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Risk of Climate Variability on Tilapia Cage Culture in Songkhram River in Northeastern Thailand

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Abstract: The cage culture of Nile Tilapia in the river is one of the most important methods for Nile Tilapia (*Oreochromis niloticus*) farming in Thailand. Songkhram river is a significant river in north-eastern Thailand where Nile Tilapia river-based cage culture has been applied widely. However, river-based cage culture is an open culturing system where farmers do not fully control weather and water quality. This study investigates the risks of climate variability on Nile Tilapia in river-based cage culture. This study recommends strategies to reduce fish yield losses. The samples of this study are the Nile Tilapia river-based cage culture farmers along the Songkhram river in 5 districts in Sakon Nakhon and Nakhon Phanom, including Thauthen, Khamtakla, Akatamnuai, Sisongkhram and Nathom. This study applies a simple random sampling method. We used structured questionnaires to collect the data from 148 fish farmers between April and December 2017**.** Hot weather during March and April was perceived to be the most important factor causing fish diseases and led to losses (68.2 %). The other significant factors that led to fish death were drought (52.7 %) and flood (40.5 %). Flood typically takes place between June and August. Cold weather was perceived not to affect the fish losses (32.4 %). However, it did affect the growth rate. Cold weather typically takes place between December and February. Regarding the hot weather, fish farmers applied preventive measures such as monitoring and surveillance, stopping or delaying stocking schedules. For drought, the fish farmers relocated the cages towards the deeper water areas and used aerators to control water quality. Most farmers tie their cages securely during flooding season and relocate them closer to the bank. The fish farmers monitored their cages more closely than usual for the cold weather and postponed the stocking date. The study of risks and loss mitigation from climate variabilities in this research will be helpful for strategic aquaculture planning to cope with climate variabilities in the future.

Keywords: Climate Variability; Tilapia Cage Culture; Songkhram River

1. Introduction

Thailand was the world's sixth-ranked aquaculture producer. The highest contribution was Nile Tilapia [1]. Around 44% of the total aquaculture production was from Nile Tilapia outputs [2]. Songkhram River is an important river in north-eastern Thailand. The river has been utilized for aquaculture purposes. Fish farmers live in Sakon Nakhon and Nakhon Phanom rear fish in the floating cages. This activity is considered to be their secondary occupation in addition to rice farming. These farmers earned annual profit from fish farming activity, approximately 13,000 baht per cage. They owned about 1-10 cages and reared fish for two crops per year [3]. Fish cage culture is a good source of household income and helps improve their well-being. Global warming has caused climate change, leading to climate variabilities, including higher global temperature and changes in rain and wind patterns. These changes have significantly impacted water quality, an essential factor for aquaculture [4]. Nile Tilapia river-based cage culture is an open culturing system prone to output losses. Water quality variability can cause fish disease and mortality [5]. Recently, tilapia culture has been affected by climate change such as extreme drought, heavy rainfall, and abrupt air temperature changes within a day [6]. In 2015, Nile tilapia production decreased 4.9% compared to 2014. In 2016, tilapia production continued to decline by 3.7%. The losses were attributed to the wet season's shift, which led to prolonged hot weather and drought [7]. This study aims to understand how the fish farmers perceive the risks regarding the tilapia cage culture and how they respond to the climate variability impacts. The findings from this study will help design the adaptation strategies for individual farmers to ensure sustainability in aquaculture as a whole.

2. Materials and Methods

This research was conducted in Sakon Nakhon and Nakhon Phanom provinces, covering five districts, including Thauthen, Khamtakla, Akatamnuai, Sisongkhram and Nathom **(Figure 1)**. The study sample size was identified using the Yamane method [8]. A total of 148 fish farmers who cultured tilapia in floating cages in Songkhram River were surveyed using the structured questionnaires. These farmers were randomly selected from 235 fish farmers that registered their farms with the Department of Fisheries. The data were collected from interviews, including close-ended and open-ended questions covering general information, farm characteristics, effects of climate variabilities on fish culture, and preparation for climate variabilities. The climate variabilities included high and low temperature, flood, drought and heavy rainfall. The survey was carried out between April and December 2017. This study also utilizes the secondary data collected from the Sakonnakhon and Nakhonphanom provincial meteorological offices. These data included the daily temperature and rainfall in the study sites in 2017. This study applies statistical software packages to conduct descriptive statistical analysis, including frequency, percentage, mean, and standard deviation. The score in question items with Likert Scale divided into 5 point: 1.00-1.79 (lowest), 1.80-2.59 (low), 2.60-3.39 (moderate), 3.40-4.19 (high), and 4.20-5.00 (highest).

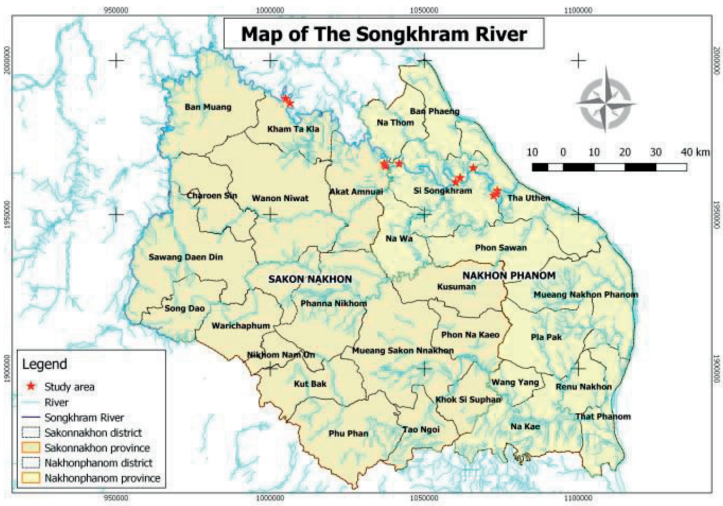

Figure 1. Map of the study area

3. Results and Discussion

3.1 Characteristics of fish farmers

The average age of the sampled fish farmers was 49.08 ± 11.48 years. The youngest farmer was 22 years old, while the oldest one was 80 years old. More than half of these farmers were male (54.7 %). They received a primary school level of education. These farmers commonly had 0 - 23 years of experience in cage culture.

The average years of experience were 8.38 ± 5.23 years. Each farmer-owned 3 - 400 floating cages. The average number of cages was 15.42 ± 34.13 cages per farm. The floating cage size was 3 x 3 x 3 metres. The fish stocking density was 32 fish m^{-3}. The fish farmers follow 4-5 month crop cycles (or around 2 crop cycles/year). Most of the fish farmers were involved in river-based cage culture throughout the year, with a pause between March and June when the amount of water in the river was low and flew too slowly.

3.2 Impacts of climate variability on fish cage culture

The fish farmers mentioned that the most impactful of climate variabilities were hot weather (68.2 %), followed by drought (52.7 %), flood (40.5 %) and cold weather (32.4 %), respectively (Table 1).

Table 1. Climate variability impacts on fish cage culture

Climate variabilities	Number (n)	Percentage (%)
Hot weather	101	68.2
Drought	78	52.7
Flood	60	40.5
Cold weather	48	32.4

Most fish farmers (101 farmers) experienced production loss from the hot weather in the present study. Last year, the average loss due to the hot weather was estimated at 4,550 ± 18,784 baht per cage. The significant losses typically took place between March and April. The highest mean air temperature was in April. However, the cold weather impacted only approximately 48 farmers. In 2016, the average loss of cold weather was estimated at 422 ± 1,132 baht per cage. The significant losses typically took place between December and February, when the air temperature reached its lowest (Figure 2) [9-10].

The overall average loss due to drought of all farms (78 farms) was estimated at 3,784 ± 14,518 baht per cage. The significant losses typically took place in April when the amount of water in the river was low. This was due to limited rainfall since January. The overall average loss due to flood of all farms (60 farms) was estimated at 2,718 ± 10,414 baht per cage. The significant loss typically took place between June and August. July had the highest recorded rainfall. Consequently, the fish farmers must find a way to cope with the high flows and flooding (Figure 3) [9-10].

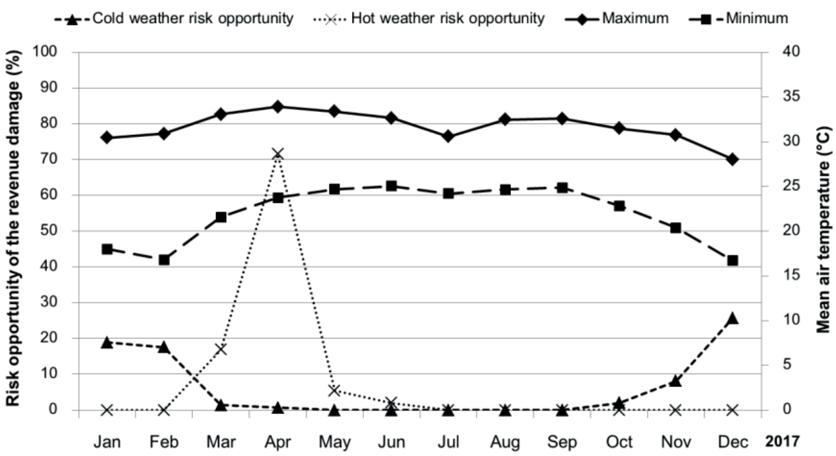

Figure 2. An association between risk opportunity and mean air temperature. **Source:** Mean air temperature in 2017 (Sakonnakhon and Nakhonphanom provincial meteorological office)

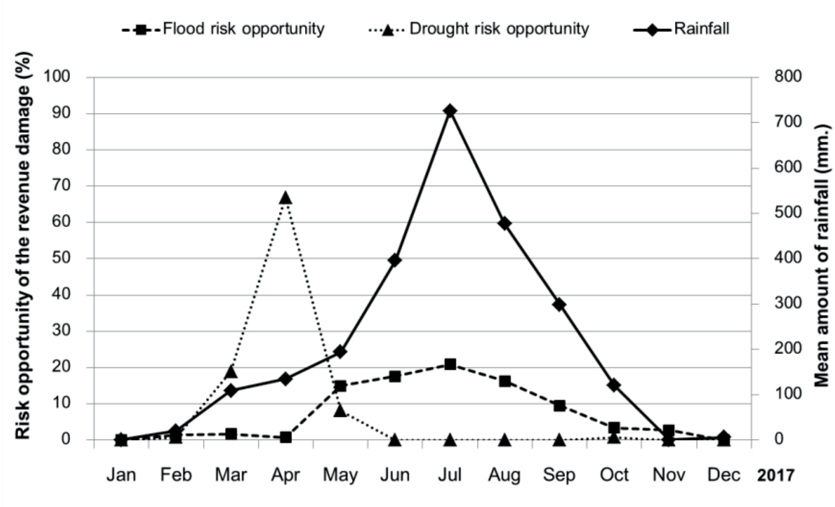

Figure 3. An association between risk opportunity and amount of rainfall. **Source:** Mean of rains in 2017 (Sakonnakhon and Nakhonphanom provincial meteorological office)

Climate variabilities impact fish cage culture differently. Hot weather, drought and flood (including high flows) led to fish death and diseases. Cold weather only led to a slow growth rate because fish consumed less feed (Figure 4).

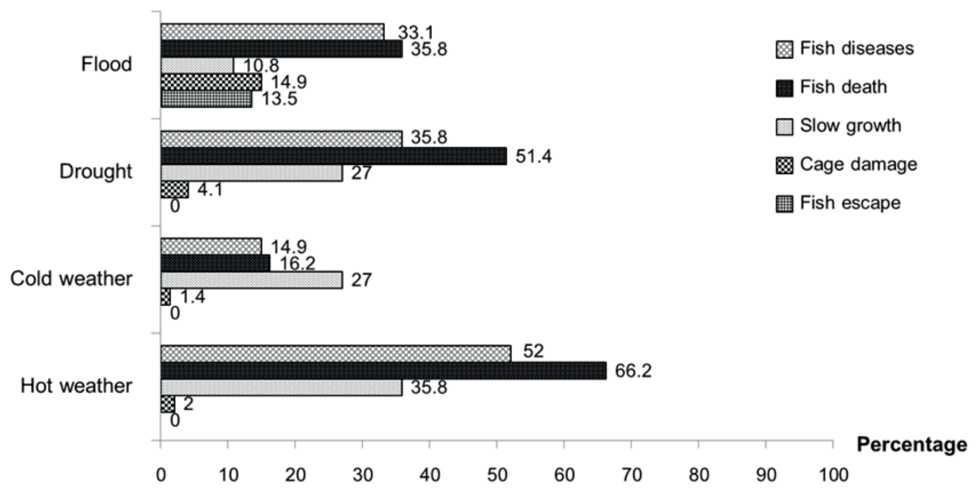

Figure 4. Types of damage from climate variability impacts.

All the fish farmers in the study areas were concerned about the impacts of climate variabilities on fish farming. The level of concern was ranked the highest in hot weather, followed by rapid temperature change, prolonged cloud cover, heavy rainfall, and cold weather, respectively (Figure 5). The fish farmers paid most attention to hot weather because it impacted the fish death and led to fish diseases.

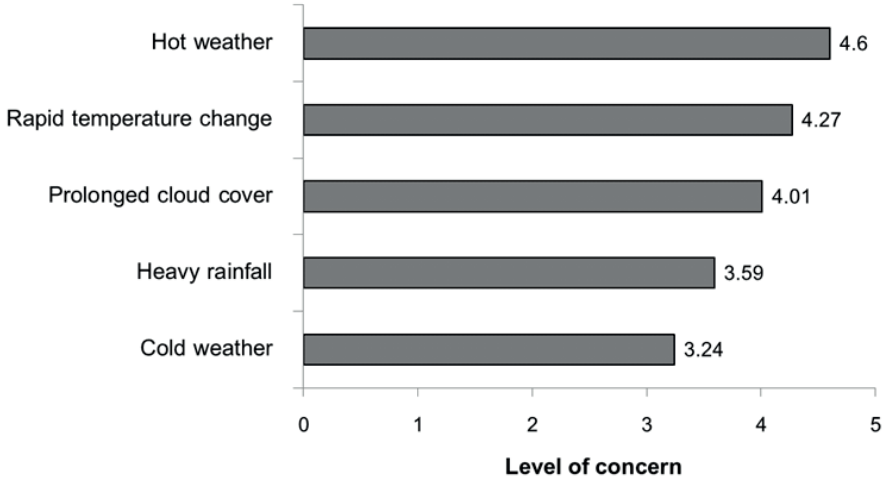

Figure 5. Level of concern on climate variabilities (a scale from 1; not concerned to 5; very concerned).

3.3 Coping strategies for climate variabilities

Most fish farmers (97.3 %) coped with a flood by tying the cages tightly. The other management practices included monitoring and surveillance, moving the floating cages closer to the bank, and delaying or postponing the stocking date (Figure 6). Regarding the drought, most fish farmers moved their cages to the deeper part of water areas, using the aerators and water pumps, and delayed or postponed the stocking date to reduce the risk of damage (Figure 7).

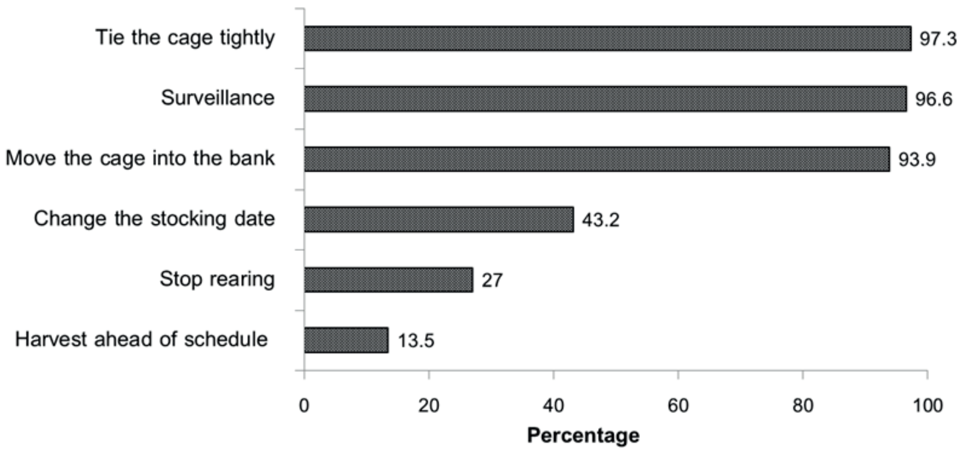

Figure 6. Coping strategies for flood.

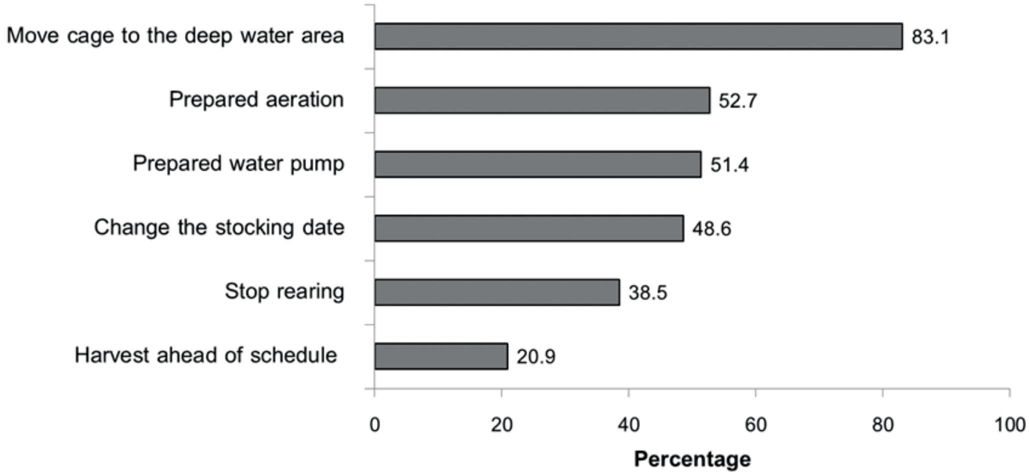

Figure 7. Preparations to cope with drought.

Most fish farmers (91.2 %) monitored their fish closely in cold weather conditions. Some delayed or postponed the stocking date. Some harvested their fish ahead of schedule to reduce the damage from the low temperature (Figure 8). Most fish farmers (89.2 %) also monitored their fish closely regarding the hot weather. Some also delayed or postponed the stocking date. Some planned to stop rearing fish during the high-temperature period (Figure 8). In the summer, the extremely high water temperature and low flows implicated less dissolved oxygen in the river. This problem typically took place in the early morning. Therefore, fish farmers should regularly clean the cages to allow for adequate water flow. They should also use aerators and reduce feeding.

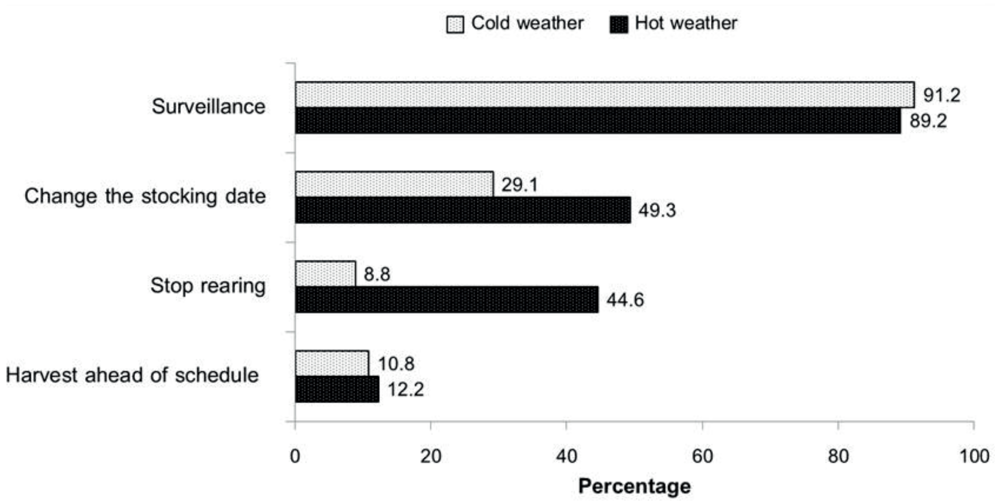

Figure 8. Coping strategies during the hot weather and the cold weather.

Climate change leads to weather variabilities, including variation in temperature, irregular rainfall, and storm. These changes affect water quality for aquaculture and lead to slow growth, more fish mortality, disease outbreak, and production loss [11]. For the past 58 years (1951 - 2008), the temperature in Thailand has tended to rise [12-13]. The average annual air temperature in Thailand increased by 0.95 °C, higher than the average yearly air temperature of other countries (0.69 °C) [13], while the amount of rainfall tends to decrease [14]. The tropical cyclone, depressions, and typhoons affect the amount and distribution of rain. In the past 56 years (1951 - 2006), the number of storms tends to decrease, but storms' severity tends to increase [15]. The weather variabilities, both in the form of changing temperature and rainfall patterns affect more the water quality [4]. Therefore, fish farmers should pay more attention to climate change.

In the present study, hot weather was the most significant weather variability that caused fish production loss. It led to fish death and fish diseases. The data from the provincial meteorological offices (Figure 2) shows that the average temperature was high between March and May. This higher temperature had led to the higher temperature in the river and hence higher water evaporation. Consequently, there was not enough water to rear fish. The rainfall data (Figure 3) shows that rainfall had been low from October until March, leading to a low flow in the river. Most fish farmers believed that the risk of loss was concentrated between March and May when the temperature was high and the amount of water in the river was low and flew too slowly (Figure 2 and 3). Low flows and less dissolved oxygen in the water also affected water quality [16]. The high temperature was also associated with drought. The low circulation of water led to a low level of dissolved oxygen and that caused disease outbreaks and fish death. Dissolved oxygen is essential for aquatic respiration and indicates water quality. The suitable level of dissolved oxygen for aquaculture is greater than 5 mg/L. The dissolved oxygen below 1 mg/L will affect the survival rate of aquatic animals [17]. To reduce the risk of losses, fish farmers moved the cages to the deeper part of the river, used aerators and water pumps, and delayed or postponed the stocking date. These practices were similar to those applied by the fish farmers rearing tilapia in the Ping River and Nan River floating cages in northern Thailand [18-19]. Using an aerator and water pump can help increase dissolved oxygen in water by circulating air through the water, creating little bubbles in the water. Fish farmers should also postpone the stocking date to sometime in July, which is in the raining season when the amount of water in the Songkram river is enough for fish cage farming.

Flooding also led to fish death, fish diseases, cage damage and fish escape from the cage. Moreover, rapid changes in water quality caused stress in fish and affected the growth rate [20]. In order to reduce losses from flood, the fish farmers tied their cages securely, monitored the cages and fish, moved the cages closer to the bank and delayed or postponed the stocking date. These practices are similar to those applied by the fish farmers rearing tilapia in the Ping River and Nan River [18-19, 21]. Moving the cages closer to the bank during the high flow season can help reduce the impact of flooding. High flow and flooding can destroy cages and the fish will use a lot of energy to swim against the turbulent flow and fatigue [22].

Cold weather typically led to slow growth. In the tropical areas, when the temperatures are lower than 25 °C, fish will consume less or stop consuming because of low metabolism and high stress [22]. This will affect the growth rate cause disease [23]. In order to reduce the losses, the fish farmers closely monitored their fish behaviours, delayed or postponed the stocking date or the entire crop during winter, and harvested fish ahead of schedule. Several published studies reported the management practices of fish farmers to overcome climate variability risks. These included changing the stocking date, reducing the stocking density, stopping fish rearing fish during weather variability, and following the weather forecast news [18-19, 21].

4. Conclusions

The study on the impacts of weather variabilities on fish cage culture in Songkhram River and the coping strategies of the fish farmers to reduce the risk of loss show that hot weather was the most significant weather variability impacting fish cage culture, followed by drought, flood or high flows and cold weather. These weather variabilities led to fish death and fish diseases. The fish farmers coped with hot weather and cold weather by monitoring their fish closely, delaying or postponing the stocking date, skipping the entire crop, and harvesting fish ahead of schedule. To cope with drought, the farmers moved the cages to the deeper part of the river, used aerators and water pumps, and changed the stocking date. To reduce the risk of fish losses from flood, these farmers tied their cages securely, monitored the cages and fish closely, moved cages closer to the bank and changed the stocking date. This study lays out the patterns of loss and damage from weather variabilities, which will be helpful for the design of the adaptation strategies for fish farmers and the aquaculture sector.

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Author Contributions:

Funding:

Conflicts of Interest: All authors declare that they have no conflicts of interest.

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