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Contributed Paper

Effects of Water Flow Rate and Water Quality on Tilapia Culture in the Mae Ping River, Thailand

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ABSTRACT

The aim of study was to find out how flow rates influence water quality and other related factors which may influence the risks of mass fish mortality events in cage aquaculture operations in the Ping River in Northern Thailand. Eight monitoring stations were located along the 120 km stretch of the river, and water was sampled every month over a period of one year. The study found significant differences in temperature, DO, pH, conductivity and water flow rate between the rainy season and dry season. High flow (floods) in rivers caused by torrential rains could damage fish cages, cause massive fish escapes and deaths. Observations of water flow rates during a spate revealed that at the rate of 294.8 m^3/s and 270 m^3/s, river cages were destroyed. On the other hand, low flows (drought) during summer season could cause fish stress resulting from low dissolved oxygen levels, especially in culture areas with many cages. Therefore, fish farmers need to improve the strength and stability of floating open-top cages, use aeration, or choose times and sites to rear fish that reduce risks of exposure to adverse water quality or flow conditions.

Keywords: water quality, water-flow rate, tilapia culture, river, climate, aquaculture

1. INTRODUCTION

Tilapia is an economically important fish cultured in Thailand. An estimated 182,841 tons of tilapia was produced in 2013, and the value of exports was approximately 4.9 million USD in 2012 [1]. Over the past few years, the rearings of red hybrid and Nile tilapia (*Oreochromis niloticus* L.) in cages in the Ping River in Northern Thailand have increased.

Tilapia are typically stocked at moderately high densities (30-60 fish per m^3) in floating open-top cages install in areas with a water depth of 2.5-3 m. Cage-based aquaculture in rivers faces a complex set of risks, including several that are strongly climate-related [2]. Extreme low and high water ows, for instance, are significant risks that fish farmers must manage [3]. Quantitative understanding of the levels of physical flow and water quality factors that pose risks to river-based aquaculture is limited. A better understanding of these factors would help develop sustainable adaptation measures at the farm level to improve the capacity of aquaculture farms manage risks under current and future climate. Therefore, the purpose of this study was to ascertain the water quality and flow rate risk to cage culture in rivers so as to inform farm management and early warning systems to prevent mass fish mortality events.

2. MATERIALS AND METHODS

2.1 Study Site

The study area was a 60 km reach of Upper Ping River in Chiang Mai and Lamphun Provinces, Northern Thailand. Eight monitoring stations (St.) consisting of areas without (St.1-2) and without culture (St.3-8) were established (Figure 1). The elevation above sea level of the selected monitoring station ranged from 283 to 357 masl.

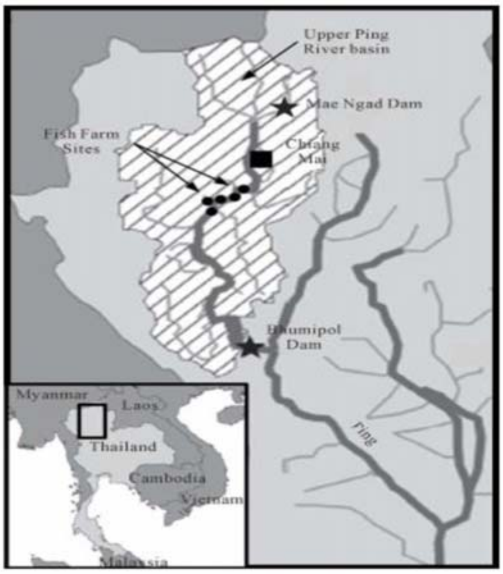

Figure 1. Location of study area in Ping river basin in Chiang Mai province, Thailand.

2.2 Water Sampling

Samples of water were collected from each station every month from August 2013 to July 2014. All samples for physico-chemical analysis were collected 40-cm below the surface, using a modified water sampler and subsequently transferred to plastic containers. Samples were preserved on ice, transported to the laboratory within 24 hours and stored at -20°C.

2.3 Water Quality and Nutrient Analysis

Temperature, pH, dissolved oxygen (DO), conductivity and turbidity were measured *in situ*, using a multimeter (TOA DKK WQC- 22A Model, Japan). Water flow rate was estimated by using a digital flow meter with back-run stop (JKY/Hydrobios 438115, Germany). Ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, orthophosphate-phosphorus, total suspended solids and bacterial counts were determined in the laboratory by standard methods [4]. Rain fall and water flow data was obtained from Hydro-1, Office of Water Management and Hydrology, Royal Irrigation Department, Chiang Mai.

3. RESULTS AND DISCUSSION

3.1 Physicochemical and Biological Water Quality Parameters

Physical, chemical and biological water quality in fish river based ecosystems influences growth and survival rate as well as reproductive and likelihood of disease [4]. The variations in the physicochemical parameters (temperature, DO, pH, conductivity and turbidity) are shown in Figure 2, and the remaining parameters (ammonium-nitrogen, nitrate-nitrogen, nitrite-nitrogen, orthophosphate and bacteria) are listed in Table 1. The suitable temperature for tilapia is 26-30 °C, while decline in growth performance possibly occurs when the temperature is higher than 34 °C [5].

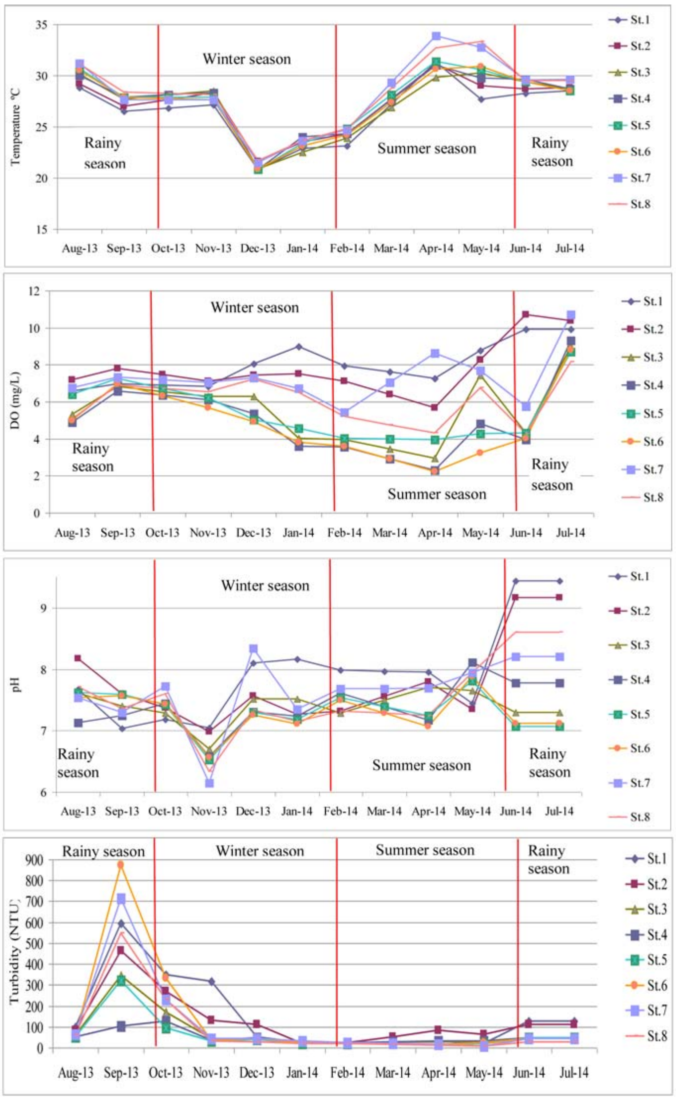

Figure 2. Physicochemical parameters (temperature, DO, pH, conductivity and turbidity) during 3 seasons (Rainy, winter and summer season).

Table 1. Physicochemical parameters (total suspensded solid, TSS; ammonium-nitrogen, NH_4-N; nitrite-nitrogen, NO_2-N; nitrate-nitrogen, NO_3-N; orthophosphate, PO_4-P and total bacteria).

Para-meters	Sampling Stations							
	1	2	3	4	5	6	7	8
TSS (mg/L)	71.0	78.4	49.0	45.4	44.5	36.3	49.6	42.3
NH_4-N (mg/L)	0.16	0.30	0.55	0.71	0.39	0.49	0.29	0.29
NO_2-N (mg/L)	0.016	0.032	0.037	0.044	0.051	0.054	0.026	0.027
NO_3-N (mg/L)	0.34	0.92	0.90	0.77	0.81	0.86	0.85	0.87
PO_4-P (mg/L)	0.31	0.39	0.54	0.57	0.60	0.63	0.52	0.46
Total Bacteria ($\times 10^3$ CFU/ml)	10.6	9.1	24.6	19.0	18.5	22.2	12.8	10.8

The highest water temperature values around 29.8-33.9°C were observed in April, while the lowest water temperature values were observed in December, around 21°C. Dissolved oxygen is an important factor for fish respiration, and is thus essential to the health of aquatic ecosystems and a key indicator in determining water quality. Low temperatures in the dry season may reduce the metabolic rates of fish, leading to increases stress levels in fish and low feed consumption, while also increasing the risk and spread of diseases. DO levels must be high enough to support aerobic metabolism in sh [6]. Most sh can maintain adequate levels of oxygen uptake at DO concentrations above 5 mg/l [6]. When concentration dropped below 1 mg/l, many species were severely affected.

The study results demonstrated that there are differences of DO in non-culture area and culture area during dry season (Figure 2). It is suggested that proper aeration should be installed especially in cages with fish that have reached marketable size. In addition, the water quality indicators related to nutrient levels (nitrogen species and phosphorous) suggest suitability of this study area for fish farming.

3.2 High River Flow Velocities

Direct observations and field measurements in this study confirmed that extremely high water flow rates (>250 m^3/s) can damage cages and cause mass mortality (Figure 3). Forced swimming of fish causing energy waste leading to exhaustion. Deformation of the regular shape of the cage leads to decreased useful water volume resulting in very high effective densities within fish cage. These were the important effects brought about by high water flow rate in the Ping River.

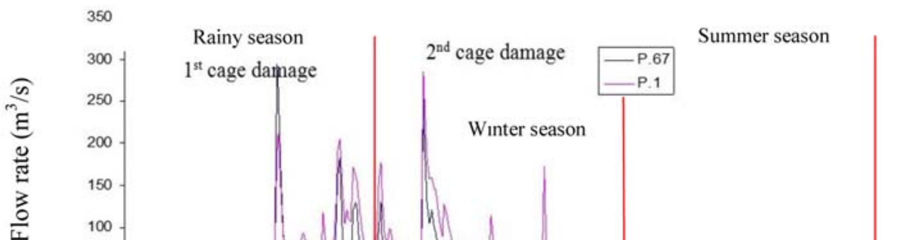

Figure 3. Relative river flow rates during the months of August and October 2013 after heavy rains.

These observations are consistent with information about mass mortality events in the past due to high discharge in 2005 and 2011 flood events reported previously in the Upper Ping River [2]. High water velocity associated with reservoir releases has also been show to impact fish cage culture in Indonesia [7]. This study also suggests that information about heavy rainfall or river discharge might be used to tailor existing early warning systems for Chiang Mai Municipality to be more directly useful for fish farmers with cages in the river.

4. Conclusions

This is one of the first papers to report in detail on climate-related water quality and flow risks on tilapia fish culture. The study results verified that very high water velocity affects floating cage fish culture in rivers, especially with a flow rate above 250 m^3/s. This finding demonstrates that fish farmers need to strengthen their floating open-top cages. Low dissolved oxygen in water was observed in the dry season due to low water supply. Finally, it is important to raise awareness to communities, particularly to farmers on the importance of climate-related risks and its impacts to aquaculture. Moreover, early warning systems and proper aeration should be implemented in order to reduce climate-related risks.

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