Occurrence and recurrence: the fish kill story in Lake Buhi, Philippines

Plutomeo M. Nieves, Antonino B. Mendoza Jr., Sandy Rey B. Bradecina

Fisheries Department, Bicol University, Tabaco Campus, Tabaco City, Albay, Philippines. Corresponding author: P. M. Nieves, plutz1122@yahoo.com

Abstract. Fish cage farming is of paramount importance to lake dwellers income and livelihood and to domestic fish supply. However, the occurrence and recurrence of fish kill have been reported annually with serious economic losses. This work explored the causes of occurrence and recurrence of fish kill in the context of finding adaptive solution. Dataset for the study was generated through key informant interview, focused group discussion and secondary data analysis. Problem Tree was used to identify the root-cause and SWOT analysis was employed to craft best practice guideline for Local Government Unit in outlining the action plans for management of cage aquaculture. Findings reveal the fish kill occurrence can be traced from the natural and human-induced stresses and mismanagement of lake's resources. Typhoons and prevailing trade winds play a major role as triggering factor while the uncontrolled number of cages and unsustainable farming practices are the major determinants of fish kill event. The interaction between water temperature, dissolved oxygen, wind mixing and by-products of decomposition (i.e. ammonia-nitrogen and H_2S) as a result of overfeed and lake over-use are the key elements of fish kill in the lake. Monitoring critical levels of water temperature and dissolved oxygen is useful information in fish kill prediction. Finally, given that the lake is a common property with multiple use nature, a multi-sectoral management approach is necessary to sustain the fish cage industry.
Key Words: fish cage, fish kill, eutrophication, problem tree analysis, dissolved oxygen.

Introduction. The success tilapia fish cage farming triggered the interest of enterprising businessmen resulting to the expansion of the industry in Buhi Lake (Escover et al 1985; Araullo 2001). However, the occurrence and recurrence of fish kill has been reported and known to cause serious economic losses and threat to food security. Records of fish kill is estimated at PhP 322.1M from 1998-2018 (Bicol Today 2013; BomboRadyo 2017; Inquirer Net 2016; Manila Bulletin 2016).

Fish kills occurrence has been implicated to dissolved oxygen (DO) depletion, high ammonia-nitrogen and hydrogen sulfide (H_2S) (Binoya et al 2008; Msiska 2017). The triggering factors include typhoon and prevailing seasonal monsoon (Northeast and Southwest), while the presence of too many cages, unsustainable farming practices (i.e. overfeeding) and improper waste disposal are the key interconnected factors associated with fish kill. Yet, the occurrence and recurrence of fish kill is a sad reality worth evaluating to increase the adaptive capacity of cage farmers and minimize or avoid economic losses. This work explored the identified causes of occurrence and recurrence of fish kill in Lake Buhi with the hope of finding adaptive solution to the problem.

Material and Method. The study was carried out from October 15, 2017 to October 14, 2018 in the cage farming communities around Buhi Lake, Camarines Sur, Philippines. Monitoring of DO and temperature at varying depths was established in two stations (Figure 1) representing the deep and shallow cage farming site.

Data collection made use of qualitative and quantitative method. Qualitative datasets was obtained through key informant interview (KII), focused group discussion (FGD) and secondary data analysis (SDA). A15-mos on-site monitoring of DO and temperature was done at varying depths (5 and 10 m) using HOBO Data LoggerU26 being known as major controlling factors in any aquaculture activities. Changes in the values were used as indicator for possible fish kill occurrence which in turn serve as a warning for fish cage operators and the local government units (LGU) office avoid the devastating consequences of fish kill. The study made use of the Problem Tree Analysis and SWOT analysis followed by action planning to craft a best practice guideline LGU in outlining the policy recommendations.

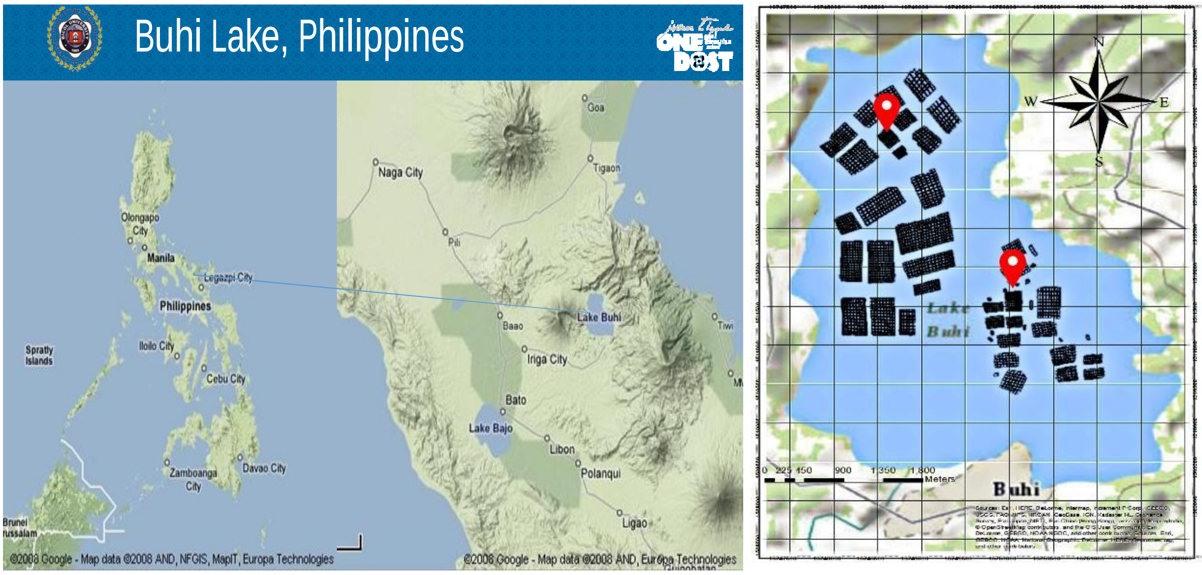

Figure 1. Location map of sampling stations within Buhi Lake.

Results and Discussion

Tilapia cage aquaculture profile. Tilapia cage farming industry in Buhi was introduced in 1978, but widespread adoption began in 1982 (Escover et al 1985). Today, there are about 1,034 fish cage operators with an estimated 16,562 units of fish cages (Buhi Municipal Fisheries Profile 2010) estimated to constitute roughly to about 70-80% of the total lake area.

Majority of the cage farmers are educated married male with mean age of 49 years, with 5-30 years experience in fish caging. Fish caging is basically monoculture Nile tilapia, *Oreochromis niloticus* and their hybrids in submerged 10m x10m x5m to 15m x15m x 5m net cages. The mean number of cage is 41 units to a maximum of 415 units. Similarly, majority (62.50%) of the fish cage farmer' harvest 1.0-5.0 tons.

Farming is characterized by extensive to intensive use of commercial sinking pellets. Stocking density of 2,500 fingerlings/cage (100 m^2), about 25-100 bags feeds are used per production cycle of 4-7 months. It is interesting to note that of the 88% who are into complete feeding, 55.33% feed their stock by personal judgment and 16.67% practice *ad libitum* feeding which clearly indicate overfeeding and projected high nutrient load in terms of nitrogen and phosphates. In summary, farming practices today is characterized by overfeeding in too many cages.

Dissolved oxygen and water temperature monitored at varying depths. The mean DO and temperature values recorded in Lake Buhi is typical among tropical lakes, however, the monthly mean DO level starts to decline in December 2017 onwards without much change in the mean temperature. The lowest recorded values are at 1.21 mg L^{-1} in May 2018 and highest at 9.41 in June 2017. For tilapias, DO concentrations of > 5.0 mg L^{-1} is most preferred while 3.0-4.0 mg L^{-1} is tolerable (Lloyd 1992; Philminaq 2008) as long as temperature and pH remain favorable. Unfortunately, in Buhi Lake, exposure to low level of DO is often linked to fish kill when upwelling or overturn is in progress. This can be attributed to the mixing effect of wind and heavy rains where bottom anoxic waters are mixed with surface waters during the changes in the seasonal monsoon or during typhoon. It is worth mentioning that during the study period, three fish kill occurrence were recorded with substantial damage to fish stocks. Most are linked to strong wind and heavy rains brought about by the trade winds and typhoon (i.e. *Karen, Salome and Urduja*) which trigger thermal stratification resulting to overturn and/or upwelling that brings oxygen-deficient together with the toxic products of decomposition in the upper layer of the lake.

Fish kill occurrence and recurrence. Historical account implicates typhoon and prevailing monsoons as a predisposing factor to fish kill (Araullo 2001). During seasonal monsoon, fish kill starts from the southwest then to the central zone and finally in the northern zones of the lake. While during the NE monsoon, fish kill starts from the northern part then to the central and the southern part (Binoya et al 2008). This pattern clearly points out the significance of nature-induced stresses in the occurrence of fish kill. It is also worth noting that they inflict severe damages to farmed stocks including livelihood assets (i.e. cages, boats, and fishing paraphernalia). Table 1 presents the identified causes of recorded fish kill from 1998 to 2018.

Table 1

The identified causes of recorded fish kill events from 1998-2018

Identified causes	*F*	*%*	*Remarks*
DO depletion	7	35	Lethal
Strong wind and heavy rain caused by Southeast Monsoon	2	10	Triggering factor
Typhoon causing overturn-upwelling (Urduja & Salome 2017; Karen 2016; Lando 2015)	5	25	Triggering factor
Changes in temperature	1	5	Lethal
Feed contamination	1	5	Lethal
Ammonia-nitrogen conc.	2	10	Lethal
Traces of H_2S	1	5	Lethal
Overstocking	1	5	Triggering factor
Total	20	100	

Note: F = frequency.

Finding reveals that 35% of fish kill is attributed to DO depletion, an end result of the interaction between human-induced stresses and nature. Mortalities are caused by suffocation because of exposure to oxygen-deficient waters. Typhoons and Southwest (*Habagat*) or Northeast (*Amihan*) trade winds, comprises 25% and 10%, respectively. The destructive effects are well documented in Table 1. In most cases, pre-fish kill events are characterized by high wind intensity and heavy rainfall followed by thermal stratification, lake water mixing and bottom perturbation which ends up into “overturn” or “upwelling. Exposure of farmed fish or wild stocks to DO-deficient water and toxic metabolites leads to mass fish mortalities (Msiska et al 2017).

Another lethal factor is ammonia-nitrogen and hydrogen sulfide comprising 10% and 5% respectively. These are products of decay and exposure directly causes mortalities. It is also interesting to note that feed contamination and overstocking was identified. It could be inferred from these findings that DO and temperature monitoring as well as changes in weather events are some important precautionary measures to predict possible fish kill and avoid economic losses.

Cause and effect analysis. Figure 2 presents the diagrammatic root-cause analysis of the occurrence and recurrence of fish kill in Buhi Lake. Inputs for this analysis were obtained from KI interview and FGD of fish cage farmer and supplemented by Bureau of Fisheries and Aquatic Resources (BFAR) records on files. The 15-months DO and water temperature monitoring data was also used as integral part of the analysis.

Fish kill occurrence and recurrence in Buhi Lake can be traced from two interacting pathways: natural and human-induced pathways depicted in Figure 2. These pathways have direct and indirect link to fish kill. It should be noted that the lakes vulnerability to natural calamity is high and inevitable considering that 20 storms hit the country each year on the average, eight or nine tropical storms make landfall each year, with another 10 entering Philippine waters.

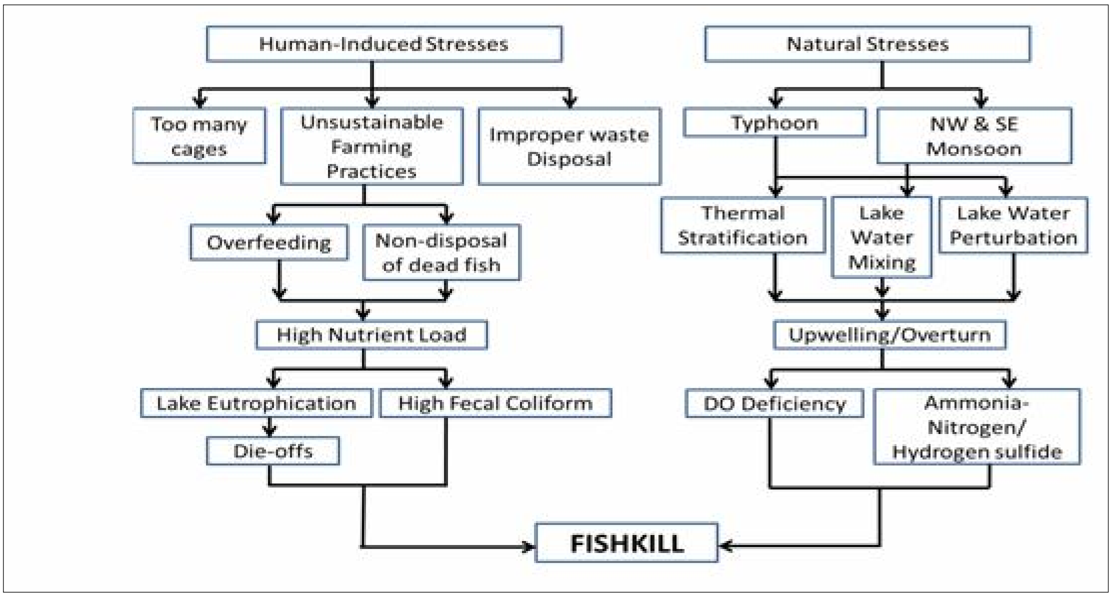

Figure 2. Diagrammatic illustration of the direct, indirect causes and issues affecting fish kill in Buhi Lake.

Overturn and/or upwelling are wind and temperature driven changes that brings upward anoxic bottom waters together with toxic by-products of decomposition. This phenomenon is the residual effects of lake-overuse, the unsustainable farming practices like overfeeding and mismanagement. The interrelated issues of high nutrient load, eutrophication, algal bloom and die-off are by itself leads to fish kill and traceable from various sources. One important source is the "*lake overuse pathway*". The presence of too many cages beyond the lakes carrying capacity is definitely putting a lot of pressure on the lake's life support system to sustain productivity. Besides it violates the law under of R.A. 8550 now amended as R.A.10654. Today, there are more than 16,562 units of cages occupying approximately some 70-80% of the lakes total area (Municipal Fisheries Profile of Buhi 2010). With too many cages, feeding excessively will result to high nutrient load and organic matter deposited directly into the lake environment (Islam 2005). Sumalde et al (2016) reported that excessive number of cages with overstocking may lead to fish kills due to deteriorating water quality and other associated damages that are detrimental to the aquaculture industry and to the greater community. This condition is aggravated by unsustainable farming practices.

Overfeeding results in excess nutrients entering the water column. The excess nutrients accumulate on the lake bottom and degrade water quality and the oxygen level in the sediment beneath the cages depletes making the area prone to fish kills (White et al 2018). This may also lead to changes of N:P ratio in the bottom sediments. High amounts of nutrients introduced to the lake will result to eutrophication especially when sunlight intensity is at its maximum. Plankton biomass assessment done during the study showed that Buhi lake waters is primarily eutrophic with high plankton biomass (583.44 g m^{-3}) (Nieves et al 2018), thus, the need for feeding moderation. This condition is further aggravated by observed nutrient discharges both from domestic sewage and agricultural wastes including the non-disposal of dead fish after fish kill. This does not only add up to the already higher organic load and nutrients but also increase the fecal coliform count of lake water.

In summary, the causal factor of mortalities is death by asphyxiation due to DO deficient lake water and the lethal effects of ammonia-nitrogen, hydrogen sulfide and methane which are the resultant effect of a combination of natural and human-induced stresses in the environment, thus, occurrence and recurrence of fish kill.

From the developmental perspective, waters of Buhi Lake although with multiple-use nature were originally designed for irrigation and power supply instead of aquaculture. With unregulated cage aquaculture in place, water quality and ecosystem integrity of the lake is under immense pressure and its sustainability threatened. Gleaning from the magnitude of technology application, it cannot be denied that it exceeded the limits of what nature can provide. This therefore necessitates multi-stakeholders participation and cooperation to save the lake and the multiple services and benefits it provides on a long-term basis.

Analysis of the strength, weaknesses, opportunities and threats. To strategically develop action plans that address the critical issues and concern affecting the industry and the environment, an assessment of the internal and external environmental was undertaken. The key strength (S), weaknesses (W), opportunities (O) and threats (T) was shown in Table 2.

Table 2

Internal strength and weakness and external opportunities and threat matrix of fish cage farming industry in Buhi Lake

Internal environment	
Strength (S)	*Weaknesses (W)*
- Supportive LGU officials; - Existence of Lake Development Office; - Existence of Fisheries and Aquatic Resources Management Council (FARMC); - Lake Buhi as natural resource capital.	- Weak law enforcement (R.A. 10654); - Unsustainable farming practices (overstocking and overfeeding); - Unorganized fish cage farmers; - Lack of lake monitoring equipment and facilities; - Inadequate solid waste management facility (including dead fish disposal).
External environment	
Opportunities (O)	*Threat (T)*
- Supportive NGA's (DA-BFAR, DENR-EMB); - High demand for food fish; - Ecotourism; - Academe support.	- Fish kill; - Typhoon and prevailing monsoon; - Lake ecosystems collapse; - Fish cage farming industry collapse.

The SWOT analysis was accomplished by matching the strength with opportunities (SO) in order to tap the internal strength to be able to take advantage of the opportunities. Similarly, the internal strength was used matched with the threats (ST) to mitigate or counteract the potential threats. Similar matching process was done on the weaknesses and opportunities (WO) and weaknesses and threats (WT). The basic strategy is to develop a fix on the weaknesses in order to take advantage of the opportunities or to counter or reverse the threats. After relevant matching, strategic options for policy recommendations were identified.

To strategically address the threats of fish kill, the LGU together with the FARMC should take advantage of the support of national government agencies (NGA's) like DA-BFAR, Department of Environment and Natural Resources-Environmental Management Bureau (DENR-EMB), the Academe, to sustain the industry and the environment. It should be noted that the lake is an important natural resource capital which contribute significantly to the livelihood, employment and income of the people. As such, it is imperative for LGU's and NGA's to regulate the number of fish cages to not more than 10% of the lake allotted for aquaculture based on the provision of Republic Act 8550 (Fisheries Code of the Philippines) and R.A.10654 (Amended R.A. 8550). In addition, BFAR, BUTC, FARMC and Feed Millers can work together in capacity building for good aquaculture practices (GAqP) that reduces promote best practice in feeds and feeding management, stocking and health management, water quality management and records management. Moreover, lake water monitoring can be improved with institutionalization of the “Fish Kill Project” spearheaded by Bicol University Tabasco Campus (BUTC) including those of BFAR and DENR. In essence these strategic options can be explored to the best interest of the LGU, the environment and the industry.

Conclusions and Recommendations. On the basis of the findings and the strategic analysis, fish kills occurrence and recurrence are basically interconnected problems of lake over-use and nature-induce stresses. While nature is difficult to mitigate, preventive measures can be done for human-induced stresses. Given this context, following policy recommendations are hereto suggested:

- regulating the number of fish cages per R.A. 10654 provisions;
- LGU to institutionalize water quality monitoring and early warning efforts started by BUTC under the “Fish Kill Project” in collaboration with fish cage operator, Feed Millers, BFAR and DENR-EMB;
- providing tax incentive to fish cage operators with good aquaculture practices (GAqP) particularly on the aspects of feeds and feeding management and stocking;
- organizing the fish cage operators and the Feed Millers as LGU and FARMC partners in maintaining the ecological integrity of the lake;
- provision of fish kill disposal facility;
- the inclusion of fish kills in the Disaster Risk Reduction (DRRM) program, projects and activities.

Acknowledgements*.* This project is funded by DOST-PCAARRD and supported by Bicol University Tabaco Campus in cooperation with the local government of Buhi. We also acknowledge cooperation of BFAR–5 and EMB-5, the LDO Staff, FARMC, Fish Cage Operator/Farmers and Santeh Feeds.

References

Araullo D. B., 2001 Aquaculture practices and their impact on Philippine lakes. In: Conservation and ecological management of Philippine lakes in relation to fisheries and aquaculture. Santiago C. B., Cuvin-Aralar M. L., Basiao Z. U. (eds), Southeast Asian Fisheries Development Center, Aquaculture Department, Iloilo, Philippines; Philippine Council for Aquatic and Marine Research and Development, Los Baños, Laguna, Philippines; Bureau of Fisheries and Aquatic Resources, Quezon City, Philippines, pp. 25-28.

Bicol Today, http://bicoltoday.com/2013/08/25/oxygen-depletion-causes-massive-fish-kill-in- lake-buhisays-govt-fisheries-agency/.

Binoya C. S., Gerpacio R. V., Southeast Asian Regional Centre for Graduate Study and Research in Agriculture, 2008 Managing and conserving Lake Buhi: an agroecosystem analysis for sustainable development. Los Baños, Laguna, Philippines: Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), 61 pp.

BomboRadyo Philippines, www.bomboradyo.com/fish-kill-sa-camsur-nag-abot-na-sa-25-metric-tons-re-epekto-kan-bagyong-urduja/.

Escover P. E. M., Claveria R. L., 1985 The economics of tilapia cage culture in Bicol freshwater lakes, Philippines. In: Philippine tilapia economics. Smith I. R., Torres E. B., Tan E. O. (eds), ICLARM Conference Proceedings, Philippine Council for Agriculture and Resources Research and Development, Los Baños, Laguna and International Center for Living Aquatic Resources Management, Manila, Philippines, pp. 50-65.

INQUIRER.NET, https://newsinfo.inquirer.net/827723/lake-buhi-fish-kill-brings-p178m-in-loss.

Islam M. S., 2005 Nitrogen and phosphorus budget in coastal and marine cage aquaculture and impacts of effluent loading on ecosystem: review and analysis towards model development. Marine Pollution Bulletin 50(1):48-61.

Lloyd R., 1992 Pollution and freshwater fish. Fishing News Books Ltd., 179 pp.

Manila Bulletin, http://news.mb.com.ph/2016/11/25/chemicals-in-tilapia-feeds-changes-in-temperature-cause-lake-buhi-fish-kill-town-in-state-of-calamity.
Msiska, G. D. Kanyere, S. Ngwira and Mtafu Manda. 2017, A prognosis of the causes of vulnerability of Lake Malawi fish resources in Karonga town. International Journal of Fisheries and Aquaculture.Vol. 9(6),pp.59-72,ISSN 2006-9839
Municipal Fisheries Profile of Buhi 2010.
Nieves P. M., Mendoza Jr. A. B., Bradecina S. R. B., Cabrera M. E., Bustamante A., 2018 Survey on plankton biomass and vertical profile of dissolved oxygen and temperature in Lake Buhi. Bicol Science Journal Vol. 4.
Philminaq, 2008 Water quality criteria and standards for freshwater and marine aquaculture. Mitigating impact from aquaculture in the Philippines, 34 pp.
Sumalde Z. M., Francisco K. L. A., Peñales M., 2016 Productivity effects of water pollution due to excessive aquaculture structures and overstocking. In: Marine and coastal ecosystem valuation, institutions, and policy in Southeast Asia. Olewiler N., Francisco H., Ferrer A. (eds), Springer, Singapore, pp. 185-200.
White P. G., Shipton T. A. Bueno P. B., Hassan M. R., 2018 Better management practices for feed production and management of Nile tilapia and milkfish in the Philippines. FAO Fisheries and Agriculture Technical Paper 614, Food and Agriculture Organization of the United Nations, Rome, 96 pp.

Received: 11 August 2019. Accepted: 06 October 2019. Published online: 28 January 2020.
Authors:
Plutomeo Moral Nieves, Fisheries Department, Bicol University, Tabaco Campus, Tayhi Tabaco City, 4511, Philippines, e-mail: plutz1122@gmail.com
Antonino Baconawa Mendoza Jr., Fisheries Department, Bicol University, Tabaco Campus, Tayhi Tabaco City, 4511, Philippines, e-mail: antox.mendoza@gmail.com
Sandy Rey Bocaya Bradecina, Fisheries Department, Bicol University, Tabaco Campus, Tayhi Tabaco City, 4511, Philippines, e-mail: reybradecina@gmail.com

How to cite this article:
Nieves P. M., Mendoza Jr. A. B., Bradecina S. R. B., 2020 Occurrence and recurrence: the fish kill story in Lake Buhi, Philippines. AACL Bioflux 13(1):152-158.