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Mass tilapia (*Oreochromis mossambicus*) mortality in floating net cages at Batur Lake, Bangli Regency, Bali Province: a case report

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Abstract. The mass death of tilapia (*Oreochromis mossambicus*) is the cause of the outbreak of mass death of cultured fish in floating net cages in Batur Lake, Bangli, Bali. The data were collected employing a field survey as material for formulating countermeasures. The sampling area is the Batur Lake, Bangli area, the center for tilapia cultivation in Bali Province. The results of our field investigation show that the upwelling phenomenon caused the cause of the mass death that occurred. The incident happened at the beginning of August, which began with changes in water temperature and wind direction (wind-driven motion). Changes in water temperature cause a mass of nutrient-rich water to move to the lake's surface, thereby reducing dissolved oxygen (DO) levels, which are contained in the water. The high stocking density and accumulation of nutrients from agricultural and anthropogenic activities are the main factors for this outbreak. With this outbreak of mass mortality of cultured fish, the government and relevant authorities are expected to manage the health of the aquaculture environment wisely and issue circulars regarding this case, especially in the center of tilapia cultivation in Batur Lake.

1. Introduction

In aquatic environments, climate change has increased water temperatures and changed the movement of water through the wind [1,2]. For example, an increase in air temperature or strong winds has affected the behavior of surface water gravity waves [3,4]. Understanding climate change can provide insight into predicting and managing water dynamics such as erosion, sedimentation, water movement, and biological responses [5,6].

Climate change is also responsible for global food production [7]. The aquaculture sector, in particular, has challenges due to the nature of its activities which have potentially crucial implications for the maintenance environments. There are related threats regarding cultivated aquatic biotas, such as decreased growth and survival ability, to impact entrepreneurs' economic decline, such as cost losses until finally achieving low profitability [8]. This fact explains that accelerating climate change has profound implications for aquaculture productivity, local community livelihoods, and the national economy [9,10]. An example is a current case in Beratan Lake, Bangli Regency, Bali Province, one of



the primary producers of tilapia (*Oreochromis mossambicus*) in Indonesia. This commodity experiences mass deaths every year in Beratan Lake. This commodity is mainly cultivated in floating net cages, which is the article's primary focus.

Therefore, it is crucial to examine the potential threats and opportunities arising from this phenomenon caused by climate change and human actions. In addition, decision-makers rarely consider the impact of climate change assessment, especially in aquaculture production. Some experts suggest that trigger factors related to climate change such as temperature, acidification, extreme events, shifts in water circulation, angina, harmful algal blooms (HABs), and knowledge gaps regarding the biological response of cultured fish to these factors [11,12].

This paper highlights the mass mortality of *O. mossambicus* in Batur Lake, Bali, which was cultivated in floating net cages. The results of this case report are significant because they can provide an overview of Batur Lake's ecological quality, which is increasingly facing challenges due to climate change and human behavior. As a result, the relevant authorities must develop strategies to control these fish deaths every year.

2. Materials and methods

2.1. Data sources

The data was obtained through field-scale research to the location of the outbreak, carrying out discussions with the Fisheries and Marine Service officers, Bangli Regency, and local fish farmers. Fish was also documented from several areas around Batur Lake (Figure 1).



Figure 1. Location of the research (Source: googlemaps.com)

2.2. Data analysis

The data were presented descriptively based on the results obtained in the field. Surveys were performed to get precise information on specific events, while a literature study was conducted to collect information related to this case. Literature was collected from scientific sources, such as research journals, electronic newspapers, theses, book chapters [13]. Field studies are carried out by observing and studying events in the field. Interviews were also conducted to obtain meaningful information in this study.

3. Results and discussion

Mass mortality of fish cultivated in cages in Batur Lake almost occurs every year, precisely in the rainy season, with the number of fish deaths up to hundreds of thousands. The report described by Suriyani [14] stated that changes in water mass caused sulfur and ammonium residues of fish feed that had

accumulated at the bottom of the water to rise to the surface. The increase in residues on the water's surface causes the lake water to turn white. Likewise, ammonium tends to be toxic, and sulfur can follow dissolved oxygen in the water, so that cultured fish are poisoned to hypoxia. Fish that experience poisoning and hypoxia generally show symptoms such as looking weak and swimming on the water's surface until the color of the fish changes to a paler color (Figure 2).



Figure 2. Mass fish mortality in floating net cages at Batur Lake, Bangli, Bali Province (Source: Authors)

The Department of Energy Facilities reported the same case studies in Tennessee and Kentucky (USA). The study evaluates the environmental impact of using sulfur-based dechlorinating agents, both sodium bisulfate and sodium thiosulfate, to industrial wastewater treatment, causing mass mortality of up to >24,000 fish. The report also confirms that under overfeed conditions and the presence of bacteria capable of metabolizing several sulfur-based agents reduces acidity and dissolved oxygen concentrations [15]. Another study indicated that the histological results show hyperplasia of catfish (*Ictalurus punctatus*) gills found in urban waterways. Ammonia is a serious problem in obtaining contaminant-free water in aquatic toxicology studies [16].

Eco-geographically, Batur Lake is a caldera of Batur Mountain, which erupted and has active sulfur content. The accumulation of pesticide residues used by farmers around the lake for vegetable maintenance can drift into the lake through run-off and surface. Vegetable crops cultivated around Batur Lake are shown in Figure 3. Heavy metals are one environmental pollutant responsible for their toxicity, persistence, and bioaccumulation properties. Based on natural sources, heavy metals could be coming from weathering rocks containing metal and volcanic eruptions, while anthropogenic sources can come from mining activities, domestic waste, and agriculture [17].



Figure 3. Vegetables cultivated around Batur Lake, Bangli, Bali Province (Source: Authors)

Heavy metal is critical because, apart from being one of the causes of fish deaths, in this case, heavy metals are highly toxic through different food sources such as fish, vegetables, and fruits that farmers around the lake cultivate. Serious metal pollutions could be accumulated in cultured fish and other aquatic biotas. In agricultural land, it causes bioaccumulation in horticultural crops. Several diseases in humans by bioaccumulation of heavy metals had Minamata and Itai-Itai diseases in Japan after consuming fish and rice contaminated with Hg and Cd [18,19].

Some recommendations that can be made to protect humans from the harmful effects of heavy metal accumulation are biomonitoring their accumulation in the food chain, in this case in the lake and agricultural environments around Batur Lake. Likewise, the role of relevant authorities and academics is needed to protect the food chain from heavy metal contamination, and untreated agricultural and industrial wastes are not allowed to flow into natural ecosystems such as lakes, rivers, and agricultural land [20,21].

In addition to eco-geographical and anthropogenic factors, natural phenomena such as upwelling are the leading cause of mass fish mortality in Batur Lake, Bangli. The latest report mentions the upwelling phenomenon, at least 14.5 tons of fish cultivated in floating net cages have died [22]. The report explains that the loss caused by the sulfur blast is around IRD 26,000 to 27,000 per kg.

The upwelling phenomenon occurs due to the different heat distribution in the lake layers, in which the lake is stratified into several zones, namely epilimnion, thermocline, and hypolimnion. The wind factor, which can produce large kinetic energy in the waters, causes the movement of water masses and stirring in the lake horizontally and vertically. The upwelling phenomenon is influenced by angina and the Ekman divergence process [23]. The schematic of the upwelling phenomenon in the aquatic environment is shown in Figure 4.

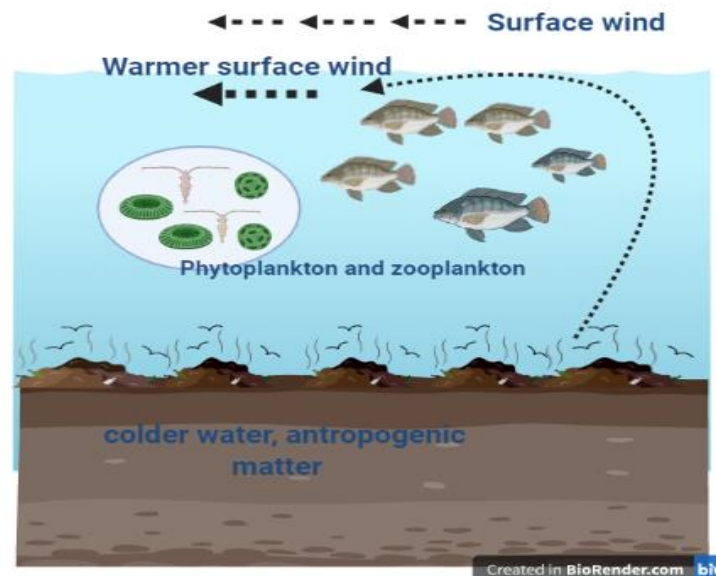


Figure 4. Schematic of upwelling phenomenon in aquatic environments (created with BioRender.com)

The upwelling phenomenon has also been reported in Jatiluhur and Saguling Lakes, West Bandung, Indonesia. The upwelling case occurs when the surface water temperature becomes lower due to the rainy season and causes the specific gravity of the surface water to be high. Therefore, organic substances found at the bottom of the water will form hydrogen sulfide, which is toxic to aquatic biota [24]. The same incident also occurred around the beginning of 2009 in Wadaslintang Lake, Central Java, where tilapia was cultivated with signs that began in the long dry season, a reduction in reservoir capacity of up to 50%, the emergence of southerly winds, and changes in the color of the air [25].

In this case, fish farmers must also start managing the cages used to reduce their stocking density. Low stocking density has ecological advantages, such as being more environmentally friendly, preventing overfeeding, water quality management, and a cage design using a filter so that easier to clean up leftover feed and waste from fish to experience further sedimentation at the bottom of the lake [14].

4. Conclusions

Mass mortality cases of fish cultured at floating net cages in Batur Lake are caused by several factors, such as eco-geographical close to Batur Mountain, agro-ecosystem around the lake, and accumulation of residues that enters the lake through run-off and surface. Fish entrepreneurs still need to consider water quality management factors of aquaculture and weather factors.

Comprehensive environmental and ecotoxicological studies of heavy metals and their effects on fish mortality should be performed to provide information that may impact health for humans and the environment around Batur Lake. We recommend that fish farmers continue monitoring water quality and reducing stocking densities to improve fish quality of life. The local communities should be educated about the dangers of long-term pesticide application to human health and the environment. Besides, wastewater from agricultural and domestic industries around the lake must be treated effectively before being discharged into natural water bodies.

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