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Multi-Hazard Action Plan on Fish Kill Events in Talisay, Batangas: Environmental Contamination, Public Health Threats, Economic Consequences, and Social Impacts

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Abstract:

This paper presents the Multi-Hazard Action Plan on Fish Kill Events in Talisay, Batangas, a municipality holding the highest number of authorized fish cages (2,500) among all Taal Lake lakeshore municipalities. Fish kill events in Talisay arise from compound hazard drivers: typhoon-induced lake overturn, Taal Volcano's sulfur dioxide emissions, eutrophication, and high fish cage density — collectively responsible for the loss of 2.87 million fish and ₱157.9 million in economic damage from 2021 to 2024. Using a mixed-methods design, 68 respondents from four priority lakeshore barangays participated in a 40-item, four-point Likert scale survey. Results showed an overall weighted mean of 3.14 (Agree), with disaster preparedness (WM 3.10) identified as the dimension most needing enhancement. Anchored in Republic Act No. 10121, the Sendai Framework for Disaster Risk Reduction 2015–2030, and the Sustainable Development Goals, the three-year action plan (2027–2029) proposes 28 programs, plans, and activities (PPAs) under four strategic goals addressing prevention and mitigation, preparedness, response, and recovery and rehabilitation. The plan establishes real-time dissolved oxygen monitoring, multi-hazard simulation drills, a unified Incident Command System, and structured livelihood recovery mechanisms to build the long-term resilience of Talisay's fisherfolk communities and lakeshore ecosystems.

Keywords — **fish kill, multi-hazard action plan, disaster risk reduction and management, Taal Lake, Talisay Batangas, aquaculture, community resilience, dissolved oxygen monitoring**

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I. INTRODUCTION

Fish kill events have become a recurring environmental and socio-economic crisis for the Municipality of Talisay, Batangas. Situated along the northern shoreline of Taal Lake — one of the Philippines' most important inland fishery ecosystems — Talisay holds the highest allocation of authorized fish cages (2,500) among all Taal Lake lakeshore municipalities. This dominant cage allocation, combined with the municipality's location entirely within Taal Volcano's 14-kilometer extended danger zone, places Talisay's 49,787 residents across all 21 barangays at compounded multi-hazard risk, where volcanic, hydrological, and anthropogenic hazards converge to produce mass fish mortality events that devastate livelihoods, threaten public health, and erode community resilience.

Bureau of Fisheries and Aquatic Resources (BFAR) records document the loss of 2.87 million fish from 2021 to 2024, with cumulative economic damages reaching ₱157.9 million [1]. The year 2023 recorded the worst single-year fish kill on record, with losses amounting to ₱69.28 million — a figure that excludes

downstream economic losses such as reduced household consumption spending, loan defaults on cage investments, and health costs associated with contaminated fish exposure [3]. Tilapia production has collapsed 83.6% from its 2020 baseline of 3,661.50 metric tons to only 602.00 MT in 2025, signaling sustained ecosystem degradation that cannot be attributed to any single incident [5].

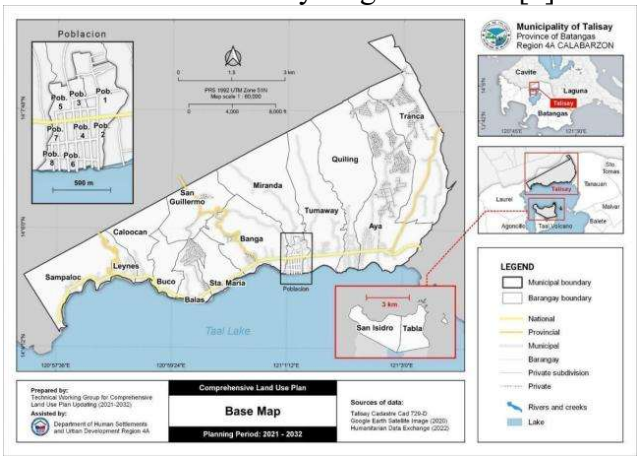

Fig. 1 Base Map of the Municipality of Talisay, Batangas (Source: DHSUD Region 4A, 2021)

Multiple converging hazards drive fish kill events, and their simultaneous occurrence produces disasters far more severe than any single hazard in isolation. Typhoon-induced lake overturn depletes dissolved oxygen (DO) to lethal levels of 0.07–0.46 mg/L — well below the ≥6 mg/L survival threshold for tilapia and bangus — typically within 24 to 48 hours of a storm's passage. Taal Volcano's sulfur dioxide emissions acidify lake water and further depress oxygen solubility during periods of elevated volcanic activity. Chronic eutrophication from excess fish feed and organic waste decomposition by approximately 9,188 operational cages — more than 50% above the TVPL-PAMB-permitted lake-wide ceiling of 6,000 cages under the Unified Rules and Regulations for Fisheries [15] — amplifies oxygen depletion episodes. Seiche events, flooding, and surface runoff add further nutrient loads that accelerate algal growth and hasten oxygen crashes.

Despite the severity and recurrence of these events, no dedicated multi-hazard action plan existed for fish kill events in Talisay prior to this study. Existing local contingency plans address general disaster response but do not incorporate fish kill-specific protocols, real-time dissolved oxygen monitoring procedures, or structured frameworks for coordination among the MDRRMO, Municipal Agriculture Office (MAO), Bureau of Fisheries and Aquatic Resources (BFAR), Philippine Institute of Volcanology and Seismology (PHIVOLCS), and the Taal Volcano Protected Landscape–Protected Area Management Board (TVPL-PAMB) [6]. This institutional gap represented the primary motivation for developing this evidence-based multi-hazard action plan as the researcher's graduate thesis in Disaster Risk Management.

The plan is anchored in Republic Act No. 10121 [12], which mandates LGUs to develop and maintain local DRRM plans; the Sendai Framework for Disaster Risk Reduction 2015–2030 [16], particularly Priority 3 (Investing in DRR for Resilience) and Priority 4 (Enhancing Disaster Preparedness for Effective Response); and the Sustainable Development Goals, particularly SDG 14 (Life Below Water), SDG 1 (No Poverty), and SDG 11 (Sustainable Cities and Communities). The plan also operates in complementarity with the TVPL-PAMB regulatory framework, including the Supreme Court Writ of Continuing Mandamus [14] directing compliance with environmental protection mandates within the Taal Volcano Protected Landscape.

Taal Lake holds exceptional ecological and economic significance for the province of Batangas. As a volcanic crater lake of approximately 234.2 square kilometers, it is home to more than 70 freshwater fish species, including the endemic tawilis (Sardinella tawilis), the world's only freshwater sardine. Taal Lake's fisheries support the livelihoods of an estimated 26,000 fisherfolk households across 11 lakeshore municipalities, with aquaculture fish cage production being the dominant economic activity in Talisay, Laurel, Agoncillo, and San Nicolas. The lake also serves as a critical water source for irrigation and domestic use in surrounding barangays, making the environmental health of Taal Lake a direct determinant of community food security, livelihood sustainability, and ecological resilience across the entire Region IV-A lakeshore corridor.

Historical fish kill records in Talisay reveal a pattern of escalating frequency and severity closely correlated with typhoon activity and Taal Volcano degassing cycles. The 2020 Taal Volcano eruption, which displaced more than 40,000 residents across

lakeshore municipalities and caused significant ashfall loading into the lake, dramatically elevated eutrophication levels that persisted through 2021 — contributing to the first major post-eruption fish kill season [13]. Subsequent fish kill events in 2022, 2023, and 2024 followed typhoon landfalls within the Taal Lake watershed, with the 2023 event (₱69.28 million in losses) occurring in the wake of Typhoon Egay's indirect effects on lake thermal stratification. This pattern of volcanic-hydrological-anthropogenic multi-hazard interaction defines Talisay's distinct risk profile and clarifies why conventional single-hazard action plans — designed for typhoon flooding, volcanic eruption, or aquaculture management independently — cannot adequately address the compounding hazard sequences that produce fish kills in Taal Lake.

II. METHODOLOGY

This study employed a descriptive-survey research design using a mixed-methods approach combining quantitative survey data, secondary data analysis, and key informant interviews. The 40-item researcher-developed survey instrument was organized into four thematic areas corresponding to the four pillars of the National DRRM Framework: (1) Prevention and Mitigation (10 items), (2) Preparedness (10 items), (3) Response (10 items), and (4) Recovery and Rehabilitation (10 items). Each item used a four-point Likert scale — Strongly Agree (4), Agree (3), Disagree (2), Strongly Disagree (1) — with responses interpreted using a weighted mean (WM) scale where 3.25–4.00 = Strongly Agree, 2.50–3.24 = Agree, 1.75–2.49 = Disagree, and 1.00–1.74 = Strongly Disagree. The instrument was validated by three expert validators with backgrounds in DRRM, aquaculture, and disaster management, and pre-tested on 15 non-sample respondents to confirm reliability before deployment in the four priority barangays.

A total of 68 respondents were purposively selected from four priority lakeshore barangays based on BFAR fish kill incidence records and MDRRMO impact documentation: Barangay Aya (n=27), the highest-exposure community with the largest concentration of fish cages; Sampaloc (n=17); Quiling (n=14); and Tumaway (n=10). Respondents included registered fisherfolk, fish cage operators, barangay officials, BDRRMC members, and selected LGU staff from MAO, MHO, and MSWDO. Secondary data on fish kill incidence, production volumes, and economic losses were sourced from BFAR Region IV-A records (2021–2024) [1], MAO Talisay [5], and MDRRMO documentation [6]. SWOC and PESTEL analyses were conducted through a combination of key informant interviews, document review, and focus group discussions with MDRRMO and MAO staff. Action plan development followed a consultative process involving MDRRMO, MAO, BFAR, barangay officials, and TVPL-PAMB representatives.

Quantitative data were analyzed using frequency, percentage, and weighted mean to describe survey responses per indicator and per thematic pillar. Descriptive statistics were used to identify priority capacity gaps that directly informed the design of the 28 PPAs. Secondary data underwent content analysis and trend mapping to establish the multi-year fish kill loss pattern, production decline trajectory, and hazard interaction sequences. Action plan PPAs were costed using unit cost estimates from BFAR Region IV-A, Department of Agriculture regional offices, and DOST project databases, and validated through consultation with MDRRMO budget officers to ensure LDRRMF funding eligibility and alignment with RA 10121 appropriation requirements for prevention, mitigation, preparedness, and response activities.

III. RESULTS: DRRM CAPACITY ASSESSMENT

A. Respondent Profile

The 68 respondents ranged in age from 22 to 67 years, with the majority (54.4%) falling in the 36–55 age bracket representing mid-career fisherfolk and barangay officials with direct experience of multiple fish kill events. Most respondents (73.5%) were male, reflecting the predominantly male composition of registered fish cage operators in the four priority barangays, while 26.5% were female — including female BDRRMC members, women's association representatives, and female-headed aquaculture households whose inclusion was intentional to capture gender-differentiated vulnerability and recovery experiences in the data. Educational attainment ranged from elementary to college graduate, with 45.6% holding secondary education

certificates and 29.4% having completed at least two years of college or vocational training — a profile consistent with fishing community demographics in Batangas Province [8].

The majority of respondents (67.6%) had been engaged in fish cage aquaculture for more than five years, ensuring that survey responses reflected direct experiential knowledge of fish kill events rather than hypothetical scenarios. Among those with five or more years of fish cage experience, 82.4% had personally experienced at least one major fish kill event resulting in financial losses, providing a highly relevant respondent pool for assessing all four DRRM pillars. By respondent category, 47.1% were registered fisherfolk and active fish cage operators; 32.4% were barangay officials and BDRRMC members; and 20.6% were LGU and agency staff from MAO, MHO, and MSWDO. The distribution ensured representation of both operational frontline perspectives and institutional governance viewpoints across all four DRRM dimensions.

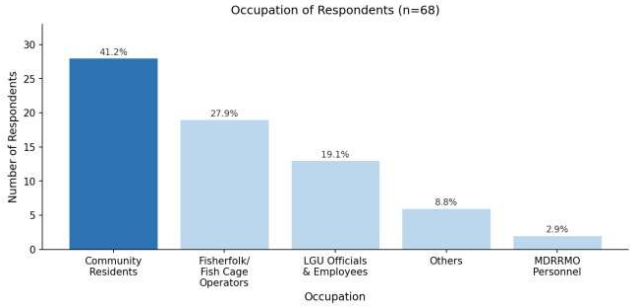

Fig. 2 Occupation Distribution of Survey Respondents (n=68)

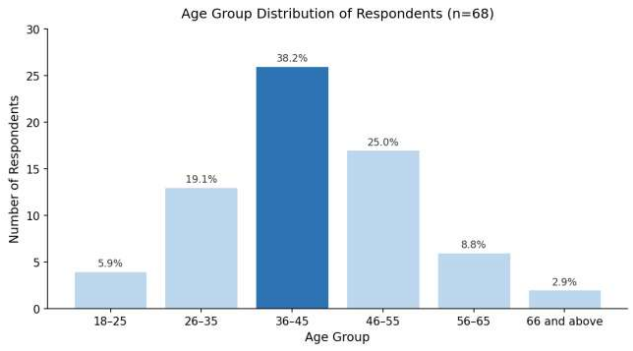

Fig. 3 Age Group Distribution of Survey Respondents (n=68)

The age distribution of respondents (Fig. 3) reflects the multigenerational nature of aquaculture dependence in the four priority barangays. The 36–55 age bracket dominated the sample (54.4%), representing established fisherfolk with direct firsthand experience of multiple fish kill events dating back to the post-2020 Taal eruption period. The 22–35 age group (25.0%) brought the perspective of younger fisherfolk who entered or inherited cage operations after the 2020 eruption, often under higher debt burdens due to restocking costs. Respondents aged 56 and above (20.6%) provided institutional memory of pre-eruption fish kill patterns and historical lake conditions, enriching the qualitative interview data on hazard trends. This age distribution confirms that fish kill vulnerability is a cross-generational concern in Talisay, reinforcing the action plan's emphasis on both technical preparedness infrastructure and inclusive community-based DRM programming that reaches all age cohorts in lakeshore barangays.

B. Key Survey Findings by DRRM Pillar

The overall weighted mean of 3.14 (Agree) across all 40 survey items indicates a moderate level of existing DRRM capacity in Talisay with respect to fish kill risks, with respondents generally affirming awareness of hazard causes, existing monitoring efforts, and post-disaster assistance — but identifying significant gaps in operational readiness, equipment availability, and institutional coordination. The consolidated weighted mean scores were: Prevention and Mitigation (3.24, Agree); Response (3.11, Agree); Recovery and Rehabilitation (3.11, Agree); and Preparedness (3.10, Agree). The narrow range between the highest and lowest pillar scores (0.14 WM units) indicates that DRRM capacity gaps are systemic across all four dimensions rather than concentrated in a single area, confirming the need for the action plan's comprehensive 28-PPA approach rather than targeted single-pillar interventions.

Prevention and Mitigation registered the highest weighted mean of 3.24 (Agree), reflecting acknowledged strengths in hazard identification, existing water quality monitoring programs, and inter-agency awareness of fish kill causes. Indicator-level analysis revealed that items on community awareness of DO thresholds and existing BFAR monitoring visits received the highest individual scores (WM 3.40–3.52, Strongly Agree range), while items on real-time DO monitoring equipment, GIS-based hazard mapping, and enforcement of cage density regulations received consistently lower scores (WM 2.85–3.05), confirming that prevention capacity

remains awareness-level rather than infrastructure-level. Respondents from Barangay Aya registered the strongest concerns about inadequate preventive infrastructure given its highest cage concentration and most frequent exposure to fish kill events.

Preparedness registered the lowest weighted mean of 3.10 (Agree), signaling the most urgent capacity gap across the four DRRM pillars. The lowest-scoring individual indicators in this dimension included availability of aerators in barangay DRRM stockpiles (WM 2.88), regularity of fish kill simulation drills (WM 2.91), and availability of DO meters for barangay monitoring (WM 2.94). Coverage of BDRRMC training specifically on fish kill response protocols, installation of early warning systems in lakeshore barangays, and the existence of Business Continuity Plans for aquaculture-dependent households all registered below 3.00. These findings directly informed the priority interventions under Goal 2, particularly the 70% BDRRMC training coverage target, the two-per-year simulation drill schedule, and the procurement of EWS equipment and DO monitoring tools.

Response registered a weighted mean of 3.11 (Agree), with the lowest individual scores on EOC activation timing consistency (WM 2.96), availability of fish kill-specific response kits in barangays (WM 2.93), and the existence of a public health advisory coordination protocol between MHO and MDRRMO (WM 2.98). Recovery and Rehabilitation also registered WM 3.11 (Agree), with the most critical gaps identified in the absence of a standardized Post-Fish Kill Needs Assessment protocol (WM 2.89), inadequate timelines for livelihood assistance processing (WM 2.92), and the lack of a structured psychosocial support program for affected fisherfolk (WM 2.95). The absence of a dedicated PFKNA protocol and a structured livelihood recovery package for registered fisherfolk represented the most frequently cited gap across all recovery-related items, confirming the urgent need for the 28 PPAs proposed across the four strategic goals.

IV. SITUATIONAL ANALYSIS

A. SWOC Analysis

Institutional strengths include Talisay's operational MDRRMO with established inter-agency coordination channels, functional BDRRMCs in all 21 barangays, existing water quality monitoring partnerships with MAO and BFAR, community-level awareness of fish kill causes and risk factors, and existing linkages with PHIVOLCS for Taal Volcano monitoring data. Prevention and mitigation registered the highest survey score (WM 3.24), reflecting community acknowledgment of these existing capacities as a foundation for enhanced planning.

Critical weaknesses include the complete absence of real-time dissolved oxygen sensors in Taal Lake within Talisay's jurisdiction, the lack of a fish kill-specific response protocol in the existing contingency plan, inadequate enforcement of fish cage density regulations (actual count of approximately 9,188 cages vs. the TVPL-PAMB ceiling of 6,000), limited GIS-based hazard and risk mapping at the barangay level, and insufficient preparedness infrastructure — including shortage of aerators, DO meters, and personal protective equipment — identified by survey respondents as among the highest-priority gaps.

Opportunities include RA 10121 mandate provisions enabling LDRRMF funding for fish kill action planning, national technical and logistical support available from BFAR, PHIVOLCS, PAGASA, DOST, and OCD, BatStateU research and technical assistance for GIS risk mapping and EWS design, growing community demand for diversified livelihoods beyond fish cage aquaculture, and national policy momentum supporting integrated water resource management in inland lake ecosystems. The TVPL-PAMB's established regulatory framework, including the Supreme Court Writ of Continuing Mandamus, provides enforceable legal authority for cage density compliance that the LGU can draw upon.

Challenges include high staff turnover in the MDRRMO that disrupts institutional knowledge continuity, jurisdictional complexity arising from the overlap of LGU, TVPL-PAMB, and BFAR authorities over Taal Lake fisheries governance, deep economic resistance to cage density reduction among fisherfolk households dependent on aquaculture income, and the inherent unpredictability of climate change impacts on Taal Lake thermal stratification, storm intensification, and volcanic activity interaction — dynamics that challenge the precision of any fixed threshold-based early warning system.

The SWOC synthesis reveals an institution with sufficient baseline infrastructure for generalist DRRM functions but with critical operational gaps specifically incompatible with the technical demands of fish kill management. The most consequential gap — the absence of real-time DO monitoring — stands at the intersection of prevention, preparedness, and response: without reliable DO threshold data, the MDRRMO cannot issue timely fish kill alerts, BDRRMCs cannot activate their response protocols, and fisherfolk cannot protect their investments before mortality onset. Addressing this single gap through PPA 1.2.1 is therefore the highest-priority capital investment in the entire plan, with benefits flowing across all four DRRM pillars simultaneously. The inter-agency data-sharing MOU (PPA 1.2.2) is the complementary institutional mechanism ensuring that DO sensor data is integrated into PHIVOLCS's volcanic lake monitoring stream, PAGASA's weather-based risk alerts, and BFAR's fish cage operational advisories — creating a multi-agency situational awareness platform currently absent from Talisay's DRRM architecture.

B. PESTEL Analysis

Politically, Talisay is mandated by RA 10121 to develop and maintain local DRRM plans, but the shared jurisdiction of the TVPL-PAMB — a multi-agency body with authority over all fish cage operations within Taal Lake — requires genuine inter-agency collaboration rather than unilateral LGU action. Economically, the ₱157.9 million cumulative loss from 2021 to 2024 demonstrates that the financial cost of inaction far exceeds the investment required for the 28 PPAs proposed in this plan. Yet the economic dependence of approximately 80% of Talisay's lakeshore households on fish cage aquaculture creates political and social resistance to regulatory enforcement on cage density and operating standards.

Socially, strong community networks and established BDRRMC structures support preparedness messaging dissemination, and community-level awareness of fish kill causes is high. However, vulnerable subgroups — female-headed households, elderly residents, and persons with disabilities — face disproportionate recovery burdens and require targeted psychosocial support and livelihood assistance. Technologically, PHIVOLCS's real-time Taal Volcano monitoring data, PAGASA seasonal weather forecasts, and GeoRiskPH hazard datasets are all accessible to LGU planners at no cost, but these data streams remain disconnected from lake-level DO monitoring — the single most critical technical gap identified in this study.

Environmentally, Taal Lake's volcanic caldera origin produces unique hydrogeochemical conditions that amplify anthropogenic eutrophication. Natural thermal stratification — particularly during post-typhoon and dry-season periods — creates hypolimnetic oxygen depletion layers that can overturn catastrophically. These dynamics, combined with sulfur dioxide inputs from Taal Volcano's sustained degassing activity, create a tipping-point ecosystem where human-induced pressures from excess fish cage density consistently push the lake toward mass fish mortality thresholds. Legally, the Supreme Court Writ of Continuing Mandamus [14], TVPL-PAMB URRF [15], RA 10121 [12], and the Philippine Fisheries Code [11] collectively mandate decisive action — creating both the legal foundation and the enforcement authority for the regulatory interventions proposed in this plan.

The legal dimension of the PESTEL analysis warrants particular emphasis as it provides the binding authority that distinguishes this action plan from a purely advisory framework. The Supreme Court Writ of Continuing Mandamus, issued in a case involving the TVPL-PAMB, directs all agencies and LGUs with jurisdiction over Taal Lake to actively enforce environmental protection mandates and reduce human pressures on the lake ecosystem — a judicial directive that makes cage density reduction and DO monitoring not merely administratively desirable but legally compelled. This writ empowers the Talisay LGU to pursue enforcement actions against non-compliant cage operators without waiting for TVPL-PAMB approval, strengthening the enforceability of PPA 1.3.1 (geo-referenced cage inventory and compliance monitoring) and PPA 1.3.3 (advocacy for a Municipal Fish Kill Prevention Ordinance). The convergence of judicial, legislative, and regulatory authority in this legal landscape represents one of the strongest PESTEL opportunities available to Talisay's municipal government for

legitimizing and accelerating the implementation of this action plan.

V. GOALS AND OBJECTIVES

The action plan is organized under four strategic goals aligned with the four thematic areas of the National DRRM Framework (RA 10121), covering the three-year implementation period from 2027 to 2029. A total of 28 programs, plans, and activities (PPAs) are distributed across 12 objectives, with funding sources drawn primarily from the LDRRMF, General Fund, and national agency counterpart programs. Estimated total plan cost is approximately ₱3.2 million across the three-year period, representing less than 2.1% of the ₱157.9 million in documented fish kill losses from 2021 to 2024 — a cost-effectiveness ratio that demonstrates the clear return on investment of proactive risk reduction over post-disaster relief and rehabilitation expenditures.

The plan's PPA structure reflects the principle of graduated risk reduction: front-loaded investment in prevention and preparedness PPAs during 2027 (Year 1) reduces the frequency and severity of fish kill events requiring response and recovery expenditures in 2028 and 2029 (Years 2 and 3). The installation of DO monitoring infrastructure (PPA 1.2.1) and early warning systems (PPA 2.2.1) in Year 1 is projected to enable earlier fish kill alerts by an estimated 12–24 hours compared to current detection timelines, allowing fisherfolk to deploy aerators, reduce cage feeding, and activate harvest plans before DO levels fall below the lethal threshold — interventions that can reduce mortality by up to 40–60% according to BFAR aquaculture emergency management guidelines. The plan thus functions as an investment portfolio with a clear sequence: infrastructure and capacity investments in Year 1 create the platform for reduced losses in Years 2 and 3.

1) Goal 1 – Disaster Prevention and Mitigation: To reduce the risks posed by fish kill events and related multi-hazards in the Municipality of Talisay through systematic risk identification, environmental monitoring, and preventive interventions that protect lives, aquaculture livelihoods, and ecological integrity. Objective 1.1 conducts a comprehensive multi-hazard risk and vulnerability assessment covering all 21 barangays with specific focus on fish kill risk zones by end of 2027; Objective 1.2 establishes and operationalizes a real-time dissolved oxygen monitoring system in Taal Lake within Talisay's jurisdiction by mid-2027; and Objective 1.3 implements regulatory and structural mitigation measures addressing fish cage density, aquaculture nutrient loading, and shoreline environmental degradation by 2027.

Key PPAs under Goal 1 include: community-based disaster risk assessments (CBDRAs) in all 21 barangays and production of a GIS-based fish kill hazard map (PPA 1.1.1 and 1.1.2, ₱180,000); procurement and installation of DO sensors at three strategic lake monitoring stations in Barangays Aya, Quiling, and Tumaway with real-time data transmission to MDRRMO (PPA 1.2.1, ₱420,000); formalization of an inter-agency data-sharing MOU among MDRRMO, MAO, BFAR, and PHIVOLCS (PPA 1.2.2, ₱45,000); geo-referenced fish cage inventory and annual compliance monitoring (PPA 1.3.1, ₱75,000); structural environmental mitigation projects in high-exposure barangays including buffer strips and runoff control (PPA 1.3.2, ₱350,000); and advocacy for a Municipal Fish Kill Prevention Ordinance (PPA 1.3.3, ₱30,000). The expected outcome is a functional DO and water quality monitoring network providing real-time early warning data to MDRRMO, MAO, and BFAR.

2) Goal 2 – Disaster Preparedness: To strengthen the disaster preparedness capacities of the MDRRMO, LGU, communities, and key stakeholders against the risk of fish kill events and related multi-hazards through capacity-building, early warning systems, and community-based preparedness programs. Objective 2.1 develops and regularly updates a Municipal Fish Kill Contingency Plan with Business Continuity Planning provisions by 2027; Objective 2.2 conducts at least two multi-sectoral fish kill simulation exercises annually and installs early warning systems in all 11 lakeshore barangays; and Objective 2.3 ensures at least 70% of barangay officials and BDRRMC members complete fish kill DRRM training by 2027.

Key PPAs under Goal 2 include: development and annual updating of the Municipal Fish Kill Contingency Plan incorporating BCP provisions (PPA 2.1.1, ₱85,000); procurement of preparedness equipment — DO meters, aerators, and protective gear — for all 11 lakeshore BDRRMCs (PPA 2.1.2, ₱480,000); installation of warning sirens and SMS-based EWS in four priority barangays (PPA 2.2.1, ₱350,000); conduct of two multi-sectoral fish kill simulation drills annually with after-action review (PPA 2.2.2, ₱90,000 per cycle); training of BDRRMC members on fish kill response, ICS operations, and first aid (PPA 2.3.1, ₱120,000); and

an IEC campaign on fish kill hazards for 21 barangays (PPA 2.3.2, ₱65,000).

The Business Continuity Planning (BCP) provisions in PPA 2.1.1 address a critical gap identified in the survey results: the absence of structured financial contingency plans for aquaculture-dependent households facing sudden total loss of stock. Informed by international best practices on agricultural BCP for smallholder farmers, the plan prescribes a BCP template covering: (1) pre-event insurance enrollment and credit facility access provisions; (2) emergency harvest protocols for at-risk fish stocks when DO approaches the 4 mg/L warning threshold; (3) household-level emergency cash reserve guidance corresponding to at least 30 days of operational costs; and (4) household-level identification of alternative livelihood options that can be activated within 48 hours of a confirmed fish kill — all of which are pre-conditions for the livelihood recovery speed targets in Objective 4.2. The BCP framework is designed to be disseminated through BFAR's existing fisherfolk registration and extension services system, using existing community touchpoints for wider reach.

3) Goal 3 – Disaster Response: To ensure a prompt, efficient, and coordinated disaster response system in Talisay that minimizes casualties, public health impacts, and economic losses from fish kill events through an activated ICS, timely public health advisories, and structured relief services. Objective 3.1 activates the EOC within one hour of any fish kill alert declaration and maintains 24/7 ICS operations throughout the response period; Objective 3.2 ensures issuance of public health advisories and timely protective actions for lakeshore communities during every confirmed major incident; and Objective 3.3 provides timely relief assistance and coordinated response services, including dead fish removal within 72 hours of incident confirmation.

Key PPAs under Goal 3 include: procurement and maintenance of EOC equipment including communication radios, situation boards, and generator sets (PPA 3.1.1, ₱220,000); development and pre-positioning of fish kill response kits in four priority barangays (PPA 3.1.2, ₱180,000); establishment of a public health advisory system linking MHO, MDRRMO, and market management offices (PPA 3.2.1, ₱35,000); deployment of mobile sanitation and dead fish collection teams with equipment (PPA 3.3.1, ₱150,000); and provision of food and non-food relief assistance to confirmed affected families within 48 hours (PPA 3.3.2, LDRRMF Quick Response Fund).

4) Goal 4 – Disaster Recovery and Rehabilitation: To facilitate the recovery, rehabilitation, and reconstruction of disaster-affected communities in Talisay in a manner that builds back better, reduces future fish kill risks, and restores the well-being and livelihoods of affected fisherfolk communities. Objective 4.1 conducts a Post-Fish Kill Needs Assessment (PFKNA) within seven days after a major fish kill event and develops a Fish Kill Recovery Plan within three months; Objective 4.2 provides livelihood assistance and psychosocial support to at least 80% of affected fisherfolk and aquaculture operators within 30 days and implements fish cage rehabilitation and restocking programs within six months; and Objective 4.3 integrates Build Back Better principles into post-fish kill rehabilitation and long-term ecological recovery measures beginning in 2027.

Key PPAs under Goal 4 include: standardized PFKNA tools, procedures, and team deployment protocols (PPA 4.1.1, ₱25,000); Fish Kill Recovery Plan template with financing pathways and inter-agency coordination protocols (PPA 4.1.2, ₱30,000); fish cage rehabilitation and TVPL-compliant restocking program with DO threshold requirements (PPA 4.2.1, ₱280,000 per major incident); livelihood diversification program for affected fisherfolk linking to DOLE and DA programs (PPA 4.2.2, ₱150,000); psychosocial support services through MSWDO and trained community volunteers (PPA 4.2.3, ₱75,000); and an ecological rehabilitation program including shoreline reforestation, cage density reduction incentives, and habitat restoration monitoring (PPA 4.3.1 and 4.3.2, ₱320,000).

The plan's inter-goal coordination structure keeps all four DRRM pillars functioning as an integrated system rather than independently managed programs. The Municipal DRRM Council, chaired by the Municipal Mayor and co-chaired by the MDRRMO head, serves as the apex coordination body for cross-cutting PPAs. The MDRRMO's EOC functions as the operational nerve center during Response phase activation, drawing on the preparedness training completed under Goal 2 and the early warning infrastructure established under Goal 1 to enable the one-hour EOC activation target in Objective 3.1. Post-event, the PFKNA process under Goal 4 feeds back into Goal 1 risk assessment updates, creating a continuous improvement loop where each fish kill event informs the next iteration of risk identification, monitoring calibration, and contingency plan revision.

This closed-loop architecture distinguishes the plan from static policy documents and positions it as an adaptive risk management system aligned with the Sendai Framework's emphasis on learning from disasters to build forward resilience.

VI. MONITORING AND EVALUATION

The action plan implements a per-PPA monitoring and evaluation (M&E) framework with objectively verifiable indicators, data sources, responsible offices, frequency of monitoring, and quarterly reporting cycles. Each of the 28 PPAs carries a specific process indicator measuring implementation progress and an outcome indicator measuring the resulting change in the target population's capacity, exposure, or vulnerability. The MDRRMO serves as primary M&E focal office, with the Municipal Agriculture Office as secondary focal office for aquaculture-related indicators.

Key performance indicators by goal include: under Goal 1, the number of DO monitoring stations installed and transmitting real-time data to the MDRRMO dashboard, and the percentage of barangays with updated GIS-based fish kill risk maps; under Goal 2, the percentage of BDRRMC members completing fish kill DRRM training and the number of simulation exercises conducted per year; under Goal 3, the elapsed time from fish kill alert issuance to EOC activation (target: ≤1 hour), the percentage of affected registered families receiving immediate relief within 48 hours, and the proportion of dead fish removed within 72 hours to prevent secondary health hazards; and under Goal 4, the percentage of affected fisherfolk receiving livelihood assistance within 30 days, and DO levels confirmed at ≥6 mg/L before any restocking authorization is granted.

Annual plan reviews will integrate updated fish kill incidence data from BFAR, environmental monitoring reports from MDRRMO and MAO, health surveillance data from MHO, and community feedback from affected barangays collected through post-incident surveys. This adaptive management cycle ensures the plan remains responsive to emerging conditions — including changes in Taal Volcano activity levels, climate projections for storm frequency, and TVPL-PAMB regulatory updates — throughout the three-year implementation period. Quarterly progress reports will be presented to the Local DRRM Council and integrated into the Annual Investment Plan review, ensuring budgetary continuity for all 28 PPAs through the LDRRMF 30% allocation for prevention and mitigation and 70% for preparedness and response.

The M&E framework assigns primary data collection responsibility to the MDRRMO for disaster response and infrastructure indicators, MAO for aquaculture production and water quality indicators, MHO for public health and food safety indicators, and MSWDO for livelihood and psychosocial support indicators. External verification will be provided by BFAR Region IV-A for production recovery data and PHIVOLCS for volcano activity correlations. A digital M&E dashboard hosted at the MDRRMO will consolidate real-time DO sensor readings, PPA implementation status, incident logs, and quarterly progress narratives for access by the Local DRRM Council, municipal mayor's office, and partner agencies. A mid-term review in mid-2028 will assess goal attainment rates and determine whether resource reallocation or PPA revisions are needed to ensure plan targets are achieved within the 2029 completion deadline.

The M&E system goes beyond compliance documentation — its purpose is to generate institutional learning. Each quarterly progress report will include a mandatory "Lessons and Adaptations" section capturing: deviations from implementation timelines and their root causes; unexpected barriers or enablers encountered during PPA execution; changes in the fish kill hazard environment — including new PHIVOLCS monitoring data, PAGASA seasonal forecasts, and BFAR aquaculture observations — that may require contingency adjustments; and community feedback on the usability and accessibility of new infrastructure such as DO monitoring stations and EWS equipment. Post-incident after-action reviews following each confirmed fish kill event will feed directly into updates to the Municipal Fish Kill Contingency Plan (PPA 2.1.1), creating a systematic documentation trail that both improves operational preparedness and contributes to the national evidence base on volcanic lake fish kill management that can inform similar action plans in Agoncillo, Laurel, San Nicolas, and other Taal Lake lakeshore municipalities facing analogous multi-hazard conditions.

The plan also establishes a community M&E feedback mechanism through twice-yearly barangay consultation sessions in the four priority barangays, where MDRRMO and MAO staff present PPA implementation updates and fisherfolk, BDRRMC members, and barangay officials assess the practical effectiveness of completed interventions. This participatory monitoring component ensures that technical progress indicators are supplemented by ground-truth community perception data — a methodological consistency with the survey-based needs assessment approach used to develop the plan, providing a comparable baseline for measuring capacity improvements across all four DRRM pillars over the three-year implementation period.

VII. CONCLUSIONS

The Multi-Hazard Action Plan on Fish Kill Events in Talisay, Batangas represents the first structured, evidence-based framework developed specifically to address the multi-hazard interactions that make fish kill events in Taal Lake particularly destructive. The community survey (overall WM = 3.14, Agree) confirms that while existing DRRM infrastructure and inter-agency coordination mechanisms are acknowledged by stakeholders, systematic capacity enhancement is urgently needed across all four DRRM pillars — most critically in preparedness (WM 3.10, the lowest-scoring pillar), where equipment deficits and insufficient simulation exercises leave lakeshore communities with inadequate operational readiness for the frequency and severity of actual fish kill emergencies.

The ₱157.9 million in documented losses from 2021 to 2024, combined with an 83.6% decline in tilapia production, confirm that recurrent fish kill events constitute a structural threat to Talisay's aquaculture economy rather than episodic incidents beyond the control of local governance. The root causes are identifiable and addressable: the absence of real-time DO monitoring, persistent excess cage density above TVPL-PAMB limits, the lack of dedicated fish kill response protocols, and the absence of structured post-disaster livelihood recovery mechanisms. These are precisely the gaps that the plan's 28 PPAs address through time-bound, fundable, and inter-agency-coordinated interventions.

Sustained implementation requires genuine multi-agency commitment from MDRRMO, BFAR, MAO, PHIVOLCS, PAGASA, MHO, MSWDO, and TVPL-PAMB, supported by political will from municipal leadership and active participation from fisherfolk associations and lakeshore communities. The integration of the Sendai Framework's Build Back Better principle into every recovery and rehabilitation activity — particularly the restocking protocol's DO threshold requirement of ≥6 mg/L — ensures that each fish kill event becomes an opportunity to reduce exposure and vulnerability rather than simply restore the conditions that produced the previous disaster. Talisay's fisherfolk communities, lakeshore ecosystems, and municipal aquaculture economy deserve — and with consistent implementation of this plan, can achieve — a measurable and sustained reduction in fish kill risk.

This action plan also carries significance beyond Talisay. As the first municipality in the Taal Lake lakeshore corridor to develop a dedicated multi-hazard action plan specifically addressing fish kill events, Talisay's experience — its survey methodology, PPA cost structures, inter-agency coordination protocols, and M&E framework — provides a replicable template for Agoncillo, Laurel, San Nicolas, Alitagtag, Cuenca, and other Batangas municipalities that share the same fish kill hazard profile. BatStateU's ongoing research presence in the Taal Lake region positions the university as a natural facilitator of this inter-municipal knowledge transfer, potentially enabling the development of a harmonized Taal Lake Fish Kill DRRM Framework that standardizes DO monitoring thresholds, alert protocols, and recovery timelines across all 11 lakeshore municipalities — creating a lake-wide early warning and response system commensurate with the scale of the fish kill threat.

VIII. RECOMMENDATIONS

1) The Sangguniang Bayan of Talisay should enact a Municipal Fish Kill Prevention and Response Ordinance providing a legislative foundation for enforcing DO monitoring protocols, cage density limits, mandatory DRRM training participation, and inter-agency data-sharing obligations — translating this action plan's regulatory interventions into permanent local law.

2) The MDRRMO should prioritize procurement of at least three real-time DO monitoring stations at Barangays Aya, Quiling, and Tumaway by Q1–Q2 2027, funded through the LDRRMF, with continuous data transmission integrated into the MDRRMO's early warning dashboard and shared with BFAR Region IV-A for lake-wide monitoring coordination.

3) The LGU, in coordination with BFAR and TVPL-PAMB, should conduct a comprehensive geo-referenced fish cage inventory across all 11 lakeshore barangays by Q3 2027 to establish an enforceable compliance baseline under the Supreme Court Writ of Continuing Mandamus and the TVPL-PAMB URRF, with results shared publicly through the barangay DRRM information system.

4) Batangas State University — The National Engineering University should formalize a multi-year research and technical assistance partnership with the Talisay LGU covering GIS-based fish kill risk mapping, continuous water quality analysis, EWS technology development, and annual evaluation of action plan implementation outcomes.

5) The MSWDO should integrate fish kill-specific psychosocial support and rapid livelihood facilitation services into its regular post-disaster response protocols, ensuring trained psychosocial support volunteers are pre-deployed in all four priority barangays and that livelihood assistance processing begins within 72 hours of a major fish kill event confirmation.

6) The MDRRMO should conduct annual plan reviews in consultation with fisherfolk associations, BFAR, PHIVOLCS, MAO, and barangay officials, incorporating lessons from each fish kill incident, updated TVPL-PAMB regulatory changes, and revised PAGASA climate projections to maintain the relevance, effectiveness, and adaptability of the action plan throughout and beyond its 2027–2029 implementation period.

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