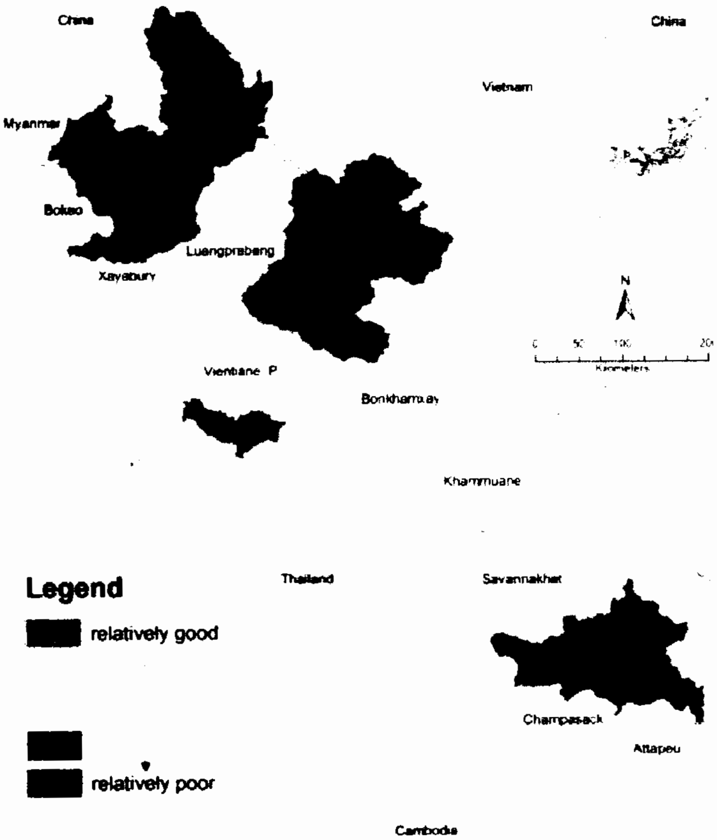

Figure 1 Relative status of food and nutrition security in Lao PDR
Source: WFP (2013)

To combat with this food security problem, there is a need on increasing the supplies of food resources. For most of Lao people, the dominant livelihood profile is that of agricultural production for own consumption and supplemented by hunting, fishing and gathering of wild products for food (Agricultural Census Office, 2012: 30-34). Several studies showed that the contribution of fish to protein supply for household consumption is about 40% of total protein consumption in Lao PDR (Table 1), in which over 80% of people consume fish at least once a week (STEA, 2003: 5; ICEM, 2010: 7). Therefore, the possibility of increased inland fish production is raised to meet the demand of animal protein food, especially for the landlocked countries as Lao PDR, (Garaway and et al., 2006: 37-45; Arthur and et al., 2010: 81-88).

Table 1 Average consumption of animal protein by source of protein (g/person/ day) between 2000 - 2003 (ICEM 2010)

Animal protein sources	Lao PDR	Other Lower Mekong Basin countries	World
Freshwater fish	4.25	3.88	1.39
Seafood	0.22	3.67	3.03
Bovine meat	2.28	1.40	3.63
Pig meat	1.76	3.72	4.40
Poultry meat	0.82	2.26	4.01
Other animal products	1.77	3.42	12.07
Total	11.09	18.36	24.11
% of freshwater fish protein in total	38.31	21.15	5.78

Source: FAO (2014)

In 2011, the capture fisheries sector of Lao PDR was accounted for about 34,000 tonnes or 26% of country's total production and aquaculture production of 95,600 tonnes for 74 percent of country's total production (SEAFDEC, 2011: 21-27). These figures are highlighted and implied the raising on the importance of aquaculture compare to wild capture in Lao PDR. However, the 26% contribution of capture fisheries to total production is about illusive because 77% of fishing households did not sell any of their fish catch and, therefore, difficult to get the data of these catches (FAO and WFP, 2011). Moreover, the fishes from the wild are easier to be accessible for the rural people than the products from aquaculture. For the average rural household, an estimated 32% of animal protein comes from wild sources, in particular fishes, and increasing to 45% in the Central/Southern Highlands (Ministry of Agriculture and Forestry, 2013: 3).

Lao PDR faces the challenge of raising the standard of living, corresponding to a rapidly expanding population, while at the same time protecting the environment which supports people's lives and livelihoods is also desired. Fisheries management, through such measures as conserving fish habitats, controlling over-fishing and restricting use of destructive gears, can play a role in conserving and maintaining fisheries, while stocking and aquaculture can also increase the yield of fisheries (MRC, 2011: 5-7). As the wild capture of freshwater fishes, i.e. inland fisheries, is so importance to Lao PDR, the measures to conserve, sustain, enhance the inland fisheries in Lao PDR are seriously required. Numbers of conservation and enhancement measures have long been applied elsewhere worldwide to mitigate the decline in freshwater fish diversity and increase inland fish yield, in which the most common practice for fishery enhancement is fish stocking program, *aka* culture-based fisheries, for a purpose to increase fish production (De Silva, 2003: 221-243). This practice is also possible to apply to water bodies in Lao PDR, where a large excess production of natural food resources have not yet utilized by the fishes in the systems (Villanueva and et al., 2008: 20-25). This is also entailed that there is a room for the stocked animal to utilize the un-exploited sources in the system by culture-based fisheries.

Fishery enhancement through stocking program, *i.e.* culture-based fisheries, is among the options to meet both the demands on food production and natural conservation. The culture-based fisheries always use the water body that has potential to produce large numbers of stocked fishes by its own the natural productivity without external nutrients added (Bell and et al., 2006; Phomsouvanh and et al., 2015: 27-38). This activity is, indeed, carried out for a number of purposes such as to increase fish food production, to augment and conserve the depleted stocks, as well as to augment sport fisheries (Peter,1998: 35; Welcomme and Bartley,1998: 351-382; Cowx, 1999: 10). Culture-based fisheries have been long been practice but scientific evidence of their successes have just recently reported. The culture-based fisheries, as a rule, involve ownership either singly, as in the case of farmer lessees of small reservoirs or group together, as in the case of community's wetland.

In Lao PDR, a very rudimentary form of the culture-based fisheries practices have been ongoing a relatively small scale for about 10 years in swamps and flood plain pools. All such fish stocking practices have been initiated by village communities of their own accord without any form of governmental intervention until recently the involvement of government office as Department of Livestock and Fisheries. There are, thus, number of rooms to be improved and understood for the best practices in

Lao PDR. In this respect, this study addresses the issues on optimal stocking density and species combination as well as the performances of stocked species of the field experimental scale in the natural wetlands of Lao PDR.

1.2 Objectives

1.2.1 To underline the effect of stocked species to the contribution of naturally recruited species production in each growth cycle;

1.2.2 To optimize the stocking density in the current culture-based fisheries practices and increase seed stock production capabilities;

1.2.3 To compare the performances (i.e. specific growth rate and condition factor) of the three major stocked species *viz.*, tilapia, common carp and silver barb

1.3 Scope of the study

This research focuses on comparing the effect of stocking of hatchery-reared seed species, contributing to the fish production, as incorporated by the naturally recruited species production. Five water bodies and three species from hatchery-reared seeds were selected to compare and examine the optimum stocking density and performance for each species. This research also emphasizes on assessing the total fish production, both wild and stocked fish yield; the relationship between production of stocked fish and stocking density; and, lastly, comparing the performance of stocked fish by species.

1.4 Expected outcomes

This research is expected to come up with recommendations that could be used as guidance for developing the culture-based fisheries in other areas in Lao PDR and the Lower Mekong Basin countries that having conditions favorable for adopting this culture system.

CHAPTER 2
LITERATURE REVIEW

2.1 Fisheries and aquaculture in Lao PDR

Lao PDR is a mountainous, landlocked country in the heart of Southeast Asia with coordinates for the center point of the country being 18 00 °N, 105 00 °E. Population of Lao PDR is about 6.7 millions in 2014, where the country is a lower-middle income economy with a GNI per capita of $1,600 in 2014 (World Bank, 2015). The country has a land area of 236,800 km^2, of which 87.7% (207,674 km^2) drains into the Mekong River, making up 26.1% of the Mekong Basin, and contributing about 35% of the Mekong River's discharge (MRC, 2011:19-21). Another 12.3% in the north-eastern area drains to the north of Viet Nam into rivers that flow to the China Sea. The topography and rivers of Lao PDR are shown in Figure 2 (MRC, 2011:19-21). The fishes in the Mekong mainstream and her tributaries in Lao PDR play the crucial role to the wealth of country, not only for its fishery resources, but also for its rich aquatic biodiversity. Of the country's population of about 5.8 million, 75 to 80% still lives a rural lifestyle, in which their livelihoods relate to agricultural activities and highly depend on natural goods and services. Their rice-based meal is always still complemented by vegetables and fishes, which subsistence and semi-subsistence fisheries, as well as small-scale rural aquaculture, are consequently most important for them (ASEAN, 2009: 5-7). The people of Lao PDR, especially those in the rural communities, still rely heavily on aquatic resources, *i.e.* fish and other aquatic animals, as the most readily available sources of animal protein, as noted by Sjorslev (2000), "*fish and other aquatic animal products form the major component of the animal protein intake of rural communities in Lao PDR*". The most current estimated yield of the country's inland fisheries amounted to 106,552 tonnes per year (Southeast Asian Fisheries Development Center (SEAFDEC), 2015: 21-27),and the estimated actual fish consumption per capita (kg/capita/year) of inland fish was 29 kg/capita/year (DLF/MAF2007).

In Lao PDR, more than 481 fish species out of the total 924 species recorded in the Lower Mekong Basin have been identified (Kottelat, 2001: 5). However, other aquatic animals and plants are still poorly known in terms of systematic, distribution and stock assessment. Moreover, about eighteen (18) indigenous fish species have been cultured in fish farming, where seed stocks primarily in the form of fry have been collected from the wild, i.e. capture-based aquaculture. Such activities are also supplemented with the artificially propagated seed stocks in private farms and some government hatcheries. The fingerling production from hatchery is not only viable for fish culture systems, but also stocking in small water bodies and reservoirs, i.e. culture-based fisheries, which are desirable strategies for enhancing the food fish production in the country. Other than the indigenous fishes, more than 10 exotic (alien) fish species have been introduced into Lao PDR, mainly for the purpose of aquaculture. These fish include the common carp or pa nai (*Cyprinus carpio)*, silver carp or pa ked lap (*Hypophthalmichthys molitrix)*, grass carp or pa kin gna (*Ctenopharyngodon idella*, bighead carp or pa houa nhai (*Hypophthalmichthys nobilis*), Nile tilapia or pa ninh (*Oreochromis niloticus),* rohu (*Labeo rohita*), migral carp (*Cirrhinus mrigala)*, catla *(Catla catla)*, and African catfish or pa douk phanh (*Clarias gariepinus)* (Kottelat, 2001: 5).

Lao PDR has 14 main tributaries and five north-eastern rivers, covering an area of 304,704 ha (Figure 2). The area of large hydropower reservoir is estimated at 96,030 ha, while shallow lakes, natural pools, peat swamps, other swamps and wetlands occupy 114,800 ha. Irrigation reservoirs and weirs are estimated to cover 60,000 ha, whereas wet-season rice-fields total 632,850 ha. Seasonal flooded areas in the Mekong Plain are believed to cover more than 60,000 ha (DLF/MAF 2007). Overall, these add up to a total water resource area of 1,238,394 ha for capture fisheries. In addition, water resources used for aquaculture cover about 42,000 ha. As aquaculture in Lao PDR expands, many forms of production system are being developed, for example pond culture, communal ponds, rice-cum-fish culture and cage culture. Such forms of production systems are divided into sub-categories depending on the nature and main activity of producers. According to the Fishery Statistical Bulletin in 2013, aquaculture production accounted for 124,085 tonnes in an area of more than 42,000 ha, including cage culture in the Mekong and some tributaries (DLF/MAF 2007).

In 2011, the capture fisheries sector of Lao PDR was accounted for about 34,000 tonnes or 26% of country's total production and aquaculture production of 95,600 tonnes for 74% of country's total production (Figure 3, SEAFDEC Statistical Bulletin 2011: 21-27). The river fisheries, in Lao PDR, are exploited largely by local communities within their own area, where traditional system for managing access and fishing effort are widespread. Moreover, the fishery is an integral part of the livelihood of entire communities (Coates and et al., 2003). Bulk of the catch is turned-over by part-time and subsistence fishers, rather than by those classified as full-time fishers, except in the large hydropower reservoirs such as Nam Ngum where commercial fishers are dominant. However, this is a relatively recent phenomenon since the Nam Ngum was constructed in 1971 (DLF/MAF 2007). The total fish production of Lao PDR (Table 2) has increased continuously from 2009 to 2013. The annual increase from 2009 to 2013 in volume was 8%. The trend of the inland capture fisheries and aquaculture production of Lao PDR in 2009-2013 is shown in Figure 4.

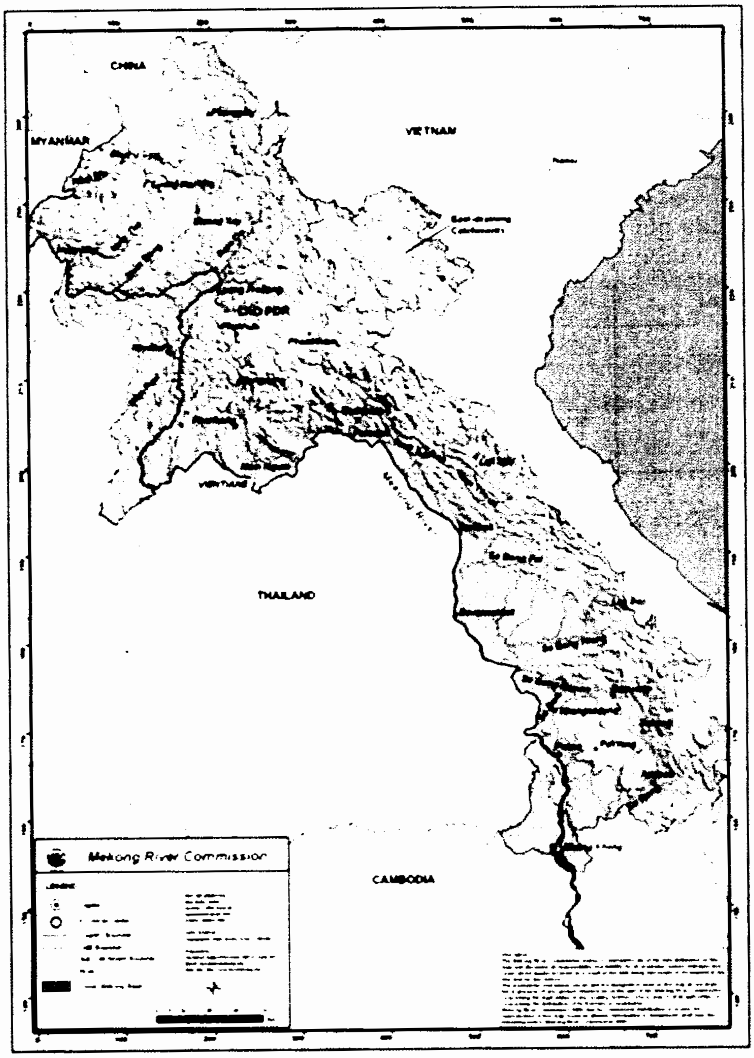

Figure 2 Topography and river of Lao PDR (MRC, 2011)

Table 2 Total fishery production of Lao PDR (in quantity, tonnes), 2009-2013

Sources/Year	2009	2010	2011	2012	2013
Capture Fisheries	30,000	30,900	34,000	34,105	40,143
Aquaculture	75,000	82,100	95,600	101,895	124,085
Total	105,000	113,000	129,600	136,000	164,228

Source: Southeast Asian Fisheries Development Center (SEAFDEC) (2015)

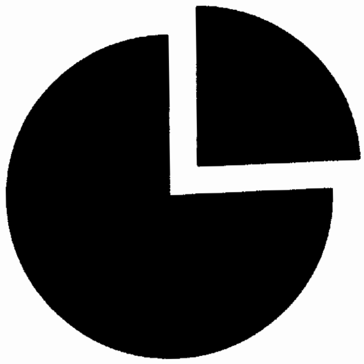

Figure 3 Percentage of the sub-sector's contribution to Lao PDR's fisheries production in 2012

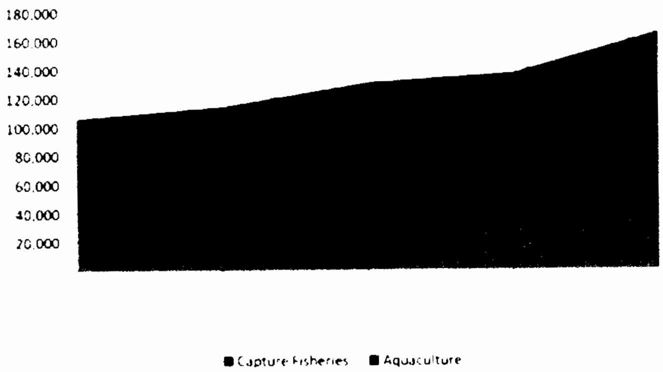

Figure 4 Trend of the inland capture fisheries and aquaculture of Lao PDR from 2008 to 2012 (tonnes)

2.2 The culture-based fishery

Numbers of conservation and enhancement measures have long been applied in the inland waters, to mitigate the decline in freshwater fish diversity and increase inland fish yield, in which the most common practice for fishery enhancement is fish stocking program, i.e. culture-based fishery, for a purpose to increase fish production (De Silva, 2003: 221-243). It is important to make a distinction between culture-based fisheries and fisheries enhancement (Welcomme and Bartley, 1998: 351-382), although the former is a mode of enhancement as;

2.2.1 *Stock enhancement of wild fisheries*: the enhancement of stocks of an existing wild, open-access fishery with species that may or may not be self recruiting. This category includes the stocking of relatively large inland water bodies where there are no property rights to the stock. Generally the recapture rate of stocked fish is low and repeated enhancement is not always necessary to maintain the fisheries.

2.2.2 *Culture*-based *fisheries* (CBF): the stocking of small water bodies is a form of enhancement that is typically undertaken in a regular basis and the stocking activity is the only means of sustaining the fishery. Typically, a person or a group of persons and/or an organization will have property rights to the stock. The source of stock for the enhancement may be derived from capture, but more typically is obtained from a hatchery operation. These features collectively amount to a form of aquaculture that according to the FAO definition (FAO, 1997: 36) is referred to as culture-based fishery.

Culture-based fisheries has been defined as "*activities aimed at supplementing or sustaining the recruitment of one or more aquatic species and raising the total production of the production of selected elements of a fishery beyond a level, which is sustainable through natural processes.*" Thus, CBF include enhancement measures, which may take various forms, such as the introduction of new species; stocking natural and artificial water bodies, including those with materials originating from aquaculture installations; fertilization; environmental engineering including habitat improvements and modification of water bodies; altering species composition including elimination of undesirable species or constituting an artificial fauna of selected species; genetic modification of introduced species (FAO, 2011b). Based on such definition, "*CBF consist of two phases – farmed phase for the provision of stocking materials, and wild phase where the onward growth of the fish stocked depends on natural processes.*"

The CBF could essentially be a form of extensive aquaculture or a farming practice conducted in small water bodies (generally less than 100 ha). De Silva (2003: 221-243) highlighted the potentials of developing CBF in the Asian region utilizing small water bodies, which are often community-managed for the main purpose of increasing food fish production (De Silva, 2003: 221-243). The implementation of CBF is always conducted in the small water bodies because of that, in general, the natural fish recruitment and production are usually is too low to support any substantial fishery in these water bodies. In addition, because of its small size, the water body has few habitats that cannot be easily fished, and though the productivity of the water body might be quite good, the natural fish population is quite vulnerable to over-fishing (De Silva and Fung-Smith, 2005: 65-81). Therefore, fisheries development in small water bodies is therefore usually done in conjunction with a regular stocking program. Other than the small water body, the artificial water bodies, which are built not for fishery or aquaculture purposes (such as aquaculture ponds) but are often built for irrigation purposes, could be applied for CBF. These perennial or non-perennial water bodies selected for a culture-based fishery could be stocked with suitable species in pre-determined proportions. The stocked fish live and grow in water bodies consuming the naturally-produced food organisms in it. The fish are harvested at a suitable time or when water level recedes (De Silva and Fung-Smith, 2005: 65-81). De Silva (2003: 221-243) also stated that CBF offers other main advantages. These include CBF being environmentally "friendly;" the only external input is seed stock; being rural in nature, CBF benefits the poor communities; generates synergies among rural communities; and is low cost and often does not involve capital outlay.

2.3 Examples of culture-based fishery practices

2.3.1 Bangladesh

Bangladesh offers a good example of the development of CBF in natural water bodies. Co-managed by communities, the country's CBF makes use of such commonly-stocked species as the silver carp (*Hypophthalamichthys molitrix*), catla (*Catla catla),* grass carp (*Ctenopharyngodon idella),* rohu *(Labeo rohita*), common carp *(Cyprinus carpio),* and mrigal (*Cirrhinus mrigala*) (Middendorp and et al., 1999: 19). Interestingly, culture-based fisheries could also impact on the production of naturally-recruited indigenous species, when the catches of the latter are almost equal to those of the stocked species, and far exceed the levels when stocking is not practiced (Hasque and et al., 1999: 141-148).

2.3.2 China

The CBF in China could be considered as the most developed in the world. Primarily making use of the Chinese major carps, i.e. grass carp, bighead carp (*Aristichthys nobilis*), silver carp, common carp, the Wuchang fish (*Megalobrama amblycephala*), black bream (*Megalobrama terminalis)*, and mud carp (*Cirrhina molitorella)*, China's CBF is successful perhaps due to the results of many factors. These could include those important elements that are taken into consideration at the planning stage of CBF, as well as in the preparation of the water bodies for effective harvesting (Li and Xu, 1995: 127). Moreover, most water bodies, in particular reservoirs, in China have their own hatcheries, and fry and fingerling rearing facilities, thereby regular supply of seed stocks is always assured.

2.3.3 Sri Lanka

Sri Lanka is reputed to have very high density of reservoir surface areas (De Silva, 1998: 128), consisting of perennial, large and medium sized reservoirs and non-perennial small reservoirs, which are all suitable for implementing CBF. The common stocked species are made use of a mix of common carp, bighead carp, silver carp, and rohu (Wijenayake and et al., 2005: 249-258). Although a number of suitable water bodies, the failure of the CBF is also experienced and could caused by i) lack of guaranteed fingerling supply which leads to the inability to stock and make full use of the growing season; ii) oversupply of produce in space and time; iii) rules, regulations and responsibilities of stakeholder organizations that are not well thought of and planned; and iv) use of undersized fingerlings that result in low returns (De Silva, 1998: 128). However, in the recent past there has been an upsurge in the development of CBF in Sri Lanka, when the Government of Sri Lanka recognizes that CBF could be a very significant avenue for enhancing food fish production in rural communities (Jayasinghe and et al., 2005a: 157-166, b: Wijeynayake and et al., 2005: 249-258; Jayasinghe and et al., 2006: 157-164; Wijeynayake and et al., 2007: 1-18).

2.3.4 Vietnam

Northern Vietnam has large numbers of small water bodies that are considered to be suitable for development of CBF (Nguyen and et al., 2001: 975-990). Although fishery activities in these water bodies have been ongoing for about 8-10 years, these are on relatively small scale. Furthermore, these water bodies are commonly referred to as farmer-managed reservoirs as these are leased to individuals or groups of individuals for fishery activities and water management by provincial authorities (Nguyen and et al., 2001: 975-990). The fisheries are dependent on the stocking of exotic species, primarily fingerlings of grass carp, silver carp, bighead carp, common carp, and mrigal carp, which are stocked in late February-March each year and harvested using large drag nets approximately 10-12 months later (Nguyen and et al., 2001: 975-990). Nonetheless, although CBF in Vietnam could be considered economically viable, further improvements to the productivity would obviously enhance economic returns, almost for the same inputs.

2.3.5 Culture-based fisheries in Thailand

Thailand is one of the economically developed countries of Southeast Asia, and inland fisheries are of considerable importance. The culture-based fisheries or community-based fisheries management is one of fisheries management approach which many of the communities in Thailand have set up their own community-based fisheries management programs. The main measure included 1) no fishing or conservation areas, usually near the village in public water bodies; 2) closed season, usually specified as the beginning of the wet season when fish spawn; and 3) restrictions on use of some gears, such as small-scale fishing gear. This management aimed to improve fisheries related to wild capture fisheries, and overall related to improving habitat or to stocking (Hortle and et al., 2008: 85).

In Northeast Thailand, culture based fisheries in village ponds have developed since the 1980s, following the expansion of government and private fish seed production, and various programs to build village ponds and to promote aquaculture. During period 1993-1996, fish culture in communal ponds and reservoirs was being promoted by the Department of Fisheries aims being the promotion of communal semi-intensive aquaculture. The communities assumed responsibility for pond management and specific decision on operational rules, including monitoring and enforcement, were taken by the village communities. The government supports included brief training in management techniques such as nursing, feeding, fertilization, and integrated agriculture-aquaculture (Garaway and et al., 2001: 5).

2.4 Culture-based Fisheries in Lao PDR

The Government of Lao PDR has recognized that CBF development is a suitable strategy to enhance food fish supplies in rural areas, particularly in the numerous flood plain depressions and coves of large reservoirs which retain water for six to nine months in a year, and are thought to be ideally suited for CBF practices. In Lao PDR, very rudimentary forms of culture-based fisheries practices have been ongoing on a relatively small scale for about 10 years in swamps and floodplain pools, in few provinces such as in Vientiane and Bolikhamxay. Such culture-based fisheries activities currently in operation have been initiated by village communities on their own accord without any form of governmental intervention. However, production achieved from such operations is relatively low. These CBF practices are currently based on stocking of common carp, big head carp, silver carp, grass carp, rohu, mrigal and tilapia (*Oreochromis niloticus*). Stocking species are sometimes supplemented with the indigenous species such as the silver barb (*Barbonymus gonionotus*), mud carp (*Cirrhinus molitorella)*, small scale river carp (*Cirrhinus microlepis)*, black shark minnow (*Labeo chrysophekadion),* broad head catfish (*Clarias macrocephalus)* and Bocourt's catfish (*Pangasius bocourti)* (De Silva and et al., 2010: 1-20). The mean production ranges from around 150-200 kg ha^{-1}, which is significantly less than those achieved in other Asian countries, *e.g.* Vietnam (400 to 980 kg ha^{-1}) and Sri Lanka (800-1200 kg ha^{-1}) (Nguyen and et al., 2006: 73-82; Amarasinghe, 2006: 50-72), and lower than the production potential of these water bodies with improved technical and husbandry inputs.

The communities participating in culture-based fisheries activities are well organized as cohesive village units but do not have had any experience in culture-based fisheries practices *per se*. The communities have the tendency to use the same procedures over the years, without any apparent improvements in fish production. The existing practices are usually sub-optimal and indeed *ad hoc* in terms of the numbers of fish stocked, species stocked and species ratios which are not based on any criteria that would optimize production. Almost always fry are stocked directly which apparently contributes to loss of productivity since in their early life stages, fish is more vulnerable to predators, i.e. piscine and avian (De Silva and et al., 2010: 1-20).

With regard to the above, the developments and improvements of CBF practices in Lao PDR will surely be economically beneficial to the communities involved, which tend to be almost always rural and poor. Apart from the direct monetary gains, this is estimated to rake in approximately 3 million kip ha^{-1} (based on a 300% improvement in productivity), the developments would also bring about more cohesiveness and greater cooperation within each village community and amongst all stakeholders, as the activities spread across six to nine months in a growth cycle. Such cooperation within a community could also lead to other synergies that could impact the "village" well being. Although the introduction of proper broodstock management and seed dissemination strategies might not have direct monetary impacts on aquaculture practices in Lao PDR, which are difficult to quantify, it could provide a platform for linking aquaculture and conservation practices, especially with respect to indigenous species (De Silva and et al., 2010: 1-20).

In view of the foreseen successes of CBF in rural communities, the Government of Lao PDR has incorporated its popularization as a major feature in its strategic agricultural development plans (Ministry of Agriculture and Forestry, 2010) and the recently enacted Fisheries Law of Lao PDR (Department of Livestock and Fisheries, 2010). One of the most interesting aspects of the CBF practices in Lao PDR is the adoption of different strategies of management and the resulting benefit sharing protocols, which had been previously dealt with only briefly (Saphakdy and et al., 2009: 2-6). According to Akhane and et al. (2015: 29-38), many Asian nations are embracing CBF as a plausible low-cost strategy to increase food fish availability that also contributes to the nutritional well being of these communities. Moreover, results of studies on the extension of aquaculture practice of culture-based fisheries in rural communities provide valuable baseline information, which could help CBF to be placed on a more scientific footing and ultimately enable the rural communities to benefit even further and make the process more sustainable in the long term.

2.5 Fish Growth indictors and condition factor

There are three typical measures that used in aquaculture to reported fish growth *viz.*, absolute growth rate, relative growth and specific growth rate. These measures can be also applied in various purposes (Hopkin,1992: 173-179) including

2.5.1 statistical evaluation of the effects of various treatments on growth

2.5.2 presentation of growth data in standard format with allows to compare growth from various experiments and

2.5.3 providing the basis for management decision, for example whether the selected species grows well under the cultured condition.

Growth is measured in units of length and weight and is best represented as the specific growth rate, SGR (Dutta, 1994: 333-336), which can be calculated to estimate the production of fish after a certain period of culture or release as

$$SGR = \left[\frac{(log_n\ final\ fish\ weight - log_n\ initial\ fish\ weight\ )}{Time\ interval}\right] \times 100$$

Other than these three measurements, measure of condition are generally intended to be the indicator of tissue energy reserves, with the expectation that a fish in good condition should demonstrate faster growth, higher survival and more well being (Pope and Kruse, 2007: 423-471). The Fulton's condition factor is widely used in fisheries science. This factor is calculated from the relationship between the weight of a fish and its length, with the intention of describing the "condition" of that individual (Nash and et al., 2006: 345-363). This factor is, therefore, reflects information on the physiological state of the fish in relation to its welfare (Ighwela and et al., 2011: 559-563). This indicator is length, species and stock dependent, i.e. vary from habitat to habitat (Blackwell and et al., 2000: 1-44). The Fulton's condition factor refers to the increase in weight conforming to the cube of the length and the formula is as $K = W/ L^3$, where K = Fulton's condition factor, W = the weight of the fish, and L is the length (usually total length).

CHAPTER 3

METHODOLOGY

3.1 Choose of water bodies

All water bodies, considered for the study, are under the "ACIAR Project: FIS/2011/013: Culture-Based Fisheries (CBF) Development in Cambodia & Lao PDR". The representative water bodies (Table 3) were selected based on experiences in other developing countries that have successfully adopted the CBF (De Silva and et al., 2006: 96; Jayasinghe and et al., 2005: 157-166; Wijenayake and et al., 2005: 249-258). A preliminary short list of the water bodies that were thought to satisfy the criteria suitable for CBF such as size at full supply level, water retention period, mean depth and accessibility, among others was initially developed. This was followed by extensive consultation with respective village communities to achieve concurrence for the introduction of CBF and related management practices. Representatives from selected community groups (CBF village management committees) had attended two days of intensive training on the aspects of CBF management at a central location in each province, by personnel of the Division of Fisheries, Department of Livestock and Fisheries of Lao PDR. This training was a component of the initiation of CBF project activities under the auspices of ACIAR and covered better practice approaches to culture based fisheries (De Silva and et al., 2006: 96). The training topics included procurement and transportation of seed stocks, stocking procedures, caring for stocked fish throughout its growth cycle, prevention of stock loss, alertness in detecting disease occurrences, regular monitoring of the stocked fish including maintaining a log book of major observations, and harvesting procedures (Phomsouvanh and et al., 2015: 8-9). Half way through the first culture cycle, a refresher-training course was conducted where community concerns over various CBF management aspects were also addressed.

Representatives from each of the communities engaged in CBF practices, selected bycommunities themselves, in each province met as a group once a year following each harvest. These stakeholders' meetings are coordinated by the respective provincial fishery officers in conjunction with the dedicated research groups of the Department of Livestock and Fisheries (DLF) for monitoring CBF activities (Saphakdy and et al., 2009: 2-6). These annual meetings facilitated the exchange of experiences on CBF practices among the communities leading to improvement in the overall management. These meetings also enabled the DLF monitoring group to provide advice on improvements, especially in monitoring CBF practices, data compilation and record keeping.

Table 3 List of water bodies that practiced CBF and their locations (province and district), the number of CBF cycles completed (fsl = full supply level)

Province/District/Water body (Area at fsl)	Households	CBF cycles
Vientiane Province		
Thoulakhom District		
Thin Kham (20 ha)	114	2007/08; 08/09; 09/10; 10/11; 11/12; 12/13
Tan Piew (3 ha)	402	2007/08; 08/09; 09/10; 10/11; 11/12; 12/13
Na Kha (5 ha)	496	2007/08; 08/09; 09/10; 10/11; 11/12; 12/13
Na Ngern (3 ha)	260	2007/08; 08/09; 09/10; 10/11; 11/12; 12/13
Vang Vieng District		
Nam Pad 1 (2 ha)[1]	35	2007/08; 08/09; 09/10; 10/11; 11/12
Nam Pad 2 (2ha)	45	2007/08; 08/09; 09/10; 10/11; 11/12; 12/13
Huy Xee (Khamsavai) (3 ha)	35	2007/08; 08/09; 09/10; 10/11; 11/12; 12/13
Huy Xee (Seng Phet) (2 ha)	30	2007/08; 08/09; 09/10; 10/11; 11/12; 12/13
Huy Xee (Seng Dao) (2 ha)	33	2007/08; 08/09; 09/10; 10/11; 11/12; 12/13

[1] New dam; water level too deep; CBF not practiced since 2012/13 cycle

Table 3 List of water bodies that practiced CBF and their locations (province and district), the number of CBF cycles completed (fsl = full supply level) (Continued)

Province/District/Water body (Area at fsl)	Households	CBF cycles
Bolikhamxay Province		
Paksan District		
Sinsay (3 ha)	158	2007/08; 08/09; 09/10; 10/11; 11/12; 12/13
Namuang (3 ha)	87	2007/08; 08/09; 09/10; 10/11; 11/12; 12/13
Nongsaman (3 ha)	92	2007/08; 08/09; 09/10; 10/11; 11/12; 12/13
Na Ngam (3 ha)	128	2007/08; 08/09; 09/10; 10/11; 11/12; 12/13
Sengsavang (3 ha)	142	2007/08; 08/09; 09/10; 10/11; 11/12; 12/13

3.2 CBF Production Cycle

As expected, CBF cycles are closely linked with prevailing rainfall patterns, for each of the water bodies, the bulk of which is man-made for downstream irrigation purposes. Although often intended for multi-purpose uses, these water bodies are generally incapable of supporting small-scale fisheries through natural recruitment. Culture-based fisheries could, therefore, utilize a stock and recapture strategy to make use of the natural productivity of these waters to produce food fish (De Silva, 2003: 221-243, 2006: 96). A schematic representation of the CBF cycle in Lao PDR in relation to water levels and other irrigation needs is illustrated in Figure 5.

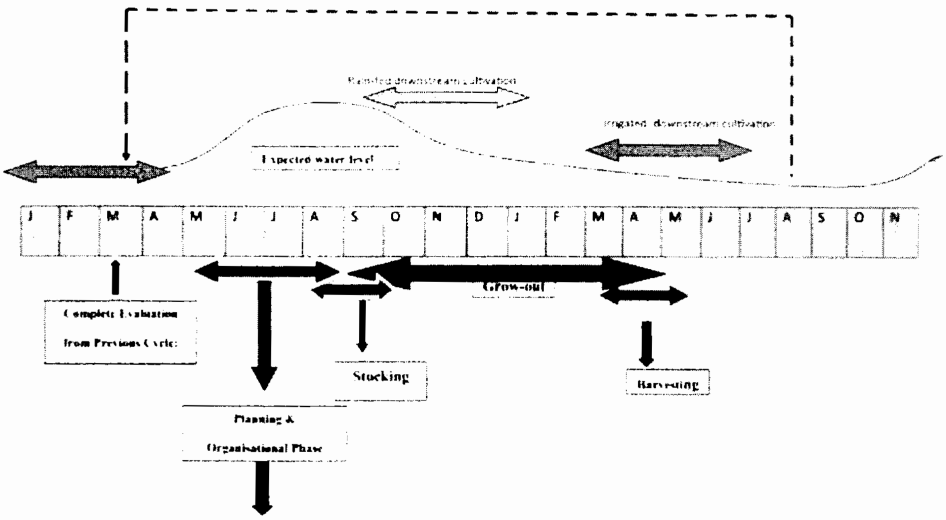

Figure 5 A schematic representation of the CBF in relation to water regime anddownstream cultivation cycle (inset gives the average monthly rainfall (in mm) in lowlands in Lao PDR)

3.3 Stocking and Monitoring

For selected CBF-waters, stocking with a pre-determined number and proportion of species was mostly done in the months of July and August when the water levels peak (Figure 5). The total number of fingerlings and species breakdown of the seed stock were determined based on experiences in countries such as in Sri Lanka and Viet Nam (De Silva and et al., 2006: 96; Jayasinghe and et al., 2005: 157-166; Nguyen and et al., 2005: 1037-1048; Pushpalatha and Chandrasoma, 2010: 99-104; Wijenayake and et al., 2005: 249-258). The species to be stocked was based on consumer and market preferences of the respective communities, which is rather uniform throughout Lao PDR and shown in Table 4.

Table 4 Stocking regimes of each water body involving in the CBF project

Regime	Stocked species	Water Bodies
I	Tilapia: Common Carp: Silver Barb	Thin Kham, Tan Piew, Na Kha, Na Ngern
II	Tilapia: Common Carp: Silver Barb: Catla: Silver Carp	Nam Pad 1, Nam Pad 2, Huy Xee (Khamsavai), Huy Xee (Seng Phet), Huy Xee (Seng Dao)
III	Tilapia: Common Carp: Silver Barb: Silver Carp	Sinsay, Namuang
IV	Tilapia: Common Carp: Silver Barb: Catla	Nongsaman, Na Ngam, Sengsavang

Seed stocks were obtained from Government and private hatcheries in Lao PDR. Most of the seed stocks were 5-7 cm in total length. Often the entire community was involved in the stocking process over 1-2 days, and it is a much-cherished participatory community activity. In the case of some water bodies, seed stock was purchased at a smaller size (cf. 3 cm) and at a reduced price, and initially reared in hapas (3 × 2 × 1.5 m; 1 mm mesh) until they reached a suitable size for release. This rearing period usually lasted 2-3 weeks. In this manner a significant saving on seed stock was made. Commonly used CBF seed stocks in Lao PDR, regardless on stocking patterns, are based on the three major species *viz.*, tilapia, silver barb and common carp, in which their contributions in the stocking density are about 30%, 20% and 20%, respectively.

3.4 Data collection and analysis

3.4.1 General aspects of management

As previously described, all water bodies are managed by the village communities, including water management for downstream agriculture and other purposes. In all communities, a management committee/ group is elected through consensus to take responsibility for CBF related activities and associated day-to-day decision making, such as ratifying proposals with regard to harvesting procedures and disbursement of CBF revenue. In this study, therefore, the management patterns from each CBF water body were examined and explained by their harvesting regimes and gains to community.

3.4.2 Yield and performances of the stocked fish

During the harvesting day, yields of the wild- and stocked- fishes were collected. From this data, the differences in yields of the wild fishes in each stocking regime were examined by mean of Analysis of Variance (ANOVA), in which the water bodies were treated as "*block*". The Tukey's HSD test was applied, when ANOVA revealed significance. For the yields of the stocked fishes, the regression analysis and relationship between the yields and the stocking densities were tested to quantify the optimum stocking density for CBF practice in Lao PDR.

During the final harvest in the Regime I stocking pattern (Table 4), the length (nearest 0.1 cm TL) and weight (nearest 0.1 g) of the three stocked species (Tilapia: Common Carp: Silver Barb) were sampled at least 30 fishes per species per water body to compare their growth performances. The specific growth rate and condition factor were compared among these three species to investigated which species is the best candidate for CBF practice in Lao PDR. The test was done by mean of Analysis of Co-Variance (ANCOVA), in which the total fish yield is the covariate. The Tukey's HSD test was applied, when ANCOVA revealed significance.

CHAPTER 4

RESULTS

The results of CBF activities in thirty-two water bodies during the present study, conducted over a minimum of two cycles to a maximum of five cycles are presented. The results include the effect of stocked species into natural water bodies, and the performances of the three major species.

4.1 Management Categories

The nature of harvesting adopted by each community may differ, with one of three basic harvesting strategies adopted by each community. In all instances, the gear permitted for harvesting includes lift nets (1.5 × 1.5 m; 0.5 mm mesh), cast nets (0.5 mm mesh), scoop nets and varying types of traps (Deap and et al., 2003: 5-28), while motorized crafts and electric fishing gear are prohibited. In general, all catches either by individual households for daily consumption and/or the communities during major harvesting days are recorded.

All communities strictly prohibited fishing four to five month post-stocking. Thereafter the communities adopt one of three strategies that are detailed in Table 5. During harvesting, naturally recruited species are harvest to stocked fish (*e.g.* silver barb (*Barbonymus gonionotus*), tilapia (*Oreochromis niloticus*), and common carp (*Cyprinus carpio*). In effect, for many households from our observations and studies these small fish are eaten whole, thereby permitting all family members a fair share of the total harvest. The nutritional value of such species and the benefit of them eaten whole have been highlighted, and the importance of this practice to the nutrition of poor rural communities is being increasingly acknowledge (Roos and et al., 2003: 329-339; 2007: 280-293; Thilsted, 2012: 57-73).

Table 5 The three basic forms of management (based on the harvesting pattern) of the water bodies are adopted through a consensus of each of the communities

Harvesting	Gains to Community
Category 1: Permit the village households to fish for their daily needs using scoop nets and hook and line, five months after stocking. The community embarks on harvesting the remaining stock via ticker system where the public can purchase the right to catch fish for sale, when the water level recedes approximately 8 to 9 months after stocking. The ticket prices various according to the gear to be used.	Daily fish needs in this manner and household are nor permitted to catch for sale; gear limited to small drag net and traditional traps only
Category 2 Similar approach to Category 1	Daily fish need and households are not permitted to catch for sale; gear limited to small drag net and traditional traps only; a portion of the ticket sale are provide to each household
Category 3 Harvest only as the water level recedes, generally 8-9 months post-stocking with engagement of the whole community; harvesting is publicized widely and the harvest auctioned on site	Fish for communal social occasions/ festivities; monetary gains based on net gains after harvest

4.2 Effect of stocked species into wild productions

The 4 combinations of stocking regimes were tested on the possible effects of wild fish yields. Although the numbers of stocked seeds were higher from cycle to cycle, less variability and non-significant difference in total wild fish yields (P > 0.05) were observed in one stocking regimes, i.e. Regimes I (Tables 6 and 9). Meanwhile, the combinations II, III and IV showed the significant difference in wild productions among cycles (Tables 7, 8 and 9). However, this differences were due to the trend of increasing in the later cycles. Meanwhile the influence of water bodies was found in Regimes I, III and IV (Tables 6, 8 and 9). Mean wild fish yields in each cycle of each stocking regimes (Figures 6-9) were ranged between 598.4 – 819.3 $kg.ha^{-1}$ (Regime I), 286.5 – 452.1 $kg.ha^{-1}$ (Regime II), 618.5 – 845.5 $kg.ha^{-1}$ (Regime III), and 690.4 – 908.9 $kg.ha^{-1}$ (Regime IV).

Table 6 ANOVA result of the effects of cycles and water bodies to wild fish yields under Regime I stocking pattern (Tilapia: Common Carp: Silver Barb)

	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Cycles	4	89355	22339	2.006	0.186510
Water Bodies	2	797099	398549	35.796	0.000102***
Residuals	8	89072	11134		

Note: *p<0.05, **p<0.01, and ***p<0.001.

Table 7 ANOVA result of the effects of cycles and water bodies to wild fish yields under Regime II stocking pattern (Tilapia: Common Carp: Silver Barb: Catla: Silver Carp)

	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Cycles	3	72390	24130	2.625	0.0184**
Water Bodies	4	21517	5379	0.585	0.6795
Residuals	12	110305	9192		

Note: *p<0.05, **p<0.01, and ***p<0.001.

Table 8 ANOVA result of the effects of cycles and water bodies to wild fish yields under Regime III stocking pattern (Tilapia: Common Carp: Silver Barb: Silver Carp)

	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Cycles	3	53070	17690	14.56	0.0271 *
Water Bodies	1	19405	19405	15.98	0.0281 *
Residuals	3	3644	1215		

Note: *p<0.05, **p<0.01, and ***p<0.001.

Table 9 ANOVA result of the effects of cycles and water bodies to wild fish yields under Regime IV stocking pattern (Tilapia: Common Carp: Silver Barb: Catla)

	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Cycles	3	81148	27049	4.450	0.0371 **
Water Bodies	2	46341	23170	3.812	0.0454 **
Residuals	6	36469	6078		

Note: *p<0.05, **p<0.01, and ***p<0.001.

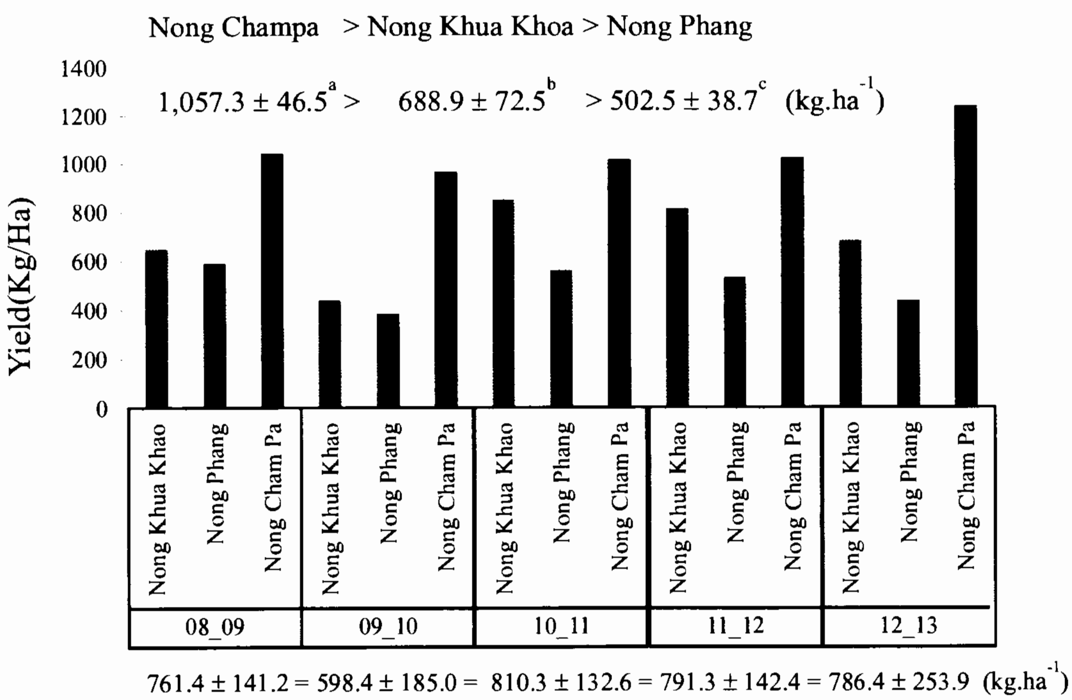

Figure 6 Mean wild fish yields, under Regime I stocking pattern (Tilapia: Common Carp: Silver Barb)

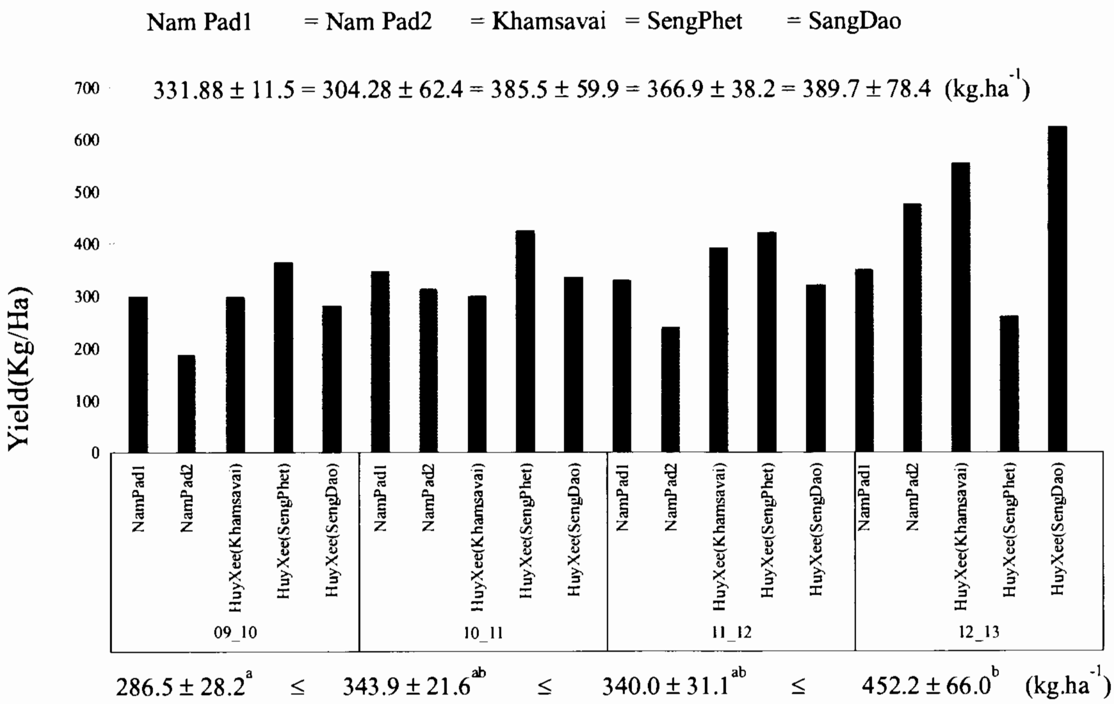

Figure 7 Mean wild fish yields, under Regime II stocking pattern (Tilapia: Common Carp: Silver Barb: Catla: Silver Carp)

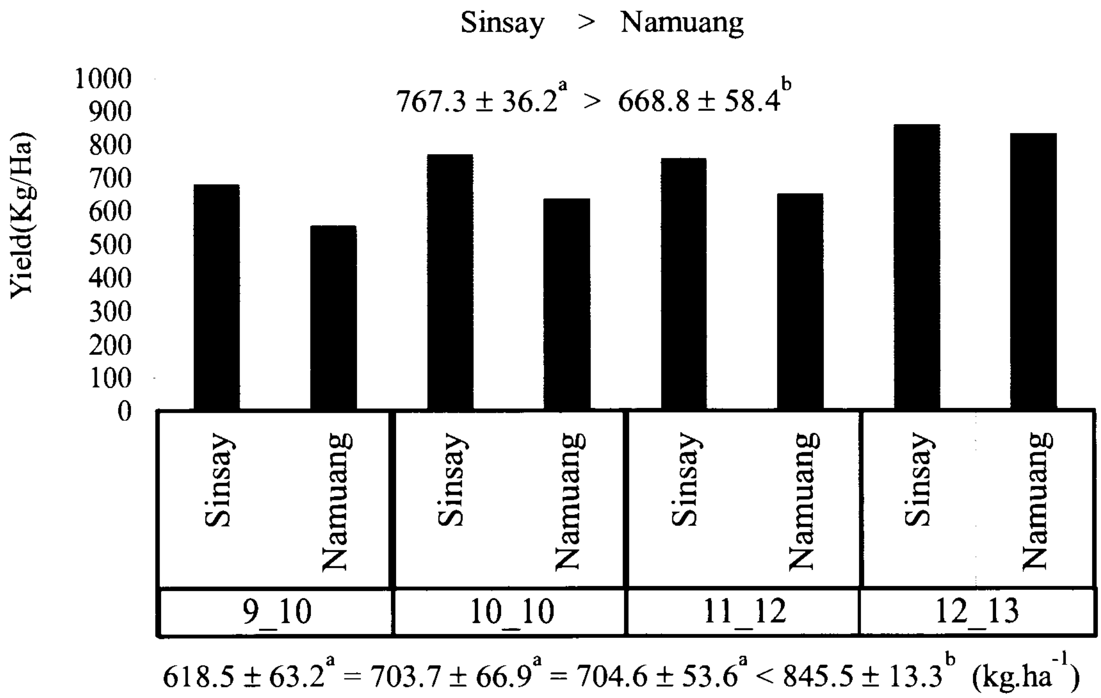

Figure 8 Mean wild fish yields, under Regime III stocking pattern (Tilapia: Common Carp: Silver Barb: Silver Carp)

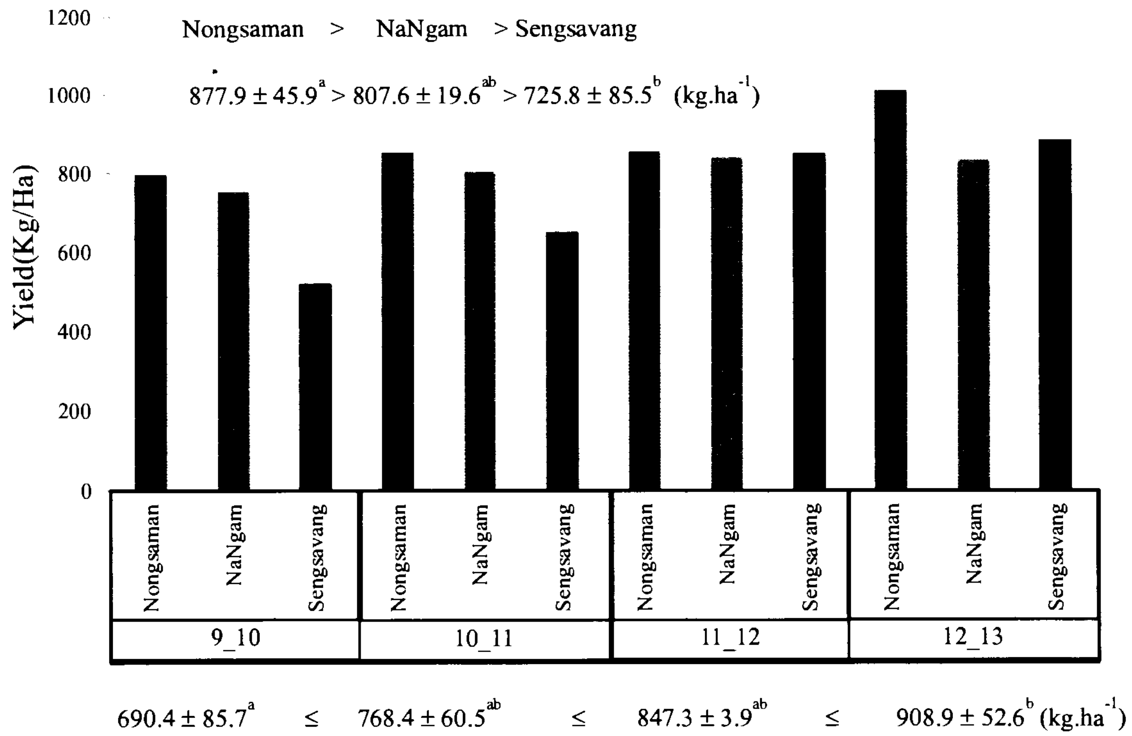

Figure 9 Mean wild fish yields, under Regime I stocking pattern (Tilapia: Common Carp: Silver Barb: Catla)

4.3 Effects of Stocking Density

The yield of the stocked species in all studied water bodies in Lao PDR in 4-5 cycles and irrespective of the species combinations and water bodies, increased in relation to stocking density. Scatter plots of the relationship between stocking density of stocked fishes (fingerlings/ ha) to the CBF yields (kg/ ha), together with the lines of best fit ($R^2 = 0.305$, P-value < 0.05) and resulting statistical relationships are shown in Figure 10. It is, therefore, estimated, from the curve obtained from the relationship, the appropriate stocking density should range between 3,000-5,000 fingerlings/ ha.

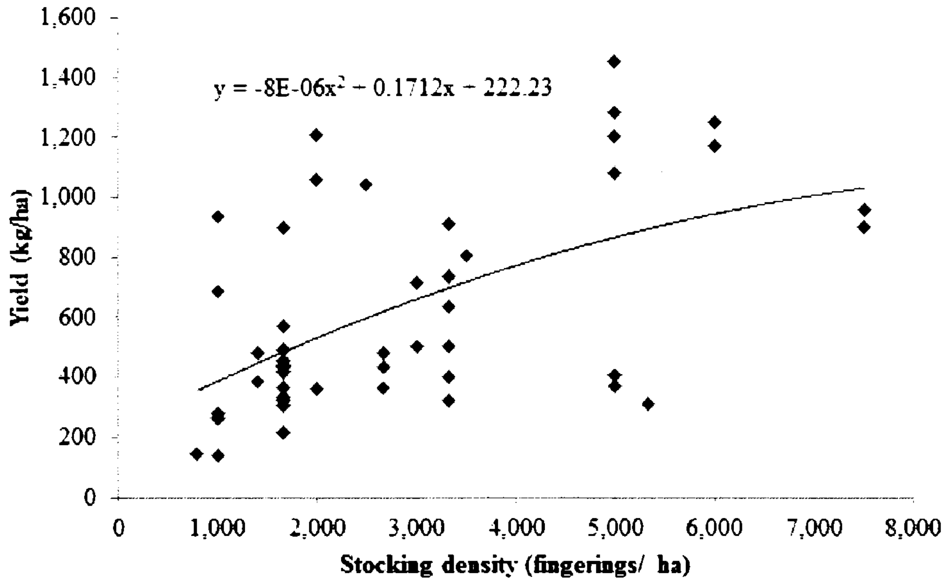

Figure 10 Scatter diagrams showing the relationship between stocking densities and yields from 4-5 CBF cycles in Lao PDR

4.4 The Performance of Stocked Species

Regardless on the patterns of combination, three fish species were commonly stocked in CBF practices in Lao PDR *viz.*, tilapia, common carp and silver barb. The performance of these three species was investigated through the specific growth rate (SGR) and condition factor (K) from the Regime I stocking pattern. The analysis was done by the analysis of co-variance (ANCOVA), in which the total yield from each lake is the covariate.

The ANCOVA result indicated that there were not significant differences in SGR the three stocking species (Tables 10 and 11). The results showed that tilapia has the highest SGR (1.79 g/day) but not significantly different to silver barb (1.73 g/day). Meanwhile, common carp showed the lowest SGR at 1.48 g/ day but not significantly different to the other two species ($P > 0.05$, TukeyHSD test). In contrast to SGR, the results of the condition factor (*K*) showed significant differences among the three species and the order of the species from the highest to lowest K is as tilapia (1.702), silver barb (1.181) and common carp (0.999), in which the K- values of all the three species were significantly different to each other ($P < 0.05$, TukeyHSD test).

Table 10 ANCOVA result of the SGR, comparing among the three common species (Tilapia: Common Carp: Silver Barb), raised under Regime I stocking pattern

	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Corrected model	3	0.490	0.163	1.724	0.190
Intercept	1	0.854	0.854	9.012	0.006
Yields	1	0.008	0.008	0.090	0.767
Species	2	0.482	0.241	2.242	0.101
Residuals	23	2.179	0.095		

Note: *$p<0.05$, **$p<0.01$, and ***$p<0.001$.

Table 11 The average SGR, comparing among the three common species (Tilapia: Common Carp: Silver Barb), raised under Regime I stocking pattern

Species	Specific Growth Rate (g/day)
Tilapia	1.79 ± 0.11
Silver Barb	1.73 ± 0.10
Common Carp	1.48 ± 0.13

Note: ($P > 0.05$, TukeyHSD test).

Table 12 ANCOVA result of the *K*, comparing among the three common species (Tilapia: Common Carp: Silver Barb), raised under Regime I stocking pattern)

	Df	**Sum Sq**	**Mean Sq**	**F value**	**Pr (>F)**
Corrected model	3	2.419	0.806	55.256	< 0.001***
Intercept	1	0.869	0.869	59.535	< 0.001***
Yields	1	0.021	0.021	1.419	0.246
Species	2	2.398	1.199	82.175	< 0.001***
Residuals	23	0.336	0.015		

Note: *p<0.05, **p<0.01, and ***p<0.001.

Table 13 The average *K*, comparing among the three common species (Tilapia: Common Carp: Silver Barb), raised under Regime I stocking pattern

Species	**Condition factor (K)**
Tilapia	1.702 ± 0.071 [a]
Silver Barb	1.181 ± 0.076 [b]
Common Carp	0.999 ± 0.183 [c]

Note: (P < 0.05, TukeyHSD test).

CHAPTER 5

DISCUSSION

The results of this study show that stocking initiatives have provided benefits due to both, (1) direct biological effects of stocking (increased recruitment of valuable species), and (2) indirect effects due to institutional change resulting from the investment into common pool resources (e.g. incentives for sustainable use, reduced fishing pressure and higher returns to labour) (Saphakdy and et al., 2009: 2-6). However, as is also shown, outcomes have often been unpredictable, different to what has been anticipated or less than optimal presence of unexpected outcomes is caused by the fact that there is still a great deal of uncertainty surrounding both the direct and indirect effects of stocking.

It is, also, widely accepted and acknowledged that culture-based fisheries is one of the most environmentally friendly aquaculture practices available, where the only external input is seed stock. It is also recognized as an efficient secondary use of water, it being a non-water consumptive activity, unlike many other land based aquaculture activities. As such culture-based fisheries are not expected to have major environmental impacts. The only possible and potential impact is the escape of artificially produced seed stocks and possible mingling of these with wild stocks and impacting on the genetic diversity of the latter. This is however, a relatively remote possibility as large numbers of escapees, over many years, will be required to bring about such an impact. It is in this regard the development of appropriate broodstock management plans for the indigenous species and planned use of the seed stocks would minimize such possibilities even further, as initiated through the study. (De Silva and et al., 2005: 65-81).

De Silva (2003: 221) estimated that if only 5% of these available water bodies are harnessed for culture-based fisheries, and that the practices are developed to the extent that an average yield of 750 kg/ha is obtained (which is not an improbability), rural fish production in Asia could be increased by 2.5 million tons per year. Therefore, culture-based fisheries have the great potential to increase the supply of fish (as food) in the region. Sustainability of culture-based fisheries depends on technical and socio-economic feasibility with the selection of suitable water bodies being a key to success. The water retention period of the water body (8-9 months is optimum for fish reaching marketable sizes) and depth of water of the effective area (2-2.5 meter is optimal) are important basic characteristics to be considered. Water bodies located near villages are more suitable because of a better capability to prevent poaching, and better accessibility to markets. Presence of waterweeds (more than 75% plant cover would make a water body unsuitable) and water pollution levels are also important factors to be considered in the selection of water bodies (De Silva and et al., 2006: 15-34).

According to De Silva et al. (2006: 15-34), the suitability of a water body for the development of a culture-based fishery is based on three factors: as (a) Physical and biological aspects of the water bodies: including water retention period, depth and surface areas, aquatic plants, productivity of water body; (b) Socio-economic conditions of communities that live in the vicinity; and (c) Socio-economic conditions of the potential practitioners and primary stakeholders of the planned activity. This study is conducted in 14 selected water bodies in Vientiane and Bolikhamxay province through village communities that are currently engaged in culture-based fisheries practices. In the selection of the study sites due to consideration was given to the hydrological cycle of each water body and functionality of the respective village community.

The obtained production, which was over 500 $kg.ha^{-1}$, of both wild- and stocked-fishes from all selected water bodies in al cycles of the study, was given the very pleasant result. This figure, i.e. > 500 $kg.ha^{-1}$, could be compared to the experiences from other countries. Yields in this study were higher than those reported for comparable water in Laos (Lorenzen and et al., 1998: 345-357), Thailand (Lorenzen and et al., 1998: 211-224), Viet Nam (Nguyencand et al., 2001: 975-990). Chandrasoma and Kumarasiri (1986: 49-55) reported that cultured-based fisheries in 23 seasonal reservoirs yielded 220-2,300 kg/ha per culture cycle with a mean yield of 892 kg/ha.

A number of fish species can be considered to culture-based fisheries, in which the desirable features for a fish stocked species included (a) market demand for that particular species; (b) acceptance as a food fish to the surrounding communities; (c) ability to depend on the available natural food resources within the water body; (c) fast growing and efficient converters of food enabling to reach a marketable size within a short period of time; and (d) ability to co-exist with other species in a water body to maximize the use of available space and productivity (De Silva and et al., 2010: 1-20). The results of this study showed that the exotic species, i.e. tilapia and common carp were the potential candidate for CBF in Lao PDR. Arthur amd et al. (2010: 81-88) conducted experiments in wetlands in southern Lao and found that the native fish biomass was not affected by stocking of the non-native species. No significant impacts on native fish species richness, diversity indices, species composition or feeding guild composition were detected.

Development of culture-based fisheries in Laotian waters requires a regular supply of good quality seed stock. Also, in view of the increasing pressures on biodiversity conservation, and a general preference of indigenous fish species for consumption by the community, the most appropriate strategy was recognized as the development of artificial propagation of species with the highest potential for use in culture-based fisheries. Based on study, it is accepted that the three major species tilapia, common carp, and silver barb were selected. Species combination of stocked fingerlings is also an important aspect in culture-based fisheries because optimal utilization of food resources in the water body is a key to achieve optimal harvests from polyculture systems (Bardach and et al., 1972: 147). The results on a comparison of fishery production from naturally recruited and stocking of hatchery reared seed in culture-based fisheries in Lao PDR indicated that in the current practices, the stocking densities could be increased further with resulting increases in fish yield. Perhaps, a combination of these strategies could result in significantly higher fish yields from culture-based fisheries practices in Lao PDR. It was evident that the different species combinations had an effect on the overall yield, and there were also local differences. In Lao PDR, the yield was obtained with combination 1 (tilapia: common carp: silver barb); combination 2 (tilapia: common carp: silver barb: catla: silver carp); combination 3 (tilapia: common carp: silver barb: silver carp); and combination

4 (tilapia: common carp: silver barb: catla), are presented that the relationship of productivity (fish yield) to the area of the CBF water bodies was not statistically significant different.

Stocking density can be expressed as the weight of fingerling per unit surface area to be stocked in a selected water body (*i.e.* no/ha). To determine the suitable stocking density for a particular water body, estimated of the surface area of the water body and the availability of natural food resources are required. Normally, the optimum stocking density lies between 2,000 and 3,000 fingerlings per hectare (De Silva and et al., 2006: 15-34). The result of study indicated that the trend of optimum stocking density were 3,000-5,000 fish/ha. This may imply the probability to increase the numbers of stock seed into the water body. However, it needs more information regarding the indication of exactly stocking density for further data analysis. Moreover, the performance of the different species in the water bodies was not evident for the different species combinations although increasing number of fish stocked releasing.

According to Wijenayake and et al. (2005: 249-258), the study on growth performance of common carp, bighead carp and rohu is desirable in the culture-based fisheries in seasonal reservoirs. The SGR of catla was highly variable compared with other stock species. Nile tilapia had the lowest SGR. In Chinese reservoirs without predatory pressure, bighead carp and silver carp are commonly used as the principal species used for stocking because of higher growth rates and food conversion rates (Li 1988: 214-223). While comparing with this study indicated that three common fish stocked, tilapia, common carp, and silver barb were significant different in SGR of three fish stocking species. The result showed that tilapia has the highest SGR compared with other stocked species. Common carp had the lowest SGR but not significant different to the other fish stocked species. Tilapia is, therefore, the best candidate for stocking and can be supplemented with silver barb and common carp. There are also evidences that stocking of these three species would not have any problems on feed overlap. Tilapia is an omnivore, which feeds mainly on zooplankton, zoobenthos and phytoplankton. At around 6 cm TL the species becomes almost entirely herbivorous feeding mainly on phytoplankton, using the mucus trap mechanism and its pharyngeal teeth (Moriarty and Moriarty, 1973: 41-55; Moriarty and et al., 1973: 25-39). The digestive tract of Nile tilapia is at least six times the total length of the fish, providing abundant surface area for digestion and absorption of nutrients from its mainly plant-based food sources (Opuszynski and Shireman, 1995). Silver barb, on the other hand, is quite selective on their preys and feeds on plant matter (e.g. leaves, weeds, *Ipomea reptans* and *Hydrilla* spp.) and, sometimes, invertebrates. The species occurs at mid-water to bottom depths in rivers, streams, floodplains, and occasionally in reservoirs. It prefers living in standing water habitats instead of flowing waters (Mohsin and et al., 1983: 284). The last candidate species, i.e. common carp, is recognized on its wide range of different natural foods, including planktonic crustaceans, insects (including their larvae and pupae), the tender parts and seeds of water plants, and also fish eggs and larvae, as well as smaller fish (McCrimmon, 1968).

In conclusion, as enhancement activities are most frequently conducted in quasi-natural waters, the apparent negative impacts on the biodiversity of the 'indigenous' flora and fauna of such waters cannot be strictly considered to be invasive as the environment has been artificially created. Indeed, the interactions and potential competition between exotic and native species in small waterbodies in the region have been barely studied. In one such study, in Sri Lanka, Wijeyaratne and Perera (2001: 333-342) concluded that although some exotic and indigenous species shared common food resources, because of the nature of these food resources and their great abundance, there was no foreseeable competition per se between the two groups.

Conversely, negative effects of culture-based fisheries could arise from exotic escapees invading the natural habitats of indigenous species, but there is no evidence yet that this has occurred. Since exotic species have been used for both fisheries enhancement and also aquaculture, it will be difficult, if not impossible to determine the specific effect of an enhancement activity. Despite this uncertainty, it is still important is to ensure that no new exotics are introduced for culture-based fisheries development per se and to make do with those species that are currently available. Additionally, it is preferable to explore the possibility of using other indigenous species, although economic considerations such as yield reductions that may result from this will have a strong influence on decisions (De Silva and et al., 2005: 65-81).

There is an urgent need to address biodiversity issues, particularly in relation to fish species usage in stock enhancement practices. Not only are the direct affects of such practices important, but also their affects on the genetic diversity of the enhanced species brought about through generations of inbreeding. Unlike in aquaculture operations where there are deliberate efforts to prevent escapees of species with reduced genetic diversity, stock enhancement activities deliberately introduce hatchery-bred stocks (which may have similarly narrow genetic diversity to aquaculture stocks) to open environments where there is a greater probability of mixing with wild stocks, thereby increasing risks to the biodiversity of natural systems (De Silva and et al., 2005: 65-81).

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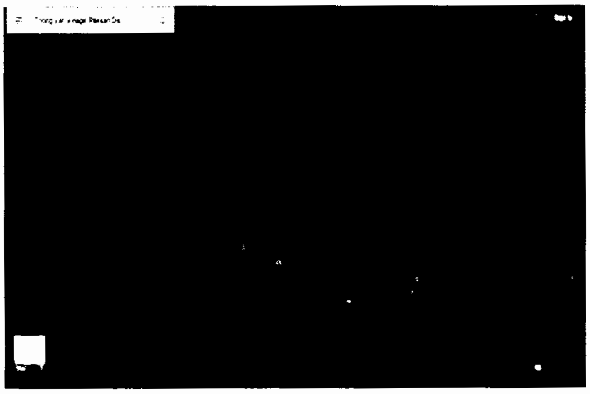
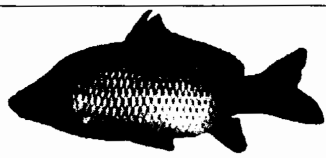
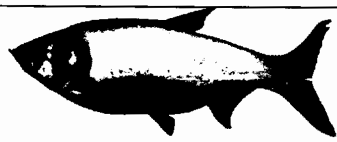
APPENDIX

I. Site Selection (Location and Type of Water Body)

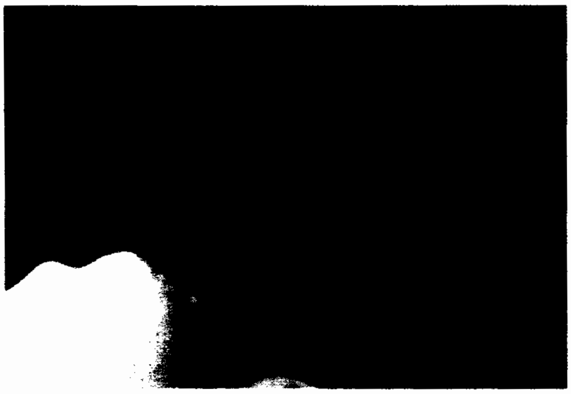


II. Table of List of Culture Species

No.	Common name	Scientific name	Photo
1.	Common Carp	*Cyprinus carpio*	
2.	Tilapia	*Oreochromis niloticus*	
3.	Silver Barb	*Barbonymus gonionotus*	
4.	Catla	*Catla catla*	
5.	Silver Carp	*Hypophthalmichthys molitrix*	

III. Fish Stocking


IV. Fish Nursing

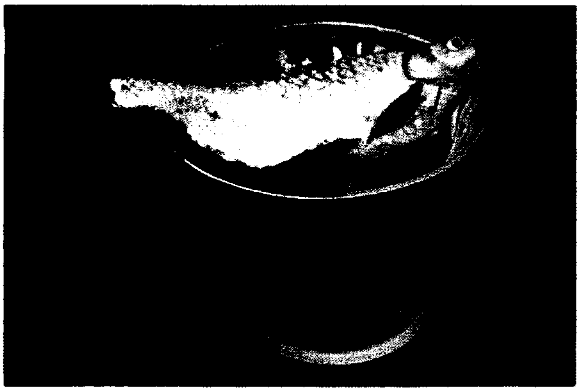
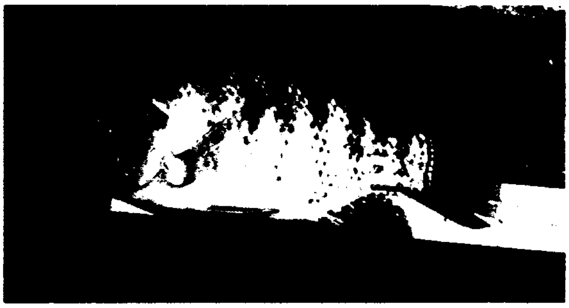
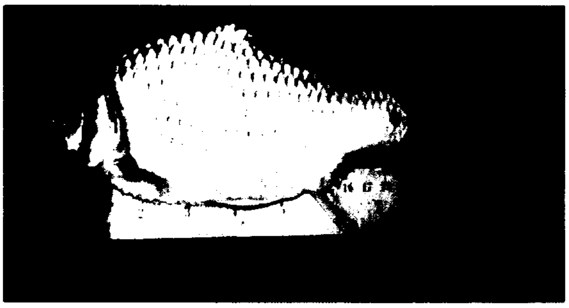



V. Fish Harvested (Regime I and II)




VI. Fish Harvested (Regime III)


VII. Data Collection

VIII. Basic Aquaculture Training for Communities member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LIST OF PUBLICATION	Phomsouvanh, A., Saphakdy, B. and De Silva, S.S. "Production trends, monetary returns and benefit sharing protocols from the extensive aquaculture practice of culture-based fisheries in

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